



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

Informative Inventory Report 2017

Emissions of transboundary air pollutants
in the Netherlands 1990-2015

RIVM Report 2017-0002

B.A. Jimmink et. al.



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

Informative Inventory Report 2017

Emissions of transboundary air pollutants
in the Netherlands 1990-2015

RIVM Report 2017-0002

Colophon

© RIVM 2017

Parts of this publication may be reproduced, provided acknowledgement is given to: National Institute for Public Health and the Environment, along with the title and year of publication.

DOI 10.21945/RIVM-2017-0002

B.A. Jimmink (author), RIVM
P.W.H.G. Coenen (author), TNO
S.N.C. Dellaert (author), TNO
R. Dröge (author), TNO
G.P. Geilenkirchen (author), PBL
P. Hammingh (author), PBL
A.J. Leekstra (author), RIVM
C.W.M. van der Maas (author), RIVM
R.A.B. te Molder (author), RIVM
S.V. Oude Voshaar (author), RIVM
C.J. Peek (author), RIVM
S.D. van der Sluis (author), PBL
W.L.M. Smeets (author), PBL
D. Wever (author), RIVM

Contact:

Benno Jimmink
RIVM - MIL/L&E
benno.jimmink@rivm.nl

This investigation has been performed by order and for the account of Ministerie voor Infrastructuur en Milieu, within the framework of KLG.

This is a publication of:

**National Institute for Public Health
and the Environment**

P.O. Box 1 | 3720 BA Bilthoven
The Netherlands
www.rivm.nl/en

Synopsis

Informative Inventory Report 2017

Emissions of transboundary air pollutants
in the Netherlands 1990-2015

Increase in ammonia emissions; whole time series adjusted downwards.

In 2015 slightly more ammonia was emitted than in 2014 and the ceiling set by the European Union was met (128 kilotons). It was more because both cattle numbers and fertilizer use increased, whereas low emission housing systems for pigs and poultry partly countered this.

Furthermore, total ammonia emissions between 1990 and 2015 have been adjusted downwards. This is because new insights have been made into the data used to calculate emissions, called emission factors. For example, from 2008 onwards, the annual amount of ammonia emitted by fertilizer use was 4 kilotons lower than previously calculated. The new insights were recommended by an international scientific review, performed at the request of the Minister for Agriculture.

Emissions of nitrogen oxides, sulphur dioxides and non-methane volatile organic compounds continue to decrease slightly; the Netherlands are, therefore, complying with the ceilings in this regard. Besides the substances mentioned above, the report also includes emissions of carbon monoxide, particulate matter, heavy metals and persistent organic pollutants. The emissions of most of these substances have decreased during the 1990 – 2015 period. The downward trend may, in particular, be attributed to cleaner fuels, cleaner car engines and to emission reductions in industry.

This is concluded by the Informative Inventory Report 2017, drawn up by RIVM and partner institutes which collaborate to annually analyse and report emission data. This is obligatory to member states. The analyses are used to support Dutch policy.

Keywords: emissions, transboundary air pollution, emission inventory

Publiekssamenvatting

Informatieve Inventory Report 2017

Toename ammoniak emissies; jaarreeks vanaf 1990 omlaag

De uitstoot van ammoniak is in 2015 licht gestegen ten opzichte van 2014 en voldoet met 127,6 kiloton aan het Europees gestelde plafond. De toename komt vooral doordat in de agrarische sector meer kunstmest is gebruikt. De toename wordt voor een deel afgezwakt door een dalende uitstoot in de varkens en pluimveesector als gevolg van schonere stalsystemen.

Verder is de totale uitstoot van ammoniak tussen 1990 en 2015 met terugwerkende kracht naar beneden bijgesteld. Dit komt door nieuwe inzichten in de zogeheten emissiefactoren; daarmee wordt de uitstoot berekend. Zo is vanaf 2008 de jaarlijkse hoeveelheid ammoniak die via kunstmest wordt uitgestoten circa 4 kiloton lager dan eerder was berekend. De inzichten zijn voortgekomen uit een internationale wetenschappelijke review die op verzoek van de staatssecretaris van Economische Zaken is uitgevoerd.

De emissies van stikstofdioxide, zwaveldioxide en niet-methaan vluchtige organische stoffen blijven licht dalen. Voor deze stoffen blijft Nederland voldoen aan de gestelde plafonds. Behalve deze stoffen is de uitstoot van koolmonoxide, fijn stof, zware metalen en persistente organische stoffen tussen 1990 en 2015 bijna zonder uitzondering gedaald. Dit komt vooral door schonere brandstoffen, schonere automotoren en door emissiebeperkende maatregelen in de industrie. Dit en meer blijkt uit de Informatieve Inventory Report 2017. Het RIVM analyseert en rapporteert hierin jaarlijks met diverse partnerinstituten de uitstoot van stoffen. Lidstaten zijn hiertoe verplicht. Nederland gebruikt de analyses om beleid te onderbouwen.

Dit en meer blijkt uit de Informatieve Inventory Report 2017. Het RIVM analyseert en rapporteert hierin jaarlijks met diverse partnerinstituten de uitstoot van stoffen. Lidstaten zijn hiertoe verplicht. Nederland gebruikt de analyses om beleid te onderbouwen.

Kernwoorden: emissies, grootschalige luchtverontreiniging, emissieregistratie

Contents

1	Introduction — 9
1.1	National inventory background — 9
1.2	Institutional arrangements for inventory preparation — 9
1.3	The process of inventory preparation — 10
1.4	Methods and data sources — 13
1.5	Key source analysis — 14
1.6	Reporting, QA/QC and archiving — 14
1.7	Uncertainties — 18
1.8	Explanation on the use of notation keys — 20
2	Trends in emissions — 23
2.1	Trends in national emissions — 23
2.2	Trends in sulphur dioxide (SO ₂) — 24
2.3	Trends in nitrogen oxides (NO _x) — 26
2.4	Trends in ammonia (NH ₃) — 27
2.5	Trends in non-methane volatile organic compounds (NMVOC) — 28
2.6	Trends in PM _{2.5} — 29
2.7	Trends in PM ₁₀ — 30
2.8	Trends in Pb — 31
3	Energy — 33
3.1	Overview of the sector — 33
3.2	Public electricity and heat production (1A1a) — 35
3.3	Industrial Combustion (1A1b, 1A1c and 1A2) — 38
3.4	Other Stationary Combustion (1A4ai, 1A4bi, 1A4ci and 1A5a) — 42
3.5	Fugitive emissions (1B) — 46
4	Transport — 49
4.1	Overview of the sector — 49
4.2	Civil Aviation — 51
4.3	Road Transport — 57
4.4	Railways — 74
4.5	Waterborne navigation and recreational craft — 77
4.6	Non-road mobile machinery (NRMM) — 83
4.7	National fishing — 89
5	Industrial Processes and Product Use (NFR 2) — 93
5.1	Overview of the sector — 93
5.2	Mineral products (2A) — 96
5.3	Chemical industry (2B) — 98
5.4	Metal production (2C) — 99
5.5	Solvents and product use (2D) — 102
5.6	Other Production Industry (2H) — 106
6	Agriculture — 109
6.1	Overview of the sector — 109
6.2	Manure management — 112
6.3	Crop production and agricultural soils — 117
7	Waste (NFR 5) — 123

7.1	Overview of the sector — 123
7.2	Solid waste disposal on land (5A) — 125
7.3	Composting and anaerobic digestion (5B) — 127
7.4	Waste incineration (5c) — 129
7.5	Waste-water handling (5D) — 132
7.6	Other waste (5E) — 132
8	Other — 135
9	Recalculations and other changes — 137
9.1	Recalculations of certain elements of the IIR2016 — 137
9.2	Improvements — 137
9.3	Effects of recalculations and improvements — 137
10	Projections — 141
11	Spatial distributions — 145
11.1	Background for reporting — 145
11.2	Methodology for disaggregation of emission data — 145
11.3	Maps with geographically distributed emission data — 146
	References — 151
	Appendix 1 Key category analysis results — 158
	Appendix 2 Planned improvements; quick view — 171

1 Introduction

The United Nations Economic Commission for Europe's Geneva 1979 Convention on Long-Range Transboundary Air Pollution (CLRTAP) was accepted by the Netherlands in 1982. Under the Convention, parties are obligated to report emission data to the Conventions' Executive Body in compliance with the implementation of the Protocols to the Convention (also accepted by the Netherlands). The annual Informative Inventory Report (IIR) on national emissions of SO₂, NO_x, NMVOC, CO, NH₃ and various heavy metals and POP is prepared using the Guidelines for Reporting Emissions and Projections Data under the Convention on Long-range Transboundary Air Pollution 2014 (UNECE, 2014).

The Dutch IIR2017 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 2015, including descriptions of methods, data sources, QA/QC activities carried out and a trend analysis. The inventory covers all anthropogenic emissions to be reported in the Nomenclature for Reporting (NFR), including individual polycyclic aromatic hydrocarbons (PAHs), which are to be reported under persistent organic pollutants (POP) in Annex IV.

1.1 National inventory background

Emission estimates in the Netherlands are registered in the national Pollutant Release and Transfer Register (PRTR). This PRTR database is the national database for sectorial 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 report to the framework of National Emission Ceilings (EU), the CLRTAP, the United Nations Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol (National System). The PRTR encompasses the process of data collection, processing and registration, and reporting on emission data for some 350 compounds. Emission data (for the most important pollutants) and documentation can be found at www.prtr.nl.

Instead of using the defaults from the EMEP/EEA air pollutant emission inventory guidebook 2013 (EEA, 2013), the Netherlands often applies country-specific methods with associated activity data and emission factors. The emission estimates are based on official statistics of the Netherlands (e.g. on energy, industry and agriculture) and environmental reports by companies in the industrial sectors. Both nationally developed and internationally recommended emission factors have been used.

1.2 Institutional arrangements for inventory preparation

The Dutch Ministry of Infrastructure and Environment (IenM) has the overall responsibility for the emission inventory and submissions to CLRTAP. A Pollutant Release and Transfer Register (PRTR) system has been in operation in the Netherlands since 1974. Since 2010, the Ministry of IenM has outsourced the full coordination of the PRTR to the Emission Registration team (ER team) at the National Institute for Public Health and the Environment (RIVM).

The main objective of the PRTR is to annually produce a set of unequivocal emission data that is up to date, complete, transparent, comparable, consistent and accurate. 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 (RWS):
 - Centre for Water Management (RWS-WD);
 - Centre for Transport and Navigation (RWS-DVS);
 - Water, Traffic and Environment (RWS-WVL);
 - Human Environment and Transport Inspectorate (RWS-ILT).
- Deltares;
- Alterra WUR;
- Wageningen UR Livestock Research;
- Agricultural Economics Research Institute (LEI);
- Fugro-Ecoplan, which co-ordinates annual environmental reporting (AER) 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 RIVM and in annual project plans.

1.3 The process of inventory preparation

Data collection

For the collection and processing of data (according to pre-determined methods), the PRTR is organised according to task forces. Task forces consist of sector experts of the participating institutes. Methods are compiled on the basis of the best available scientific views. Changes in scientific views lead to changes in methods, and to recalculation of historical emissions. The following task forces are recognised (see Figure 1.1):

- Task Force on Agriculture and Land Use;
- Task Force on Energy, Industry and Waste Management - ENINA;
- Task Force on Traffic and Transportation;
- Task Force on Water - MEWAT;
- Task Force on Service Sector and Product Use - WESP.

Every year, after collection of the emission data, several quality control checks are performed by the task forces during a yearly 'trend analysis' workshop. After approval by participating institutes, emission data are released for publication (www.prtr.nl). Subsequently, these data are disaggregated to regional emission data for national use (e.g. 5x5 km grid, municipality scale, provincial scale and water authority scale).

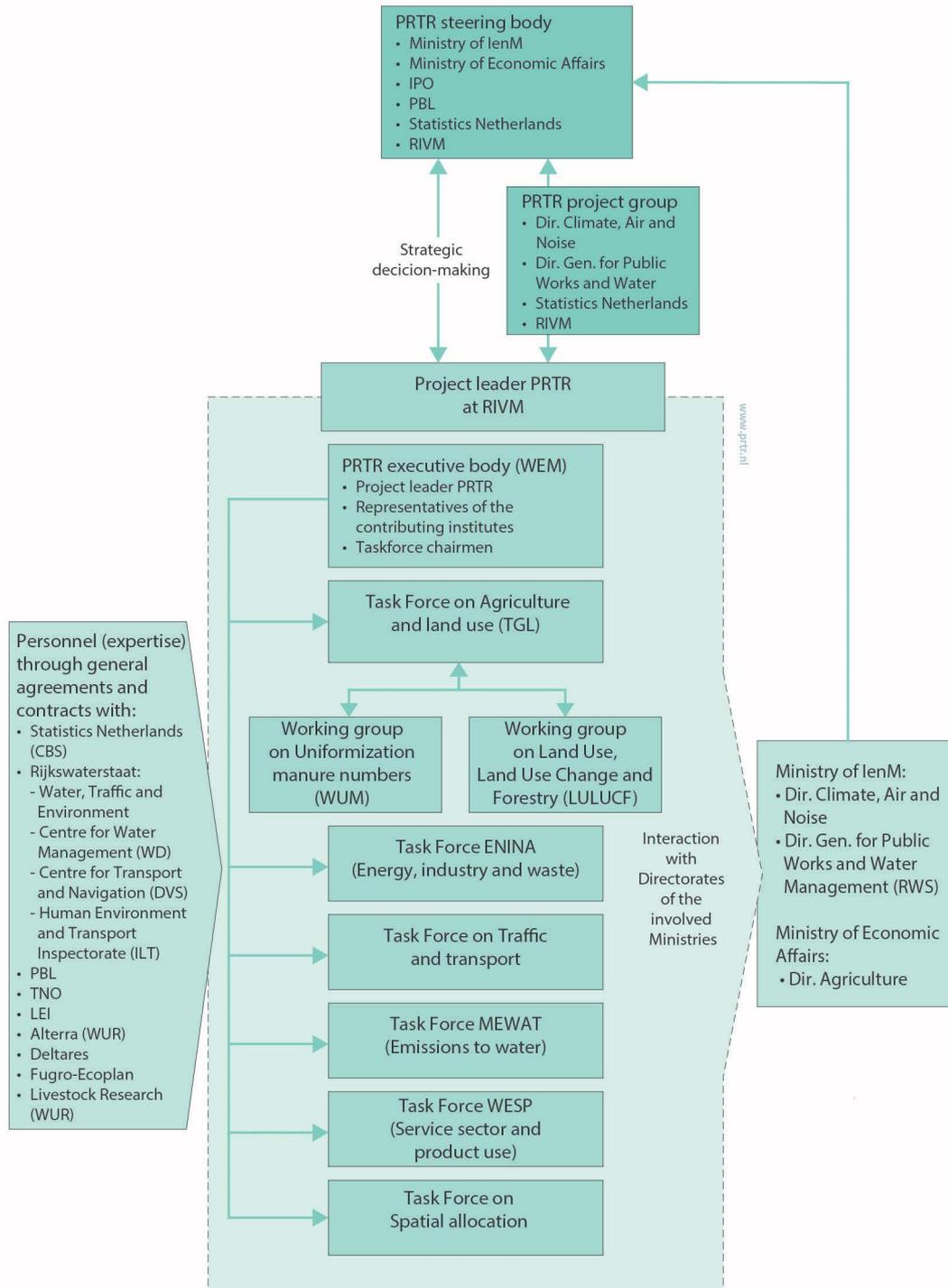


Figure 1.1 The organisational arrangement of the Netherlands Pollutant Release and Transfer Register (PRTR)

1.3.1 *Point-source emissions*

As result of the Netherlands' implementation of the EU Directive on the European Pollutant Release and Transfer Register (E-PRTR), since 2011 about 1000 facilities are legally obligated to submit data on their emissions of air pollutants when they exceed a certain threshold. For some pollutants the Dutch implementation of the E-PRTR directive (VROM, 2008) has set lower thresholds. As a consequence, the total reported amount of the main pollutants for each subsector approximately meets 80% of the subsector total. This criterion has been set as safeguard for the quality of the supplementary estimate for Small and Medium-sized Enterprises (SMEs).

As from 1 January 2010, the above-mentioned companies can only submit their emissions as part of an Annual Environmental Report (AER), electronically. All these companies have emission monitoring and registration systems with specifications in agreement with the competent authority. Usually, 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 formally remains property of the companies involved.

Data on point-source emissions in the AER database are checked for consistency by the task forces. The result is a selection of validated data on point-source emissions and activities (ER-I) which are then stored in the PRTR database (Dröge & Ten Broeke, 2012). The ER-I data is combined with supplementary estimates for Small and Medium-sized Enterprises (SMEs). Several methods are applied for calculating these emissions. TNO has derived emission factors for NO_x emissions from small installations, for instance Van Soest-Vercammen *et al.*, (2002), while, for other substances, the Implied Emission Factors (IEFs) derived from the AERs are applied to calculate sector emissions.

1.3.2 *Data storage*

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

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.

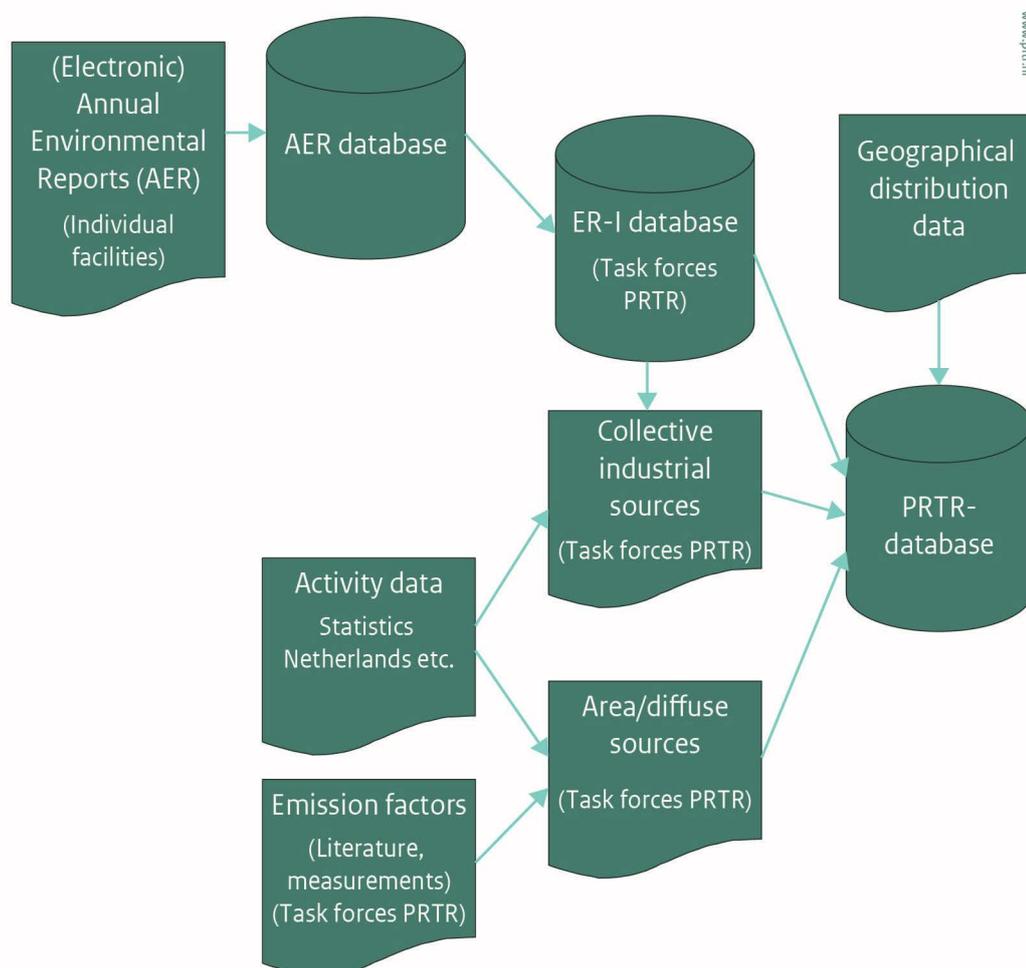


Figure 1.2 The data flow in the Netherlands Pollutant Release and Transfer Register

1.4 Methods and data sources

Methods used in the Netherlands are documented in several reports and protocols, and in meta-data files, available from www.prtr.nl. However, some reports are only available in Dutch. For greenhouse gases (<http://english.rvo.nl/nie>), particulate matter (PM) and all emissions related to mobile sources, the documentation has been translated in English.

In general, two emission 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 with 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.
- A model for emissions from *diffuse sources* (e.g. road transport, agriculture), which are calculated from activity data and emission

factors from sectorial emission inventory studies in the Netherlands (e.g. SPIN documents produced by the 'Co-operation project on industrial emissions').

In addition, these assumptions are important to consider:

- Condensable emissions are only included for transport emissions, not for emissions from domestic wood burning or industrial emissions.
- Road transport emissions have been calculated using 'on-road' measured emission factors, so emission data are insensitive to 'the diesel scandal'.

1.5 Key source analysis

A trend assessment was carried out for the emission inventory of all components, in addition to a level assessment, to identify key source categories. In both approaches key source categories were identified using a cumulative threshold of 80%. Key categories are those which, when summed together in descending order of magnitude, add up to more than 80% of the total level (EEA, 2013). The level assessments were performed for both the latest inventory year 2015, as well as for the base year of the inventory, 1990. The trend assessments aim to identify categories for which the trend is significantly different from that of the overall inventory. See Appendix 1 for the actual analysis.

1.6 Reporting, QA/QC and archiving

Reporting

The Informative Inventory Report is prepared by the inventory compiling team at RIVM (RIVM-NIC), with contributions by experts from the PRTR task forces.

QA/QC

The RIVM has an ISO 9001:2008 based QA/QC system in place. The 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 (RIVM, 2016). The general QA/QC activities meet the international inventory QA/QC requirements described in part A, chapter 6 of the EMEP inventory guidebook (EEA, 2016).

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 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 the annual quality assurance;

- As part of the RIVM-quality system internal audits are performed at the Department for Emissions and air quality of the RIVM Centre for Environmental Quality;
- Furthermore, there are annual external QA checks 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 (for results see Table 1.1). The QC checks built into the work plan focus on issues such as consistency, completeness and accuracy of the emission data. The general QC for the inventory is largely performed within the PRTR as an integrated part of the working processes. For the 2016 inventory the PRTR task forces filled in a standard-format database with emission data from 1990 to 2015. After an automated first check of the emission files, by the data exchange module (DEX) for internal and external consistency, the data becomes available to the specific task force for checking consistency and trend (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 are facilitated 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). Results of this workshop, including actions for the task forces to resolve the identified clarification issues, are documented at RIVM. Required changes to the database are then made by the task forces.

Table 1.1 Key items of the verification actions on data processing 2016 and NFR/IIR 2017

QC Item/action	Date	Who	Result	Documentation *
Automated initial check on internal and external data consistency	During each upload	Data Exchange Module (DEX)	Acceptation or rejection of uploaded sector data	Upload event and result logging in the PRTR-database
Input of hanging issues for this inventory	08-07-2016	RIVM-PRTR	List of remaining issues/actions from last inventory	"Actiepunten voorlopige cijfers 2015 v 8 juli 2016.xls"
Input for checking allocations from the PRTR-database to the NFR tables	20-10-2016	RIVM-NIC	List of allocations	"NFR-ER-Koppellijst-2016-10-20-dtt5148_bj.xlsx"
Input for error checks	22-11-2016	RIVM-PRTR	Comparison sheets 2014-2015 data	"Verschiltabel_LuchtActueel_22-11-2016.xlsx"

Input for trend analysis	29-11-2016	RIVM-PRTR	Updated list of required actions and updated Comparison sheets 2014-2015 data	"Actiepunten definitieve cijfers 1990-2015 v 29 nov 2016.xls"; "Verschiltabel_LuchtActueel 28-11-2016.xlsx"
Trend analysis workshops	01-12-2016	Sector specialists, RIVM-PRTR	Explanations for observed trends and actions to resolve before finalising the PRTR dataset	<ul style="list-style-type: none"> – "Emissies uit de landbouw reeks 1990-2015 Trendanalyse.pptx"; – "Presentatie ENINA TrendAnalyse reeks 1990-2015.pptx"; – Trendanalyse verkeer reeks 1990-2015.pptx"; – WESP Trendanalyse reeks 1990-2015.pptx"; – TA-dag NEC plafonds NL reeks 1990-2105.pptx".
Input for resolving the final actions before finalising the PRTR dataset	2-12-2016	RIVM-PRTR	Updated Action list	"Actiepunten definitieve cijfers reeks 1990-2015 v 2 december 2016.xls"
Request to the contributing institutes to endorse the PRTR database	14-12-2016 till 19-12-2016	PRTR project secretary, Representatives of the contributing institutes	Reactions of the contributing institutes to the PRTR-project leader	<ul style="list-style-type: none"> – Email (14-12-2016 13:46) with the request to endorse the PRTR database; – "Actiepunten definitieve cijfers 1990-2015 v 14 dec 2016.xls"; Emails with consent from PBL, Deltares and CBS (CBS-15-12-2016 15:16; PBL-19-12-2016 15:27; Deltares- 19-12-2016 08:54).
Input for compiling the NEC report (in NFR-format)	19-12-2016	RIVM-NIC	List of allocations for compiling from the PRTR-database to the NFR-tables	"NFR-ER-Koppellijst-2016-12-19-dtt52-verwerktBL.xlsx"

List of allocations for compiling from the PRTR-database to the NFR-tables	08-02-2017	RIVM	Input for compiling the EMEP/LRTAP report (NFR format)	"NFR-ER-Koppellijst-2017-02-08-dtt52-verwerktBL.xlsx"
--	------------	------	--	---

* All documentation (e-mails, data sheets and checklists) are stored electronically on a data server at RIVM.

Text box 1.1 Trend verification workshops

About a week in advance of a trend analysis meeting, a snapshot from the database is made available by 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 for relevant gases and sectors. The totals for the sectors are then compared with the previous year's data set. Where significant differences are found, the task forces evaluate the emission data in more detail. The results of these checks form the subject of discussion at the trend analysis workshop and are subsequently documented.

Furthermore, the PRTR-team provides the task forces with time series of emissions per substance for the individual sub sectors. 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 1990 to 2014 from the new time series were compared with the time series of last years' inventory and 2) the data for 2015 were compared with the trend development per 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 and
- level values of implied emission factors.

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 2 weeks or be dealt with in next year's inventory.

Archiving and documentation

Internal procedures are agreed on (e.g., in the PRTR work plan) for general data collection and the storage of fixed data sets in the PRTR database, including the documentation/archiving of QC checks. As of 2010, sector experts can store relating 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. Moreover, updating of monitoring protocols for substances under the CLRTAP is one of the priorities within the PRTR system. Emphasis is placed on documentation of methodologies for calculating SO_x, NO_x, NMVOC, NH₃, PM₁₀ and PM_{2.5}. Methodologies, protocols and emission data (including emissions from large point sources on the basis of Annual Environmental Reports), as well as such emission reports as the National Inventory

Report (UNFCCC) and the Informative Inventory Report (CLRTAP), are made available on the website of the PRTR: www.prtr.nl.

1.7 Uncertainties

Uncertainty assessments constitute a means to either provide the inventory users with a quantitative assessment of the inventory quality or to direct the inventory preparation team to priority areas, where improvements are warranted and can be made cost-effective. For these purposes, quantitative uncertainty assessments have been carried out since 1999. However, awareness of uncertainties in emission figures was expressed earlier in the PRTR in so-called quality indices and in several studies on industrial emissions and generic emission factors for industrial processes and diffuse sources. To date, the Dutch PRTR is restricted to one value per type of emission (calculation result, rounded off to three significant digits).

The information on the uncertainty about emission figures presented here is based on the TNO report 'Uncertainty assessment of NO_x, SO₂ and NH₃ emissions in the Netherlands' (Van Gijlswijk *et al.*, 2004), which presents the results of a Tier 2 'Monte Carlo' uncertainty assessment. This uncertainty assessment is based on emissions in the year 2000. Since then, several improvements in activity data and methods (e.g. total N to TAN; see Chapter 6) have been implemented. Furthermore, for use of the uncertainties in prioritising improvements it's necessary that the uncertainties are quantified at the level of emission sources, both for activity data as for emission factors. Therefore, it is necessary to update the uncertainty assessment. This update was started in 2015 with estimating the uncertainties for activity data and emission factors based on expert judgements from the emission experts. The estimation of uncertainties will be finalised in 2017. The uncertainty data is stored in the PRTR database. To process the uncertainty information to the national, sectorial and sub-sectorial level a Monte Carlo-analysis is implemented in the database. The Monte Carlo-analysis on the uncertainties for the pollutants NH₃, NO_x, SO_x, NMVOC and PM is planned for 2017 and results will be presented in the next IIR.

Known – but unquantifiable - systematic biases in emission estimates are not explicitly addressed in the Monte Carlo-analysis. E.g. the share of condensable particles in PM-emissions is still unknown and also possible gaps in enforcement of emission regulations cannot be quantified.

1.7.1 Quantitative uncertainty

Uncertainty estimates on national total emissions have been reported in the Dutch Environmental Balances since 2000 (PBL, 2012). These estimates were based on uncertainties per source category, using simple error propagation calculations (Tier 1). Most uncertainty estimates were based on the judgement of RIVM/PBL emission experts. A preliminary analysis on NMVOC emissions showed an uncertainty range of about 25%. Van Gijlswijk *et al.* 2004) assessed the uncertainty in the contribution from the various emission sources to total acidification (in acidification equivalents) according to the Tier 2 methodology (estimation of uncertainties per source category using Monte Carlo

analysis). See Table 1.2 for results. A comparison was also made between the Tier 1 and Tier 2 methodologies. This was not straightforward, as the two studies used a different knowledge collection. The 2000 Tier 1 analysis used CLRTAP default uncertainties for several NO_x processes, which explains the difference with the 1999 Tier 1 results. For NH₃, the difference between the 2000 Tier 1 and Tier 2 can be explained by taking non-normal distributions and dependencies between individual emission sources per animal type into account (both are violations of the Tier 1 assumptions: effects encapsulated in the 1999 Tier 1 analysis). The differences for SO₂ and total acidifying equivalents are small. The conclusion drawn from this comparison is that focusing on the order of magnitude of the individual uncertainty estimates, as in the RIVM (2001) study, provides a reasonable first assessment of the uncertainty of source categories.

Table 1.2 Uncertainty (95% confidence ranges) in acidifying compounds and for total acidifying equivalents for 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 ₂	± 8%	± 6%	± 6%
Total acid equivalents	± 9%	± 8%	± 10%

The RIVM (2001) study draws on the results from an earlier study on the quality of nitrogen oxide (NO_x) and sulphur dioxide (SO₂) emissions, as reported by individual companies for point sources under their national reporting requirements. In addition to providing quantitative uncertainty estimates, the study yielded important conclusions. For example, it was concluded that a limited number of facilities showed high uncertainties (e.g. 50% or more for NO_x), which could be reduced with little extra effort, and that companies generally have a lack of knowledge on the uncertainty about the emissions they report.

In the study by Van Gijlswijk *et al.* (2004), emission experts were systematically interviewed on quantitative uncertainties, which provided simultaneous information on the reliability and quality of the underlying knowledge base. For processes not covered by interviews, standard default uncertainties, derived from the Good Practice Guidance for CLRTAP emission inventories, were used (Pulles & Van Aardenne, 2001). The qualitative knowledge (on data validation, methodological aspects, empirical basis and proximity of data used) was combined into a score for data strength, based on the so-called NUSAP approach (Van der Sluijs *et al.*, 2003; Van der Sluijs *et al.*, 2005). The qualitative and quantitative uncertainties were combined in so-called diagnostic diagrams that may be used to identify areas for improvement, since the diagrams indicate strong and weak parts of the available knowledge (see Figure 1.3). Sources with a relatively high quantitative uncertainty and weak data strength are thus candidates for improvement. To effectively reduce uncertainties, their nature must be known (e.g. random,

systematic or knowledge uncertainty). A general classification scheme on uncertainty typology is provided by Van Asselt (2000).

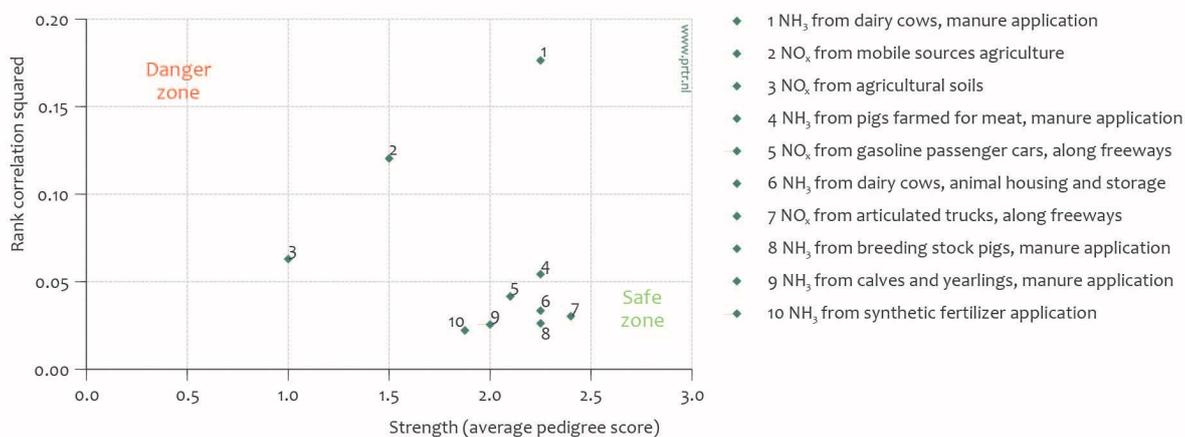


Figure 1.3 NUSAP diagnostic diagram indicating strong and weak elements in the available knowledge on acidifying substances

1.8 Explanation on the use of notation keys

The Dutch emission inventory covers all relevant sources specified in the CLRTAP that determine the emissions to air in the Netherlands. Because of the long history of the inventory it is not always possible to specify all subsectors in detail. This is the reason why notation keys are used in the emission tables (NFR). These notation keys will be explained in tables 1.3 to 1.5. For most cases where 'NE' as notation key has been used, the respective source is assumed to be negligible and sometimes there is also no method available for estimation of the respective source. IE notation keys have been included in the category listed under Notes in NFR-tables, see column D.

Table 1.3 The Not Estimated (NE) notation key explained

NFR13 code	Substance(s)	Reason for not estimated
All	PCBs	respective sources are assumed negligible
1A1b	NH ₃ , Pb-Zn, PAHs, HCBs	respective source is assumed negligible; no method available
1A1c	All, except SO ₂ and NO _x	respective sources are assumed negligible
1A2a	NH ₃ , As, Cu, Ni, Se, PAHs HCBs	respective sources are assumed negligible
1A2b	HCBs	respective sources are assumed negligible
1A2c	Pb, Cd, As, Se, PAHs, HCBs	respective sources are assumed negligible
1A2d	Pb, Cd, As, Se, PAHs, HCBs	respective sources are assumed negligible
1A2e	Pb-Zn	respective source is assumed negligible; no method available
1A2f	All	respective source is assumed negligible
1A2gvii	HCBs	respective source is assumed negligible
1A3b-d	HCBs	respective sources are assumed negligible
1A4aii	HCBs	respective source is assumed negligible

NFR13 code	Substance(s)	Reason for not estimated
1A4bi	NH ₃	respective source is assumed negligible
1A4bii	HCBs	respective source is assumed negligible
1A4ci	NH ₃ , Pb-Zn	respective source is assumed negligible
1A4cii	HCBs	respective source is assumed negligible
1A4ciii	Pb-As, Se, HCBs	respective source is assumed negligible
1A5a	NH ₃ , Pb-Zn, HCBs	respective source is assumed negligible
1A5b	HCBs	respective source is assumed negligible
1B1a	NMVOC, SO _x , CO, Pb-Zn, HCBs	respective source is assumed negligible
1B2	SO _x	respective sources are assumed negligible
1B2av	NMVOC	respective source is assumed negligible
1B2c	Pb-Zn, PCDD/PCDF, PAHs, HCBs	respective sources are assumed negligible
1B2d	All, except NO _x	respective sources are assumed negligible
2D3b, 2D3c	All	respective sources are assumed negligible
3B	NMVOC	respective sources are assumed negligible
3D, except 3Dc, 3Df	TSP, PM ₁₀ , PM _{2.5}	respective sources are assumed negligible
3Da4	NO _x , NH ₃ , TSP, PM ₁₀ , PM _{2.5}	respective source is assumed negligible
3De	NO _x , SO ₂	respective source is assumed negligible
3Df	NO _x , NMVOC, SO ₂ , NH ₃ , CO, Pb-Se	respective source is assumed negligible
3F	All	respective sources are assumed negligible
3I	All	respective sources are assumed negligible
6A	All, except NH ₃ , TSP, PM ₁₀ , PM _{2.5}	respective sources are assumed negligible

Table 1.4 The Included Elsewhere (IE) notation key explained

NFR13 code	Substance(s)	Included in NFR code
1A3aii(i)	All	1A3ai(i)
1A3e	All	1A2f, 1A4cii, 1B2b
1B1a	TSP, PM ₁₀ , PM _{2.5}	2H3
1B2c	NMVOC, TSP, PM ₁₀ , PM _{2.5} , CO	1B2b, 1B2aiv
2A2	NO _x , NMVOC, SO ₂	2A6
2A5a	NMVOC	2H3
2A5b	NO _x , NMVOC, SO ₂	2A6
2A5c	NO _x , NMVOC, SO ₂	2A6
2B1	NMVOC, NH ₃	2B10a
2B2	NMVOC, NH ₃	2B10a
2B5	NMVOC, NH ₃	2B10a
2B6	NMVOC, NH ₃	2B10a
2B7	NMVOC, NH ₃	2B10a
2B10b	NMVOC, NH ₃	2B10a
2C4	All	2C7c
2C7d	All	2H3
2D3g	NMVOC	2B10a
2G	All	2D3i

NFR13 code	Substance(s)	Included in NFR code
2L	All	2H3
3B4giii	NO _x , NH ₃ , PM ₁₀ , PM _{2.5}	3B4gii
3B4giv	NO _x , NH ₃ , PM ₁₀ , PM _{2.5}	3B4gii
3Da1	NO _x	11C
3Da3	NO _x	11C
5A	NO _x , SO ₂ , TSP, PM ₁₀ , PM _{2.5} , BC, CO	1A1a
5B2	NO _x , SO ₂ , TSP, PM ₁₀ , PM _{2.5} , BC, CO	1A4ai
5D1	NO _x , SO ₂ , TSP, PM ₁₀ , PM _{2.5} , BC, CO	1A4ai
5D2	NO _x , SO ₂ , TSP, PM ₁₀ , PM _{2.5} , BC, CO	1A4ai

Table 1.5 Sub-sources accounted for in reporting 'other' codes

NFR13 code	Substance(s) reported	Sub-source description
1A2gviii		Combustion in not elsewhere reported industries, machineries, services and product making activities.
1A5a		Combustion gas from landfills.
1A5b		Recreational navigation and ground machinery at airports.
2A6		Processes, excl. combustion, in building activities and production of building materials.
2B10a		Production of chemicals, paint, pharmaceuticals, soap, detergents, glues and other chemical products.
2C7c		Production of non-ferrous metals.
2D3i		Smoking tobacco products, burning candles, air conditioning, use of pesticides; cosmetics, fireworks, preservation and cleaning of wood and other materials.
2H3		Making products of wood, plastics, rubber, metal, textiles and paper. Storage and handling.
3B4h	NO _x , NH ₃ , TSP, PM ₁₀ , PM _{2.5}	Rabbits and furbearing animals.
3Da2c	NO _x , NH ₃	Use of compost.
5E		Preparation for recycling, scrapping of white goods and decontamination.
6A		Human transpiration and breathing; manure application to private domains and nature; horses and ponies from private owners.
11C	NO _x	Volatilization of nitrogen oxides from agricultural and non-agricultural land.

2 Trends in emissions

2.1 Trends in national emissions

The Dutch NH₃ emission series are dangling about the national emission ceiling set for the year 2010 (NEC2010). For NO_x, SO₂ and NMVOC the Netherlands is in compliance with the respective ceilings in 2015. The emissions of all substances showed a downward trend in the 1990-2015 period (see Table 2.1). The major overall drivers for this trend are:

- emission reductions in the industrial sectors;
- cleaner fuels;
- cleaner cars.

Road transport emissions have decreased 87% since 1990 for NMVOC, 76% for PM, 70% for NO_x and 99% for SO₂, despite a growth in road transport of 13%. The decrease is mainly attributable to European emission regulations for new road vehicles. For PM and NO_x, standards have been set for installations by tightening up the extent of emission stocks of heating installations (BEES). In meeting these requirements, Dutch industrial plants have realised a reduction of 93% in PM emissions and 62% in NO_x emissions, since 1990. Sections 2.2-2.8 elaborate in more detail on the drivers for the downward emission trend for specific substances.

Table 2.1 Total national emissions, 1990-2015

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	604	490	193	369	51	74	97	13	1143
1995	505	349	131	227	38	55	73	11	918
2000	420	244	73	178	28	43	51	10	752
2005	369	181	64	156	22	35	43	8	723
2010	300	165	34	135	17	30	37	5	675
2014	234	143	29	127	13	27	35	3	563
2015	228	139	30	128	13	26	34	3	570
1990-2015 period ¹⁾	-376	-351	-163	-241	-38	-48	-64	-10	-573
1990-2015 period ²⁾	-62%	-72%	-84%	-65%	-75%	-64%	-65%	-75%	-50%

¹⁾ Absolute difference in Gg

²⁾ Relative difference to 1990 in %

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	332	2.1	3.6	742	20	1.3	12	37	73	0.4	224
1995	153	1.1	1.5	66	10	0.9	8.5	38	84	0.3	146
2000	27	1.0	1.1	31	5.1	0.9	5.0	39	19	0.5	95
2005	30	1.8	1.0	30	5.1	1.3	4.3	41	10	2.6	88
2010	38	2.6	0.6	31	4.9	0.6	3.8	45	2	1.5	102
2014	9	0.6	0.6	22	4.7	0.7	3.5	43	2	0.8	117
2015	9	0.6	0.5	22	4.7	0.7	3.4	41	2	1.0	101
1990-2015 period ¹⁾	-323	-1.5	-3.0	-721	-15	-0.6	-8.4	3.8	-71	0.6	-123
1990-2015 period ²⁾	-97%	-71%	-85%	-97%	-76%	-49%	-71%	10%	-97%	150%	-55%

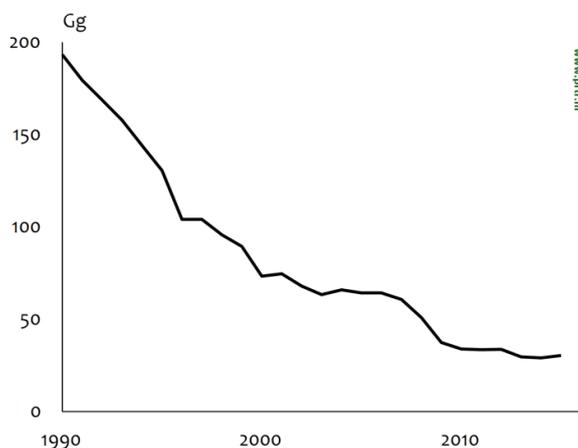
¹⁾ Absolute difference in Gg

²⁾ Relative difference to 1990 in %

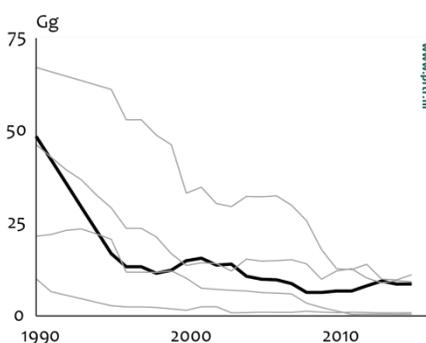
2.2 Trends in sulphur dioxide (SO₂)

The Dutch SO_x emissions (reported as SO₂) decreased by 163 Gg in the 1990-2015 period, corresponding to 84% of the national total in 1990 (Figure 2.1). Main contributions to this decrease came from the energy, industry and transport sectors. The use of coal declined and major coal-fired electricity producers installed flue-gas desulphurisation plants. The sulphur content in fuels for the (chemical) industry and traffic was also reduced. At present the industry, energy and refining sector (IER) is responsible for 97% of the national SO₂ emissions.

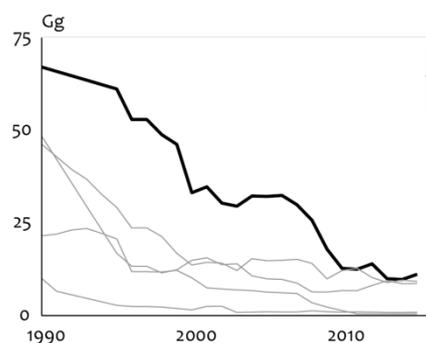
Total SO₂ emissions



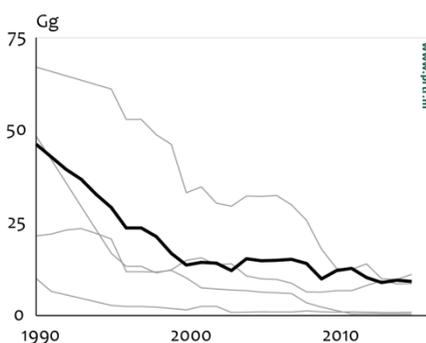
1A1a Public power



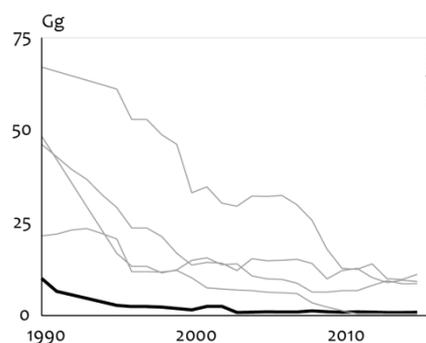
1A1b Refining



1A2 Industrial and Small Combustion



2 Industrial processes



1A3 Transport

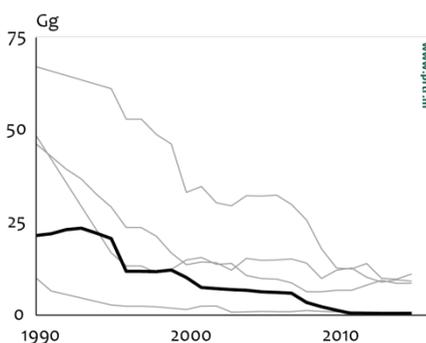
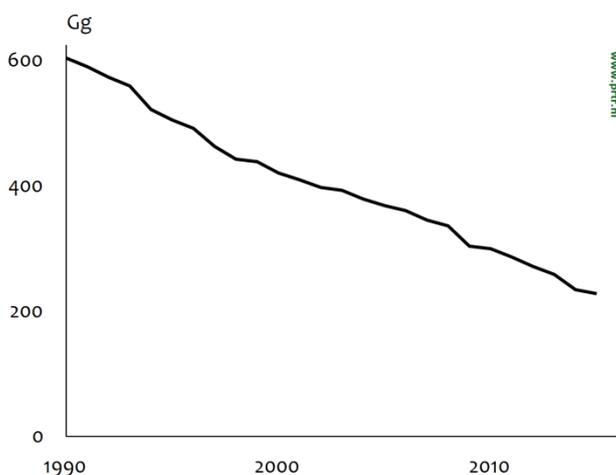


Figure 2.1 SO₂ emission trends 1990-2015

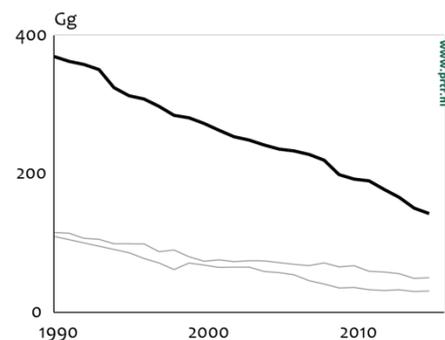
2.3 Trends in nitrogen oxides (NO_x)

The Dutch NO_x emissions (NO and NO₂, expressed as NO₂) decreased by 376 Gg in the 1990-2015 period, corresponding to 62% of the national total in 1990 (Figure 2.2). Main contributors to this decrease are road transport and the energy sector. Although emissions per vehicle decreased significantly in this period, an increase in number and mileages of vehicles partially negated the effect on total road transport emissions. The shares of the different NFR categories in the national total did not change significantly.

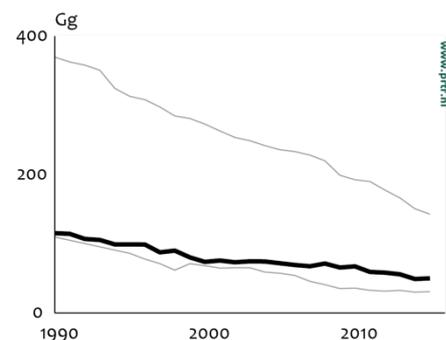
Total NO_x emissions



1A3 Transport



1A2 Industrial and 1A4 Small Combustion



1A1 Energy

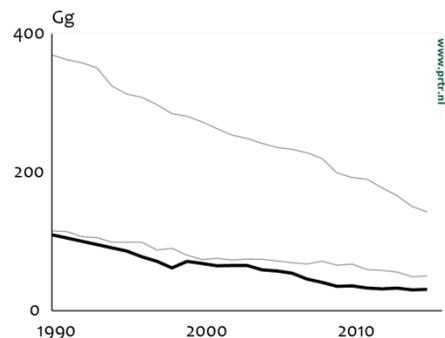
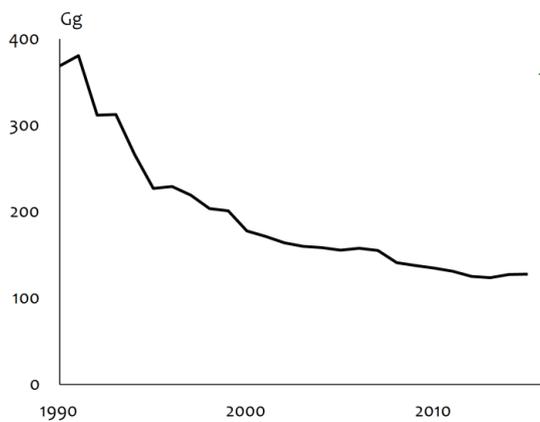


Figure 2.2 NO_x emission trends 1990-2015

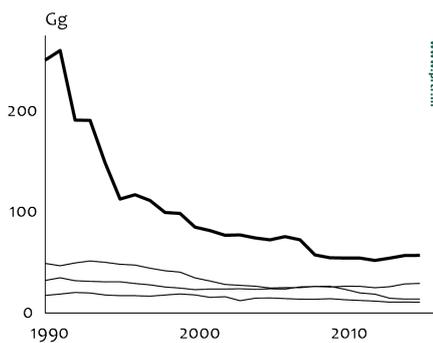
2.4 Trends in ammonia (NH₃)

Most of the NH₃ emissions (at present, 87%) come from agricultural sources. From 1990-2013, the decreasing trend in NH₃ due to emission reductions from agriculture also shows in the decreasing trend of the national total. From 2014 onwards, however, NH₃ emissions rose to a national total just around 128 Gg which is the maximum set to this by the European Union since 2010. As a result of the good quality of grass, fed to dairy cattle, digestibility and therefore NH₃ emission per animal increased. In combination with the growth in animal number, total NH₃ emissions increased.

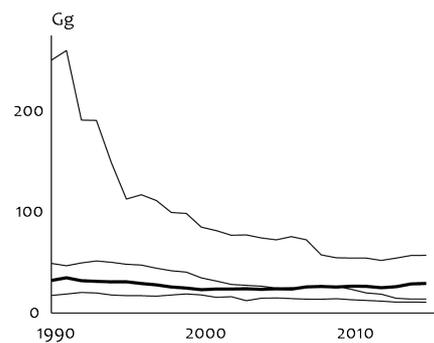
Total NH₃ emissions



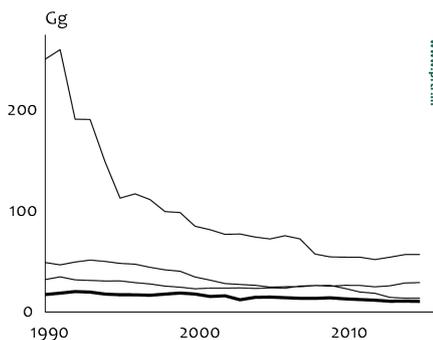
3D Agricultural soils



3B1 Cattle



3B4g Poultry



3B3 Swine

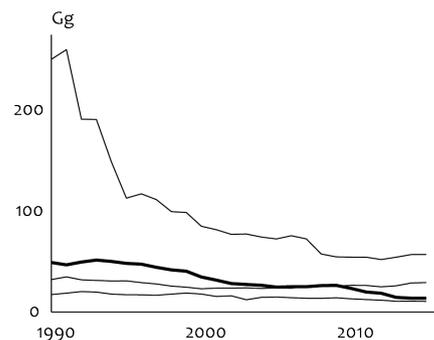
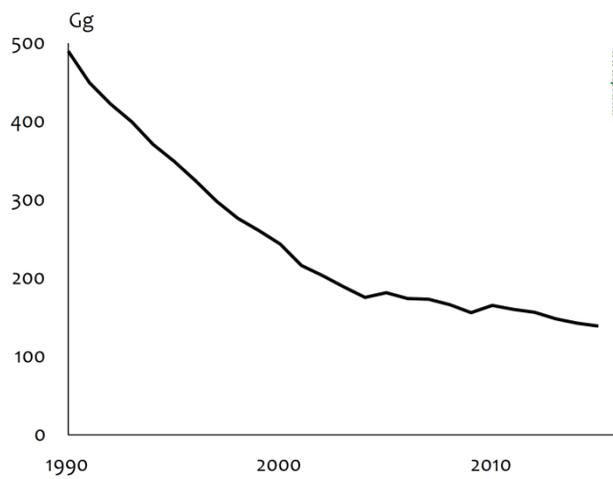


Figure 2.3 NH₃ emission trends 1990-2015

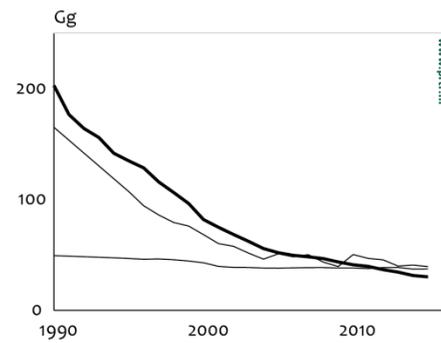
2.5 Trends in non-methane volatile organic compounds (NMVOC)

The Dutch NMVOC emissions decreased by 351 Gg in the 1990-2015 period, corresponding with 72% of the national total in 1990 (Figure 2.4). 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 specific for NMVOC).

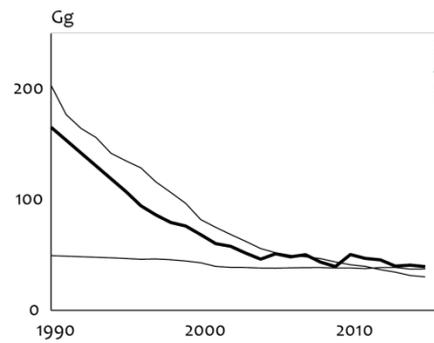
Total NMVOC emissions



1A3 Transport



2 Industrial Processes



2D3 Solvents

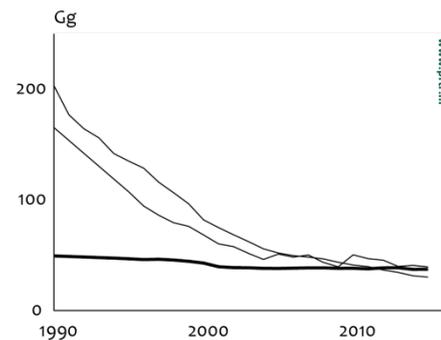
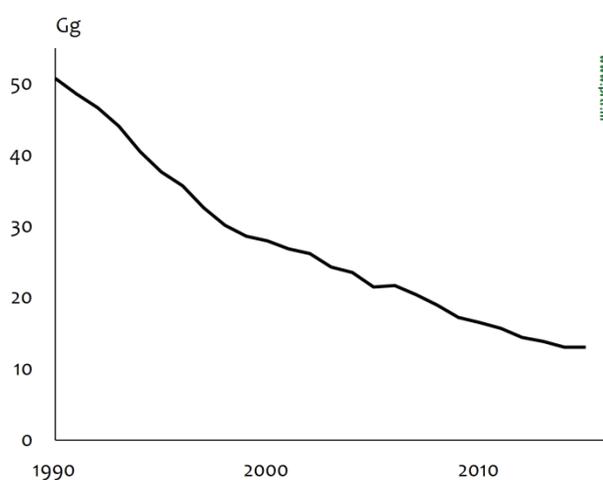


Figure 2.4 NMVOC, emission trends 1990-2015

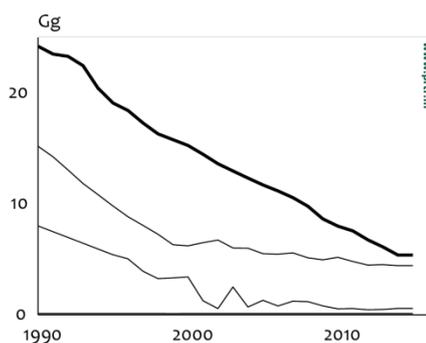
2.6 Trends in PM_{2.5}

PM_{2.5} emissions are calculated as a specific fraction of PM₁₀ by sector (based on Visschedijk *et al.*, 2007) and decreased by 38 Gg in the 1990-2015 period, corresponding with 75% of the national total in 1990 (Figure 2.5). The two major source categories contributing to this decrease were the industrial sector (combustion and process emissions), due to cleaner fuels in refineries and the side effect of emission abatement for SO₂ and NO_x and the transport sector.

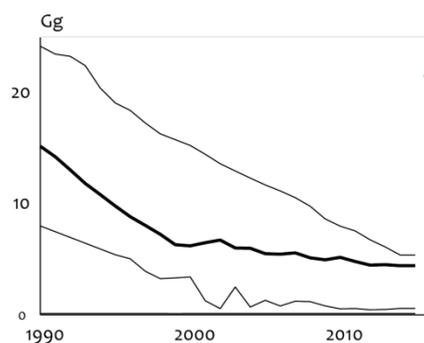
PM_{2.5} emissions



1A3 Transport



2 Industrial processes



1A1, 1A2 Energy & Industry

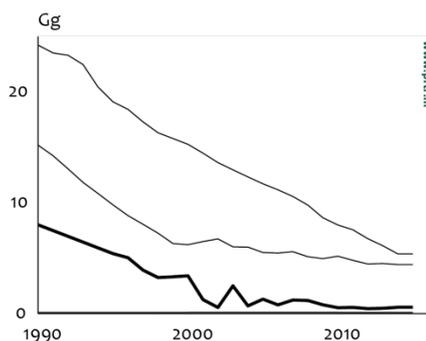


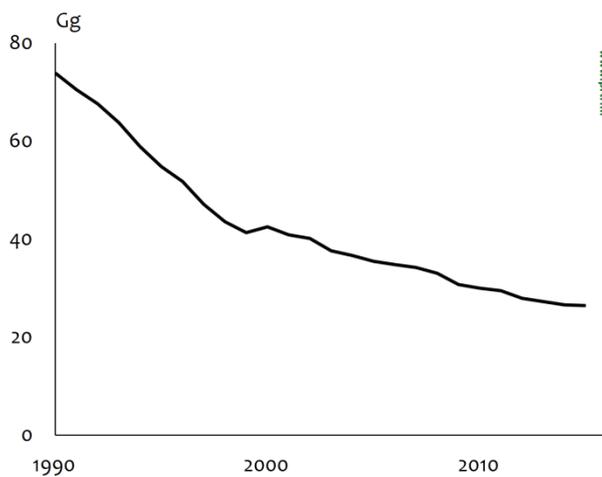
Figure 2.5 PM_{2.5} emission trends 1990-2015

2.7 Trends in PM₁₀

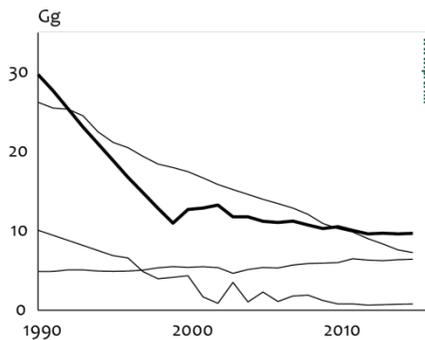
Dutch PM₁₀ emissions decreased by 48 Gg in the 1990-2015 period, corresponding with 64% of the national total in 1990 (Figure 2.6). The major source categories contributing to this decrease are:

- industry (combustion and process emissions), due to cleaner fuels in refineries and the side-effect of emission abatement for SO₂ and NO_x;
- traffic and transport.

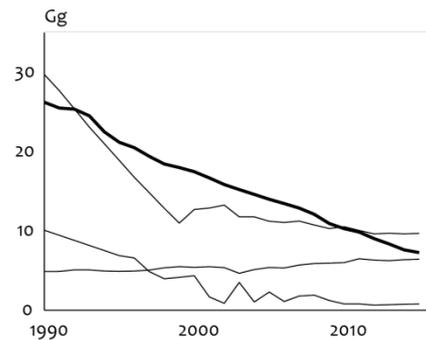
PM₁₀ emissions



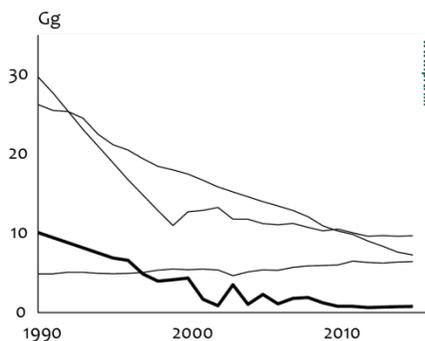
2 Industrial processes



1A3 Transport



1A1, 1A2 Energy & Industry



3 Agriculture

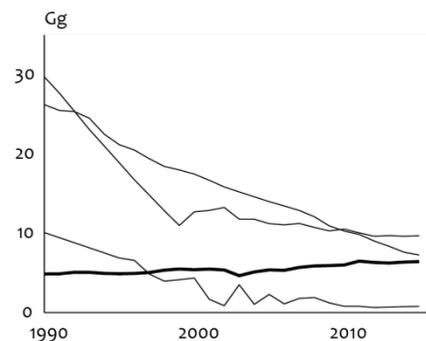


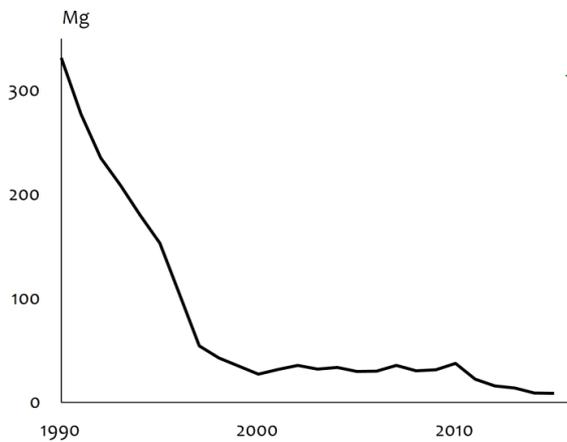
Figure 2.6 PM₁₀, emission trends 1990-2015

PM₁₀ emissions from animal husbandry in agriculture did not change significantly; neither did the emissions from consumers (1A4bi).

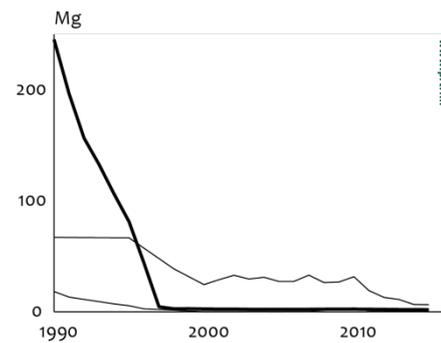
2.8 Trends in Pb

Lead (Pb) emissions in the Netherlands decreased by 323 Mg in the 1990-2015 period, corresponding with 97% of the national total in 1990 (Figure 2.7). This decrease is attributable to the transport sector, where, due to the removal of Pb from gasoline, the Pb emissions collapsed. The remaining sources are industrial process emissions, in particular from the iron and steel industry.

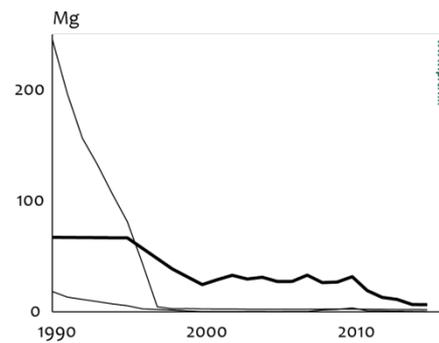
Pb emissions



1A3 Transport



2 Industrial processes



1A1, 1A2 Energy & Industry

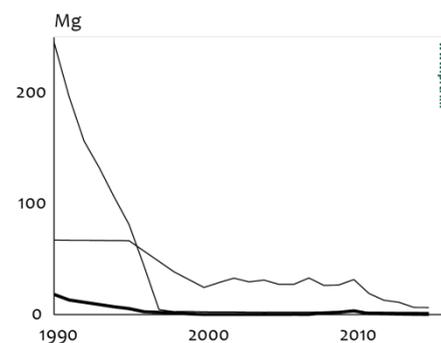


Figure 2.7 Pb, emission trends 1990-2015

3 Energy

3.1 Overview of the sector

Emissions from this sector include all energy-related emissions from stationary combustion. Furthermore it includes fugitive emissions from the energy sector.

Part of the emissions from stationary combustion for electricity production and industry (NFR categories 1A1 and 1A2) are reported based on environmental reports by large industrial companies. For SO₂, 98% of the emissions is reported based on environmental reports, while for other pollutants this is 99% (NH₃), 87% (NMVOC), 85% (NO_x) and 90% (PM₁₀) in 2015. It should be noted that these percentages include not only the data directly from the AERs but also the initial gap filling at company level performed by the competent authorities. The emission data in the Annual Environmental Reports (AERs) come from direct emission measurements or from calculations using fuel input and emission factors. Most of the emissions from other stationary combustion (categories 1A4 and 1A5) are calculated with energy statistics and default emission factors.

As for most developed countries, the energy system in the Netherlands is largely driven by the combustion of fossil fuels. In 2015, natural gas supplied about 41% of the total primary fuels used in the Netherlands, followed by liquid fuels (39%) and solid fossil fuels (15%). The contribution of non-fossil fuels, including renewables and waste streams, is rather limited (5%). Figure 3.1 shows the energy supply and energy demand in the Netherlands.

The energy statistics are available on the website of Statistics Netherlands. The following link refers to the energy statistics of 2015. Using the button "Change selection" on the website, it is possible to select the data of another year.

Energy statistics of 2015:

<http://statline.cbs.nl/Statweb/publication/?VW=T&DM=SL&EN&PA=83140&ENG&D1=a&D2=3-4,6-10,13-16,18-34,43-45,47-48&D3=l&HD=160128-1200&LA=EN&HDR=G2,G1&STB=T>

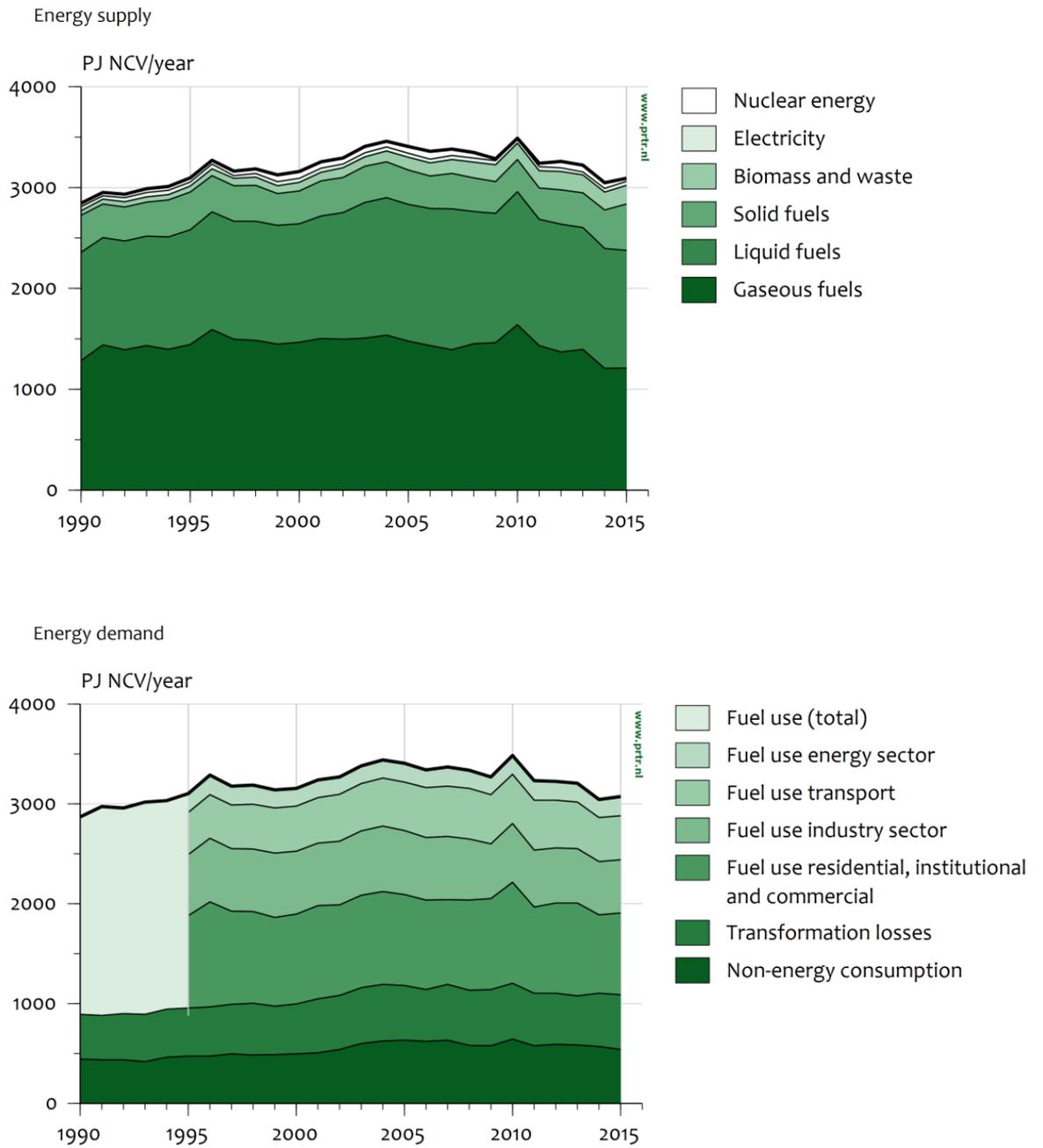


Figure 3.1 Energy supply and demand in the Netherlands. For the years 1990 – 1994, only the total fuel use is shown

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, with many of the latter being operated as joint ventures with industries. Compared to 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 for the pollutants mentioned in Table 3.1.

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

Category / Sub-category	Pollutant	Contribution to national total of 2015 (%)
1A1a Public electricity and heat production	SO _x	28.5
	NO _x	8.8
	PM _{2.5}	2.2
	Hg	40.8

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 2015, while fuel consumption increased over the same period.

The NO_x and SO_x emissions decreased by 76% and 82%. Other pollutant emissions decreased by 29% to 99%. The decrease in emissions was partly caused by a shift from coal to gas consumption. Furthermore, the decrease in emissions was caused by technological improvements. The only pollutants for which the emissions have increased are NMVOC and NH₃ due to an increase in activity rate. For Se, the increase of a factor 45 is caused by environmental reports being considered for the later years, while for the earlier years only little or no information was available.

Table 3.2 Overview of trends in emissions

Year	Main Pollutants				Particulate Matter				Other
	NO _x	NMVOG	SO _x	NH ₃	PM _{2.5}	PM ₁₀	TSP	BC	CO
	Gg	Gg	Gg	Gg	Gg	Gg	Gg	Gg	Gg
1990	83	0.7	48	0	1.9	2.2	2.3	0	8.2
1995	62	1.1	17	0.039	0.4	0.5	0.5	0	7.4
2000	52	2.2	15	0.038	0.3	0.3	0.3	0	15.8
2005	43	0.6	10	0.252	0.4	0.5	0.6	0	8.2
2010	26	0.3	7	0.074	0.2	0.3	0.4	0	5.0
2014	19	1.4	9	0.081	0.2	0.3	0.5	0	4.4
2015	20	0.5	9	0.090	0.3	0.4	0.5	0	4.2
1990-2015 period ¹⁾	-63	-0.2	-40	0.090	-1.6	-1.8	-1.8	0	-4.0
1990-2015 period ²⁾	-76%	-29%	-82%		-85%	-83%	-78%		-49%

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	16	0.95	1.9	568	0.17	0.50	0.62	2.05	2.49	0.02	40.7
1995	2	0.16	0.4	6.0	0.05	0.20	0.37	0.44	1.41	0.05	3.3
2000	0.2	0.08	0.4	0.1	0.00	0.08	0.19	0.17	0.08	0.45	0.3
2005	0.2	0.09	0.4	0.7	0.01	0.16	0.33	0.28	1.91	1.68	0.5
2010	0.3	0.18	0.2	1.2	0.01	0.11	0.14	0.15	0.16	1.33	3.9
2014	0.2	0.03	0.2	1.0	0.02	0.07	0.18	0.18	0.08	0.70	4.4
2015	0.2	0.03	0.2	1.0	0.03	0.06	0.17	0.17	0.17	0.91	4.1
1990-2015 period ¹⁾	-16	-0.9	-1.7	-567	-0.14	-0.44	-0.5	-1.9	-2.3	0.9	-36.6
1990-2015 period ²⁾	-99%	-97%	-88%	-100%	-83%	-88%	-73%	-92%	-93%	4497%	-90%

¹⁾ Absolute difference

²⁾ Relative difference to 1990 in %

3.2.4 Activity data and (implied) emission factors

Emission data are based on Annual Environmental Reports (AERs) and collectively estimated industrial sources. For this source category, 90% to 100% of the emissions are based on AERs. For estimation of emissions from collectively estimated industrial sources, National Energy Statistics (from Statistics Netherlands) are combined with implied emission factors from the AERs or with default emission factors (see table 3.3).

3.2.5 Methodological issues

Emissions are based on data in Annual Environmental Reports (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 implied emission factors (IEFs). If environmental reports provide data of high enough quality, the information is used for calculating an 'implied emission factor' for a cluster of reporting companies (aggregated by NACE code). These emission factors are fuel and sector dependent and are used to calculate the emissions from companies that are not individually assessed.

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

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 implied emission factor. If the data from the individual companies are insufficient to calculate an implied emission factor, then a default emission factor is used (see Table 3.3).

$$ER-C_{\text{emission}}(\text{NACE, fuel}) = EF_{ER-I}(\text{NACE, fuel}) * \text{Energy Statistics}(\text{NACE, fuel})$$

where:

ER-C = Emission Registration database for collective emission sources

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

Table 3.3 Default emission factors for electricity production (g/GJ)

Substance name	Natural gas	Biogas	Cokes	Dieseloil	LPG	Petroleum	Coal	Fuel oil	Wood
Hydrocarbons	12	9	91	15	2	10	3	7	120
Sulphur dioxide		2	370	87		46	300	450	10
Nitrogen oxides as NO ₂	37	27	100	60	27	50	45	64	120
Carbon monoxide	15	20	12437	30	10	10	50	10	70
Particulate matter	0.15	2	6	4.5	2	1.8	60	22.5	1
Coarse particulates			4	0.5		0.2	40	2.5	

3.2.6 Uncertainties and timeseries consistency

Uncertainties are explained in section 1.7.

3.2.7 *Source-specific QA/QC and verification*

The emissions and fuel consumption data in the AERs are systematically examined for inaccuracies by checking the resulting implied emission factors. If environmental reports provide data of high enough quality (see section 1.6 on QA/QC), the information is used.

3.2.8 *Source-specific recalculations*

Emissions of the following sources have been recalculated:

- Following an update in the calculation methodology, Zn and PM₁₀ emissions from waste incineration plants used for electricity generation have been recalculated for the period 2006-2014
- In the waste incineration plants, emissions from other pollutants have been corrected in 2014 following the use of updated emission factors

3.2.9 *Source-specific planned improvements*

There are no source-specific planned improvements.

3.3 **Industrial Combustion (1A1b, 1A1c and 1A2)**

3.3.1 *Source category description*

This source category consists of the following categories:

- 1A1b Petroleum refining
- 1A1c Manufacture of solid fuels and other energy industries
- 1A2a Iron and Steel
- 1A2b Non-ferrous Metals
- 1A2c Chemicals
- 1A2d Pulp, Paper and Print
- 1A2e Food Processing, Beverages and Tobacco
- 1A2f Non-metallic minerals
- 1A2gviii Other

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

3.3.2 *Key sources*

The sectors 1A1b, 1A2c and 1A2gviii are key sources for the pollutants mentioned in Table 3.4.

Table 3.4 Pollutants for which the Industrial Combustion (NFR 1A1b, 1A1c and 1A2) sector is a key source

Category / Sub-category	Pollutant	Contribution to total of 2015 (%)
1A1b Petroleum refining	SO _x	28.5
1A2a Stationary combustion in manufacturing industries and construction: Iron and steel	SO _x	9.9
	NO _x	2.6
	CO	11.5
1A2c Stationary combustion in manufacturing industries and construction: Chemicals	NO _x	4.0
1A2gviii Stationary combustion in manufacturing industries and construction: Other	SO _x	8.7
	Hg	7.7

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 reduced since 1990 for most pollutants, except for NH₃ and dioxins. Reduction in emissions of main pollutants has been caused by improvement in used abatement techniques. Fluctuation in dioxin emissions have been caused by differences in fuels used and/or incidental emissions. Emission reduction of SO₂ and PM₁₀ is mainly caused by a shift in fuel use by refineries from oil to natural gas.

Table 3.5 Overview of trends in emissions

Year	Main Pollutants				Particulate Matter				Other
	NO _x	NMVOG	SO _x	NH ₃	PM _{2.5}	PM ₁₀	TSP	BC	CO
	Gg	Gg	Gg	Gg	Gg	Gg	Gg	Gg	Gg
1990	101	6.3	110	0.57	6.1	7.9	8.3	0.37	266
1995	78	6.9	89	0.32	5.0	6.4	6.6	0.36	215
2000	49	2.1	46	0.05	3.1	4.7	4.7	0.29	160
2005	49	2.6	46	0.06	0.9	1.8	2.0	0.11	153
2010	40	3.9	24	0.43	0.35	0.5	0.8	0.02	124
2014	35	3.5	19	0.30	0.34	0.5	0.6	0.01	90
2015	35	2.9	20	0.40	0.31	0.4	0.6	0.01	96
1990-2015 period ¹⁾	-66	-3.3	-90	-0.17	-5.8	-7.5	-7.7	-0.36	-170
1990-2015 period ²⁾	-65%	-53%	-82%	-30%	-95%	-95%	-93%	-98%	-64%

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	1.9	0.14	0.18	0.01	0.99	0.17	2.5	1.4	64	0.04	2.9
1995	3.9	0.17	0.08	1.02	0.38	0.15	3.1	2.3	79	0.05	3.5
2000	0.04	0.01	0.11	0.35	0.004	0	0.51	0.15	17	0.002	0.84
2005	0.01	0.003	0.004	0.94	0.10	0.78	0.08	0.09	7	0.08	0.51
2010	3.1	1.28	0.02	5.79	0.13	0.013	0.14	1.13	0.02	0.12	9.8
2014	0.12	0.001	0.05	0.20	0.09	0.001	0.01	0.00	0.11	0.0001	0.9
2015	0.09	0.001	0.05	0.19	0.10	0.001	0.01	0.00	0.11	0.0001	1.2
1990-2015 period ¹⁾	-1.79	-0.14	-0.13	0.18	-0.90	-0.17	-2.47	-1.39	-64	-0.04	-1.78
1990-2015 period ²⁾	-95%	-99%	-73%	2108%	-90%	-100%	-100%	-100%	-100%	-100%	-61%

¹⁾ Absolute difference

²⁾ Relative difference to 1990 in %

3.3.4 *Activity data and (implied) emission factors*

Petroleum refining (1A1b)

All emission data have been based on Annual Environmental Reports (AERs).

Manufacture of solid fuels and other energy industries (1A1c)

Emission data have been based on AERs and collectively estimated industrial sources.

Iron and steel (1A2a)

Emission data have been based on AERs and collectively estimated industrial sources. For this source category, 1% of the SO_x emissions are collectively estimated (in 2015), thus 99% based on the AERs.

Non-ferrous metals (1A2b)

Emission data have been based on AERs and collectively estimated industrial sources. For this source category, 23% of the NMVOC emission, 9% of the NO_x emissions and 16% of the SO_x emissions are collectively estimated (in 2015).

Chemicals (1A2c)

Emission data have been based on AERs and collectively estimated industrial sources. For this source category, 4% of the NO_x, 3% of the SO_x emissions and 2% of the NMVOC and 1% of the PM₁₀ emissions are collectively estimated (in 2015).

Pulp, paper and print (1A2d)

Emission data have been based on AERs and collectively estimated industrial sources. For this source category, 32% NMVOC emissions and 12% of NO_x emissions are collectively estimated (in 2015).

Food processing, beverages and tobacco (1A2e)

Emission data have been based on AERs and collectively estimated industrial sources.

Non-metallic minerals (1A2f)

Emission data have been based on AERs and collectively estimated industrial sources.

Other (1A2gviii)

This sector includes all combustion emissions from the industrial sectors not belonging to the categories 1A2a to 1A2e. Emission data have been based on AERs and collectively estimated industrial sources.

For some of the above mentioned categories, emissions were not entirely available from the AERs. For these sectors, emissions were calculated using National Energy Statistics and implied emission factors from the environmental reports or default emission factors (see Table 3.6).

3.3.5 *Methodological issues*

Emissions are based on data in 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 implied emission factors. If environmental reports provide data of high

enough quality, the information is used for calculating an 'implied emission factor' for a cluster of reporting companies (aggregated by NACE code). These emission factors are fuel and sector dependent and are used to calculate the emissions from companies that are not individually assessed.

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

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 implied emission factor. If the data from the individual companies are insufficient to calculate an implied emission factor, then a default emission factor is used (see Table 3.6).

$$ER-C_emission(NACE, fuel) = EF_{ER-I}(NACE, fuel) * \text{Energy Statistics}(NACE, fuel)$$

where:

ER-C = Emission Registration database for collective emission sources

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

Table 3.6 Emission factors for the industrial sector (g/GJ)

Substance name	Natural gas	Biogas	Cokes	Diesel oil	LPG	Petroleum	Coal	Fuel oil	Wood
Hydrocarbons	12	9	91	15	2	10	3	7	120
Sulphur dioxide		2	370	87		46	300	450	10
Nitrogen oxides as NO ₂	37	27	100	60	27	50	45	64	120
Carbon monoxide	15	20	12437	30	10	10	50	10	70
Particulate matter	0.15	2	6	4.5	2	1.8	60	22.5	1
Coarse particulates			4	0.5		0.2	40	2.5	

3.3.6 Uncertainties and timeseries consistency

Uncertainties are explained in section 1.7.

3.3.7 *Source-specific QA/QC and verification*

The emissions and fuel consumption data in the AERs were systematically examined for inaccuracies by checking the resulting implied emission factors. 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*

Emissions of the following sources have been recalculated:

- Activity data for diesel in the energy statistics have been improved
- PM₁₀, PM_{2.5}, BC, NO_x and SO_x have been corrected for earlier years (2013, 2014) from the corrected annual environmental reports of two companies
- An error has been corrected in the NO_x emissions extracted from the Annual Environmental Reports for 2013 and 2014
- PM_{2.5} emissions from the chemical industry have been updated, following the use of a company specific EF instead of the default

3.3.9 *Source-specific planned improvements*

There are no source-specific planned improvements.

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, such as banks, schools and hospitals, trade, retail and 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 by 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. This sector includes stationary combustion of waste gas from dumping sites.

3.4.2 *Key sources*

The Small Combustion sector is a key source for the pollutants presented in Table 3.7.

Table 3.7 Pollutants for which the Small Combustion (NFR 1A4 and 1A5) sector is a key source sector

Category / Sub-category	Pollutant	Contribution to total of 2015 (%)
1A4ai Commercial/institutional, stationary	NO _x	2.9
1A4bi Residential, stationary	NO _x	3.6
	NM VOC	8.1
	CO	13.7
	PM ₁₀	7.9
	PM _{2.5}	15.5
	BC	20.7
	Cd	9.4
	Dioxine	31.9
1A4ci Agriculture/forestry/fishing, stationary	PAH	86.9
1A4ci Agriculture/forestry/fishing, stationary	NO _x	4.8

3.4.3 *Overview of shares and trends in emissions*

An overview of the trends in emissions is shown in Table 3.8. Emissions of almost all pollutants have decreased since 1990, while fuel use increased slightly.

Table 3.8 Overview of trends in emissions

Year	Main Pollutants				Particulate Matter				Other
	NO _x	NMVOG	SO _x	NH ₃	PM _{2.5}	PM ₁₀	TSP	BC	CO
	Gg	Gg	Gg	Gg	Gg	Gg	Gg	Gg	Gg
1990	42	16.2	3.3	0	2.7	2.8	5.5	0.9	81
1995	46	17.0	1.5	0	2.6	2.7	5.2	0.9	86
2000	41	15.7	0.9	0	2.3	2.4	4.8	0.9	83
2005	37	15.2	0.7	0	2.3	2.4	4.7	0.8	85
2010	38	15.4	0.6	0	2.2	2.3	4.5	0.7	85
2014	25	13.7	0.5	0	2.0	2.1	4.4	0.7	81
2015	26	13.9	0.6	0	2.0	2.1	4.4	0.7	83
1990-2015 period ¹⁾	-16	-2.3	-2.8	0	-0.6	-0.7	-1.1	-0.3	2
1990-2015 period ²⁾	-38%	-14%	-83%		-23%	-23%	-20%	-27%	2%

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	0.12	108	3.8	0.05	3.5	0.72	2.7	0.0036	2
1995	0.12	0.05	0.04	8.1	4.0	0.02	0.05	0.34	0.5	0.0018	0.77
2000	0.08	0.05	0.03	7.3	3.9	0.01	0.00	0.32	0.01	0.0000	0.70
2005	0.08	0.05	0.03	7.0	4.1	0.00	0.01	0.35	0.2	0.0001	0.76
2010	0.09	0.05	0.03	6.8	4.1	0.01	0.00	0.38	0.02	0.0000	0.82
2014	0.09	0.06	0.03	6.9	4.2	0.00	0.00	0.40	0.01	0.0000	0.85
2015	0.09	0.06	0.04	7.0	4.2	0.00	0.00	0.40	0.01	0.0000	0.86
1990-2015 period ¹⁾	-0.69	-0.01	-0.08	-101	0.4	-0.05	-3.5	-0.32	-2.7	-0.0036	-1.1
1990-2015 period ²⁾	-88%	-13%	-69%	-94%	11%	-97%	-100%	-44%	-100%	-100%	-57%

¹⁾ Absolute difference²⁾ Relative difference to 1990 in %

3.4.4 Activity data and (implied) emission factors

Commercial/institutional (1A4ai)

Combustion emissions from the commercial and institutional sector have been based on fuel consumption data (from Statistics Netherlands) and emission factors (see Table 3.9).

Table 3.9 Emission factors for stationary combustion emissions from the services sector (g/GJ)

Substance name	Natural gas	Biogas	Diesel oil	LPG	Petroleum	Coal	Fuel oil	Wood
Hydrocarbons	12	8	15	2	10	3	7	40
Sulphur dioxide		2	87		46	300	450	10
Nitrogen oxides as NO ₂	¹⁾	80	60	40	50	45	64	120
Carbon monoxide	15	20	30	10	10	50	10	70
Particulate matter	0.15	2	4.5	2	1.8	60	22.5	1
Coarse particulates			0.5		0.2	40	2.5	

¹⁾ see table on NO_x emission factors in Van Soest-Vercammen *et al.* (2002) for the services sector and in Kok (2014) for the agriculture sector

Residential (1A4bi)

Combustion emissions from central heating, hot water and cooking have been based on fuel consumption data (from Statistics Netherlands) and emission factors (see Table 3.10). The fuel mostly used in this category is natural gas. The use of wood in stoves and fireplaces for heating is almost negligible compared to the amount of natural gas used. Combustion emissions from (wood) stoves and fireplaces have been calculated by multiplying the fuel consumption per apparatus type and fuel type (Statistics Netherlands) by emission factors per household (Jansen & Dröge, 2011).

Table 3.10 Emission factors for combustion emissions from households (g/GJ)

Substance name	Natural gas	Diesel Oil	LPG	Petroleum	Coal
Hydrocarbons	6.3	15	2	10	60
Sulphur dioxide	0.22	87	0.22	4.6	420
Nitrogen oxides as NO ₂	¹⁾	50	40	50	75
Carbon monoxide	15.8	60	10	10	1500
Particulate matter	0.3	4.5	2	1.8	120
Coarse particulates		0.5		0.2	80

¹⁾ See table on NO_x emission factors in Van Soest-Vercammen *et al.* (2002) and Kok (2014)

Agriculture/forestry/fishing (1A4ci)

Stationary combustion emissions have been based on fuel consumption obtained from Statistics Netherlands, which in turn has been based on data from the Agricultural Economics Research Institute, and default emission factors (Table 3.11).

Table 3.11 Emission factors for stationary combustion emissions from the Agriculture/forestry/fishing sector (g/GJ)

Substance name	Natural gas	DieselOil	LPG	Petroleum	Coal	Fuel oil
Hydrocarbons	30	10	2	10	35	10
Sulphur dioxide	0.22	87	0.22	4.6	460	450
Nitrogen oxides as NO ₂	¹⁾	50	40	50	300	125
Carbon monoxide	10	10	10	10	100	10
Particulate matter	0.15	4.5	2	1.8	20	45
Coarse particulates		0.5	8	0.2	80	5

¹⁾ See table on NO_x emission factors in Van Soest-Vercammen *et al.* (2002) and Kok (2014)

3.4.5 Methodological issues

A Tier 2 methodology was used for calculating emissions from the sectors for several techniques by multiplying the activity data (fuel consumption) by the emission factors (see previous section).

3.4.6 Uncertainties and timeseries consistency

Uncertainties are explained in section 1.7.

3.4.7 Source-specific QA/QC and verification

General QA/QC is explained in section 1.3.

3.4.8 Source-specific recalculations

Emissions of the following sources have been recalculated:

- Activity data (energy statistics) for diesel have been improved

3.4.9 Source-specific planned improvements

There are no source-specific planned improvements.

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:

- 1B2ai Fugitive emissions oil: Exploration, production, transport
- 1B2aiv Fugitive emissions oil: refining / storage
- 1B2b Fugitive emissions from natural gas
- 1B2d Other fugitive emissions from energy production

3.5.2 Key sources

The Fugitive emissions sector is a key source for the pollutants presented in Table 3.12.

Table 3.12 Pollutants for which the Fugitive emissions category (NFR 1B) is a key source sector

Category / Sub-category	Pollutant	Contribution to total of 2015 (%)
1B2ai Oil and gas production	NMVOOC	3.8
1B2aiv Refining	NMVOOC	5.7

3.5.3 Overview of shares and trends in emissions

An overview of the trends in emissions is shown in Table 3.13. The emissions from NMVOOC decreased between 1990 and 2015.

Table 3.13 Overview of trends in emissions

Year	NMVOOC	PAH
	Gg	Mg
1990	47	0.006
1995	34	0.025
2000	29	0
2005	21	0.039
2010	15	0
2014	14	0
2015	14	0
1990-2015 period ¹⁾	-33	-0.006
1990-2015 period ²⁾	-70%	-100%

¹⁾ Absolute difference

²⁾ Relative difference to 1990 in %

3.5.4 Activity data and (implied) emission factors

Emissions from category 1B2ai were available from environmental reports. Activity data for categories 1B2aiv and 1B2b were available from the Netherlands Energy Statistics.

3.5.5 Methodological issues

The fugitive NMVOOC emissions from category 1B2ai comprise process emissions from oil and gas production and were completely derived from the companies' environmental reports (Tier 3 methodology). The fugitive NMVOOC emissions from category 1B2aiv comprise dissipation losses from gasoline service stations, leakage losses during vehicle and airplane refuelling and refinery processes. Emissions were calculated based on annual fuel consumption (Tier 2 methodology). The fugitive NMVOOC emissions from category 1B2b comprise emissions from gas transport (compressor stations) and gas distribution networks (pipelines for local transport). The NMVOOC emissions from gas transport were completely derived from the companies' environmental reports (Tier 3 methodology). The NMVOOC emissions from gas distribution were

calculated on the basis of a NMVOC profile with the CH₄ emission from annual reports of the sector as input (Tier 2 methodology).

3.5.6 *Uncertainties and timeseries consistency*
Uncertainties are explained in section 1.7

3.5.7 *Source-specific QA/QC and verification*
General QA/QC is explained in section 1.6

3.5.8 *Source-specific recalculations*
No source-specific recalculations have been made for this sector.

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, PM₁₀ 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 source category *Transport* (1A3) comprises the following subcategories: *Civil aviation* (1A3a), *Road Transport* (1A3b), *Railways* (1A3c) and *Waterborne navigation* (1A3d). 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 all four source categories, national activity data and (mostly) country-specific emission factors were used. Emissions from civil aviation and water-borne navigation were calculated based on fuel used, whereas emissions from railways and road transport were calculated using fuel sales data.

It should be noted that since the 2016 submission, emissions of NO_x, PM₁₀, PM_{2.5}, EC, NMVOC, CO and NH₃ from road transport are reported on a fuel sold basis. Up until the 2015 submission, road transport emissions were reported on a fuel used basis. The difference between fuel used and fuel sold emission totals is described in section 4.3.

This chapter also covers non-road mobile machinery, recreational craft and national fishing. The emissions from non-road mobile machinery were reported in several different source categories within the inventory (i.e. 1A2gvii, 1A4aaii, 1A4bii, 1A4cii, 1A5b), as shown in Table 4.1. Emissions from non-road mobile machinery were calculated using a Tier 3 method based on fuel used, using national activity data and a combination of country-specific and default emission factors. Emissions from recreational craft and vehicles operating at airports were reported under 1A5b 'Other, mobile' and were calculated using a Tier 3 and Tier 2 methodology respectively. Emissions from fisheries were reported under 1A4ciii 'National fishing' and were also calculated using a Tier 3 method.

In this chapter, trends and shares in emissions are described for the different source categories within the transport sector. The methodologies used for emission calculations are also described in general. A more detailed description of these methodologies and overviews of transport volumes, energy use and emission factors for the different source categories can be found in Klein *et al.* (2015).

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 used
1A5b	Other, Mobile (including military, land based and recreational boats)	Tier 3	NS	CS	Fuel used

NS = National Statistics

CS = Country-Specific

4.1.1 Key sources

The source categories within the transport sector are key sources for different pollutants, as is shown in Table 4.2. The percentages in Table 4.2 relate to the 2015 level and the 1990-2015 trend (in italics) assessment. Some source categories are key sources for both the trend and the 2015 level assessment. In those cases, Table 4.2 shows to which of the two these source categories contribute the most. The full results of the trend and level key source analysis are presented in Annex 1.

Table 4.2 Key source analysis for the transport sector. Percentages in italics are from the trend contribution calculation

NFR code	Source category description	SO ₂	NO _x	NMVOC	CO	PM ₁₀	PM _{2.5}	BC	Pb
1A3ai(i)	International aviation LTO (civil)								9.5%
1A3aii(i)	Domestic aviation LTO (civil)								
1A3bi	Passenger cars	6.4%	25.1%	17.4%	40.0%	7.0%	7.9%	16.4%	45.5%
1A3bii	Light-duty vehicles	2.9%	9.3%	2.7%	7.8%	3.6%	7.5%	22.0%	
1A3biii	Heavy-duty vehicles and buses	10.0%	16.4%	3.8%		10.1%	14.3%	33.1%	
1A3biv	Mopeds and motorcycles			5.9%	13.9%				
1A3bv	Gasoline evaporation			9.2%					
1A3bvi	Automobile tyre and brake wear					5.2%	2.1%		
1A3bvii	Automobile road abrasion					4.2%			
1A3c	Railways								2.0%
1A3di(ii)	International inland waterways		7.6%				3.7%	6.1%	
1A3dii	National navigation (shipping)		6.5%				2.8%	6.3%	
1A2gvii	Mobile Combustion in manufacturing industries and construction		3.5%				3.9%	7.8%	
1A4aii	Commercial/institutional: mobile								
1A4bii	Residential: household and gardening (mobile)				8.1%				
1A4cii	Agriculture/forestry /fishing: off-road vehicles and other machinery		3.8%				3.6%	7.1%	
1A4ciii	Agriculture/forestry /fishing: National fishing								
1A5b	Other, Mobile (including military, land based and recreational boats)								

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) from domestic and international civil aviation in the Netherlands. This includes emissions from both scheduled and charter flights, passenger and freight transport, air taxiing and general aviation. Emissions from helicopters are also included. Emissions

from civil aviation result from the combustion of jet fuel (jet kerosene) and aviation gasoline and from wear of tyres and brakes. It also includes emissions from auxiliary power units on board large aircraft. Most civil aviation in the Netherlands stems from Amsterdam Airport Schiphol, which is by far the largest airport in the country. Some regional airports have grown rather quickly though since 2005.

The Civil aviation source category does not include emissions from ground support equipment at. This equipment is classified as mobile machinery, and the resulting emissions were reported under source category *Other, Mobile* (1A5b). Emissions from the storage and transfer of jet fuel were reported under source category *Fugitive emissions oil: Refining/storage* (1B2aiv). Cruise emissions from domestic and international aviation (i.e. emissions occurring above 3000 feet) are not part of the national emission totals and were not estimated. Due to a lack of data, the split of LTO-related fuel consumption and resulting emissions between domestic and international aviation could not be made. Due to the small size of the country, there is hardly any domestic aviation in the Netherlands though with the exception of general aviation. Therefore, all fuel consumption and resulting emissions from civil aviation were reported under *International aviation* (1A3i) in the NFR.

4.2.2 *Key sources*

Civil aviation is a key source for for lead (2015 level and 1990-2015 trend) in the emission inventory.

4.2.3 *Overview of shares and trends in emissions*

Fuel consumption in civil aviation, including fuel use for auxiliary power units, has more than doubled between 1990 and 2015, increasing from 4.5 to 10.1 PJ. Amsterdam Airport Schiphol is responsible for over 90% of total fuel consumption by civil aviation in the Netherlands. Fuel consumption (LTO) at Amsterdam Airport Schiphol has 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. In 2015, total fuel consumption by civil aviation at Schiphol Airport increased by 1.7% compared to 2014.

Fuel consumption by civil aviation at regional airports in the Netherlands was fairly constant at 0.4-0.5 PJ between 1990 and 2004. After 2004 fuel consumption increased steadily to 0.9 PJ in 2015. This can be attributed to an increase in air traffic at regional airports, particularly at the two largest regional airports in The Netherlands: Rotterdam Airport and Eindhoven Airport. The number of passengers at Rotterdam Airport has increased by 163% since 2003 to 1.7 million in 2015, whereas the number of passengers at Eindhoven Airport increased from 0.4 million to 4.3 million in this time span.

Table 4.3 Trends in emissions from 1A3a Civil Aviation

Year	Main Pollutants			Particulate Matter				Other	Priority Heavy Metals
	NO _x	NMVOG	SO _x	PM _{2.5}	PM ₁₀	TSP	BC	CO	Pb
	Gg	Gg	Gg	Gg	Gg	Gg	Gg	Gg	Mg
1990	1.2	0.4	0.1	0.02	0.03	0.03	0.02	3.51	1.8
1995	1.8	0.3	0.1	0.03	0.03	0.03	0.02	3.97	1.9
2000	2.4	0.3	0.2	0.03	0.04	0.04	0.02	3.73	1.5
2005	2.7	0.3	0.2	0.03	0.04	0.04	0.02	3.52	1.1
2010	2.8	0.3	0.2	0.03	0.04	0.04	0.02	3.67	1.3
2014	3.1	0.3	0.2	0.03	0.04	0.04	0.02	3.40	0.9
2015	3.2	0.3	0.2	0.03	0.04	0.04	0.02	3.36	0.8
1990-2015 period ¹⁾	1.9	-0.1	0.1	0.00	0.01	0.01	0.00	-0.15	-1.0
1990-2015 period ²⁾	155%	-23%	127%	6%	38%	38%	-2%	-4%	-55%

¹⁾ Absolute difference in Gg

²⁾ Relative difference to 1990 in %

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 in the past 25 years has led to an increase in emissions of NO_x, SO_x, TSP, PM₁₀ and PM_{2.5}. Fleet average NO_x emission factors have not changed significantly throughout the time series, therefore NO_x emissions have more than doubled between 1990 and 2015, following the trend in fuel consumption. Fleet average PM₁₀ exhaust emission factors (per unit of fuel) have decreased by 56% since 1990, but since total fuel consumption more than doubled between 1990 and 2015, PM₁₀ (and PM_{2.5}) exhaust emissions still increased throughout the time series. PM₁₀ emissions due to tyre and brake wear increased by 232% between 1990 and 2015, in line with the increase in the maximum permissible take-off weight (MTOW) of the airplanes. As a result, the share of tyre and brake wear in PM₁₀ emissions from civil aviation increased from 20% to 68% between 1990 and 2015.

Aviation gasoline still contains lead, whereas gasoline for other transport purposes has been unleaded for quite some time. With lead emissions from other source categories decreasing substantially, the share of civil aviation in lead emissions in the Netherlands increased to 10% in 2015, thereby being a key source in the 2015 level assessment. The share of civil aviation in total emissions of NO_x (1.4%), SO_x (1.6%), BC (1.4%) and other substances (<1%) is small.

4.2.4 Activity data and (implied) emission factors

The exhaust emissions of CO, NMVOG, NO_x, PM, SO₂ and heavy metals from civil aviation in the Netherlands were calculated using a flight-based Tier-3 method. Specific data was used on the number of aircraft movements per aircraft type and per airport, derived from the airports and from Statistics Netherlands. These data have been used in the CLEO model to calculate LTO fuel consumption and resulting emissions (see also Dellaert & Hulskotte, 2017). The CLEO model was derived from the method for calculating aircraft emissions of the US Environmental

Protection Agency (EPA), using four flight modes that correspond with specific engine settings (power settings) of the aircraft. These power settings result in specific fuel consumption per unit of time. For each engine type, specific emission factors were used for calculating the emissions. The fuel consumption per unit of time, along with the accompanying fuel-related emission factors, were determined as part of the certification of aircraft engines with a thrust greater than 30 kN. The emission factors used in CLEO were taken from the ICAO Engine Emissions DataBank. The CLEO model also contains a number of emission factors for smaller (piston) engines. The sources for these emission factors are a report by the Swiss Federal Office for Civil Aviation (Rindlisbacher, 2007), and the EPA's AP42 publication (EPA, 1985). Emission factors for aircraft with turboprop engines are also included in the EMASA model. These factors were gathered by the Swedish FFA in the so-called Hurdy-Gurdy-database (Hasselrot, 2001). Emission factors for commercial helicopters (by flight phase) were derived from Rindlisbacher (2009).

Per group of aircraft engines the PM emission factors were calculated from 'Smoke Numbers' according to the method described in Kugele *et al.* (2005). In this methodology only the soot-fraction of PM is calculated. Based on results of Agrawal *et al.* (2008) it has been estimated that the soot-fraction (assumed to be equal to the EC-fraction) of PM is only half of total PM-emissions. Therefore to calculate emission factors of PM the results obtained by the formula of Kugele *et al.* 2005 are multiplied by a factor of two. The $PM_{2.5}/PM_{10}$ ratio for engine exhaust emissions is assumed to be 1. The PM emissions due to tyre and brake wear were calculated from the maximum permissible take-off weight and the number of take-offs according to a methodology described by British Airways (Morris, 2007). The $PM_{2.5}/PM_{10}$ ratios for tyre (20%) and brake (15%) wear were assumed equal to those for road transportation.

Emissions of lead and SO_2 are directly related to the characteristics of the fuel type used. For jet fuel, emission factors of SO_2 are based on the EMEP/EEA guidebook (EMEP/EEA, 2016). For aviation gasoline, the SO_2 emission factors are based on the Dutch SO_2 emission factors for petrol (see Klein *et al.*, 2017). The emission factor for lead is estimated based on the lead content of AvGas 100LL, which is the most commonly used fuel type for piston engines.

Emissions of different VOC and PAH species were calculated using species profiles as reported in Klein *et al.* (2017). The duration of the different flight modes (except the Idle mode) was derived from US EPA (1985). The average taxi/idle time was calculated based on measurements conducted by the airports in The Netherlands (Nollet, 1993) and the Dutch national air traffic service (RLD) for taxi times per individual runway combined with the usage percentages per runway. For heavier aircraft (JUMBO class) a separate category was introduced with somewhat longer times for the flight modes Take-off and Climb-out. This information was also obtained from the RLD.

The emissions from Auxiliary Power Units (APUs) were calculated based on the estimated quantity of fuel that is consumed during power

generation. Information on the type of APU that is installed in specific aircraft types was taken from a report for the Global Atmosphere Division of DEFRA (Netcen, 2004), while emission factors and fuel use for these APU types were also taken from this report and data from KLM (KLM, 2016). NMVOC emissions from storage and transfer of jet kerosene were derived from the total volume of kerosene that was delivered annually and an emission factor. The emission factor was derived from an environmental report by Aircraft Fuel Supply (AFS), the company which handles all aircraft fuelling and fuel handling at Schiphol airport (AFS, 2013).

4.2.5 *Methodological issues*

Due to a lack of data, the split of LTO fuel consumption and resulting emissions between domestic and international aviation could not be made. Due to the small size of the country, there is hardly any domestic aviation in the Netherlands with the exception of general aviation. Therefore, all fuel consumption and (LTO) emissions from civil aviation were reported under *International aviation* (1A3i).

The methodology for calculating fuel consumption and resulting emissions from Auxiliary Power Units (APUs) needs to be updated because the assumed fuel consumption per passenger has not been verified in recent years. It should be noted though that the EEA Emission Inventory Guidebook does not provide a methodology yet for estimating emissions from APUs.

4.2.6 *Uncertainties and time series consistency*

In 2016, an expert workshop was organised to discuss and estimate the uncertainties in the activity data and emission factors used for the emission calculations for the transport sector. Consistent methodologies have been used throughout the time series.

4.2.7 *Source-specific QA/QC and verification*

Trends in the estimated fuel consumption for civil aviation were compared with trends in LTOs and passenger numbers at Amsterdam Airport Schiphol and regional airports, see also section 4.2.3. Agreement between both trends is good.

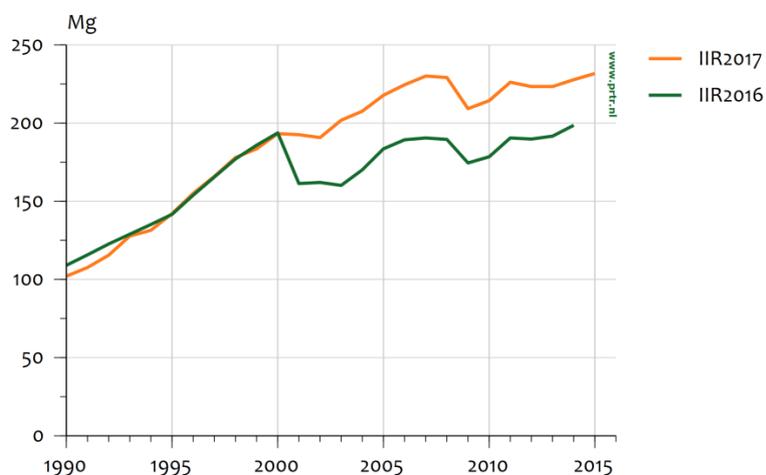
4.2.8 *Source-specific recalculations*

There have been a number of methodological improvements and error corrections.

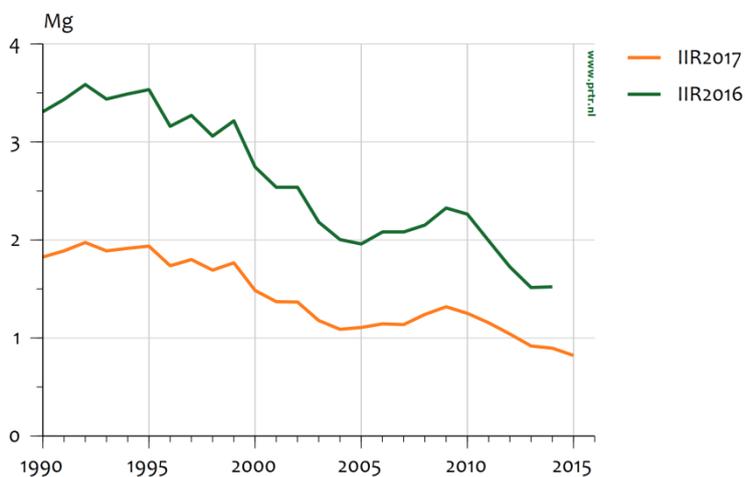
1. The method for calculating APU fuel use and emissions has been updated and improved in this year's inventory.
2. The emission factor for fuelling and fuel handling has been updated for the year 2012 onwards, leading to lower NMVOC emissions in these years.
3. Den Helder airport has been added to the CLEO model and emissions have been calculated for activities related to this airport for the complete time series.
4. Aircraft emissions of NH₃ are no longer calculated or reported since they are estimated to be negligible and no reliable emission factors are available.
5. Several errors have been corrected in the model, correcting the linking between aircraft types, engine types and emission factors.

6. An error has been corrected in the calculation of fuel use of ground support equipment, leading to higher fuel use over the complete time series.
7. Emissions from ground support equipment have been calculated for Lelystad airport for the complete time series.
8. The emission factors for piston engines have been updated based on a recent report on piston engine emission measurement data.

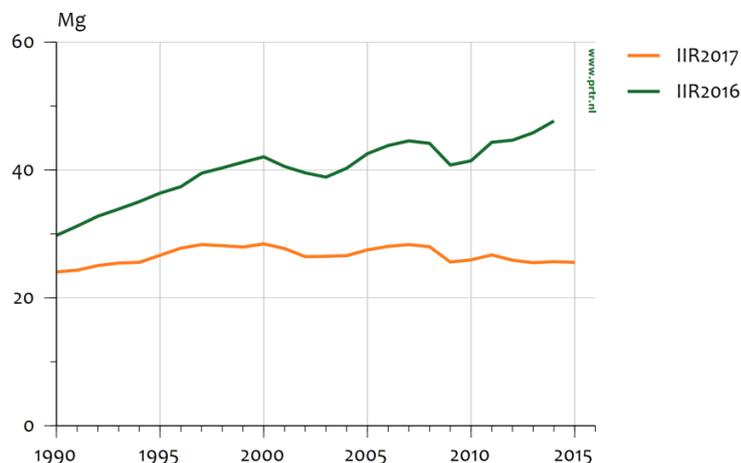
SO_x emissions civil aviation



Pb emissions civil aviation



PM_{2.5} emissions civil aviation



NMVO emissions civil aviation

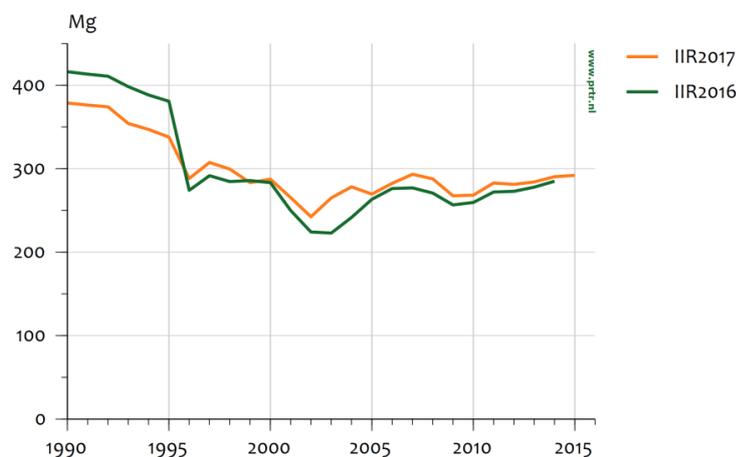


Figure 4.1 Recalculated emissions of civil aviation for SO_x, Pb, PM_{2.5} and NMVOC.

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) and *PM emissions from tyre and brake wear* (1A3bvi) and *road abrasion* (1A3bvii). PM emissions caused by resuspension of previously deposited material were not included.

Historically, emissions from road transport in the Netherlands have been calculated and reported based on 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. The UNECE guidelines on reporting emission data under the LRTAP convention state that emissions from transport should be consistent with national energy balances as reported to Eurostat and the International Energy Agency. As such, emissions from road transport should be estimated based on *fuel sold* (FS) on national territory. In addition, emissions from road transport may also be reported based on FU or kilometres driven on national territory (UNECE, 2009). In previous inventories, the FS emission totals for road transport were reported as a memo item in the NFR-tables. In the current inventory however, reported emissions from road transport are based on fuel sold. The FU emissions from road transport are reported as a memo item. The methodologies used to estimate both FU and FS emissions are described in detail below.

4.3.2 Key sources

The different source categories within Road Transport are key sources for many substances in both the 1990-2015 trend assessment and the 1990 and 2015 level assessments, as is shown in Table 4.4.

Table 4.4 Key source analysis for road transport subcategories

Source category		1990 level	2015 level	1990-2015 trend
1A3b i	Passenger cars	NO _x , NMVOC, CO, PM ₁₀ , PM _{2.5} , BC, Pb	NO _x , NMVOC, CO, PM ₁₀ , PM _{2.5} , BC, Pb, Cd, Hg	SO _x , NO _x , NMVOC, CO, PM ₁₀ , PM _{2.5} , BC, Pb, Cd, Hg
1A3b ii	Light-duty vehicles	NO _x , CO, PM ₁₀ , PM _{2.5} , BC	NO _x , PM ₁₀ , PM _{2.5} , BC	SO _x , NO _x , NMVOC, CO, PM ₁₀ , PM _{2.5} , BC
1A3b iii	Heavy-duty vehicles and buses	SO _x , NO _x , NMVOC, PM ₁₀ , PM _{2.5} , BC	NO _x , PM _{2.5} , BC	SO _x , NO _x , NMVOC, PM ₁₀ , PM _{2.5} , BC
1A3b iv	Mopeds and motorcycles	NMVOC, CO	NMVOC, CO	CO
1A3b v	Gasoline evaporation	NMVOC		NMVOC
1A3b vi	Tyre and brake wear		PM ₁₀	PM ₁₀ , PM _{2.5}
1A3b vii	Road abrasion		PM ₁₀	PM ₁₀

4.3.3 Overview of shares and trends in emissions

Road transport is a major contributor to air pollutant emissions in the Netherlands. Combined, the different source categories within road transport accounted for 37% of NO_x emissions (national totals), 20% of PM₁₀, 22% of PM_{2.5}, 46% of BC, 17% of NMVOC and 54% of CO in The Netherlands in 2015. The trends in emissions from road transport are shown in Table 4.5. The emissions of the main pollutants and particulate matter have decreased significantly throughout the time series with the exception of NH₃. 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 of road transport in the national

emission totals for NO_x , PM_{10} and $\text{PM}_{2.5}$ decreased only slightly between 1990 and 2015 as emissions in other sectors decreased as well. Road transport therefore is still a major source of pollutant emissions in the Netherlands.

Emissions of SO_2 decreased by 99% between 1990 and 2015 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). The share of road transport in total SO_x emissions in the Netherlands subsequently decreased from 7% in 1990 to less than 1% in 2015.

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 (TWC) for gasoline passenger cars. Since 2005, NH_3 emissions from road transport have decreased slightly. Notwithstanding the increase in emissions, road transport is still only a minor source of NH_3 emissions in the Netherlands with a share of 3% in national totals in 2015.

Emissions of heavy metals have increased, with the exception of Pb. Cd and Hg emissions from passenger cars are key sources in the 2015 level assessment and in the 1990-2015 trend assessment. Passenger cars were also a key source of Pb in the 1990 level assessment and although Pb emissions have decreased significantly with the introduction of unleaded gasoline, passenger cars are no longer a key source of Pb in the 2015 level assessment. Below, the trends and shares in emissions of the different source categories within Road Transport are described.

Table 4.5 Trends in emissions from 1A3b Road transport

Year	Main Pollutants				Particulate Matter				Other
	NO _x	NMVOG	SO _x	NH ₃	PM _{2.5}	PM ₁₀	TSP	BC	CO
	Gg	Gg	Gg	Gg	Gg	Gg	Gg	Gg	Gg
1990	282	188	15	0.9	19	21	21	9	713
1995	223	120	14	2.4	14	16	16	7	520
2000	179	67	4	4.3	11	13	13	6	399
2005	157	40	0	5.3	8	10	10	5	386
2010	128	32	0	5.1	5	7	7	3	375
2014	91	25	0	4.3	3	5	5	2	304
2015	85	24	0	4.2	3	5	5	1	305
1990-2015 period ¹⁾	-197	-165	-15	3.2	-16	-16	-16	-8	-408
1990-2015 period ²⁾	-70%	-87%	-99%	344%	-85%	-76%	-76%		

Year	Main Pollutants				Particulate Matter				Other
	NO _x	NMVOG	SO _x	NH ₃	PM _{2.5}	PM ₁₀	TSP	BC	CO
	Gg	Gg	Gg	Gg	Gg	Gg	Gg	Gg	Gg
1990	282	188	15	0.9	19	21	21	9	713
1995	223	120	14	2.4	14	16	16	7	520
2000	179	67	4	4.3	11	13	13	6	399
2005	157	40	0	5.3	8	10	10	5	386
2010	128	32	0	5.1	5	7	7	3	375
2014	91	25	0	4.3	3	5	5	2	304
2015	85	24	0	4.2	3	5	5	1	305
1990-2015 period ¹⁾	-197	-165	-15	3.2	-16	-16	-16	-8	-408
1990-2015 period ²⁾	-70%	-87%	-99%	344%	-85%	-76%	-76%		

¹⁾ Absolute difference in Gg

²⁾ Relative difference to 1990 in %

Passenger cars (1A3bi)

The number of kilometres driven by passenger cars in the Netherlands has steadily increased from approximately 82 billion in 1990 to 103 billion in 2015 (Figure 4.2). The kilometres driven by diesel cars has grown the fastest. Since 1995, the share of diesel-powered passenger cars in the Dutch car fleet has grown significantly, leading to an increase in diesel mileages by 95% between 1995 and 2008. Gasoline mileages increased by only 11% between 1995 and 2008. Since 2008 the total diesel mileage has remained constant however. The share of LPG in the passenger car fleet has decreased significantly, leading to a decrease in LPG mileages by 81% between 1990 and 2015. Figure 4.2 shows that even though the number of diesel kilometres has increased significantly, gasoline still dominates the vehicle kilometres driven by passenger cars. Throughout the time series, the share of gasoline in total kilometres driven in the Netherlands has fluctuated between 64% and 69%. The share of diesel has increased from 20% in 1990 to 31% in 2015, mostly

at the cost of the market share of LPG which decreased from 16% to 2% in the same time span.

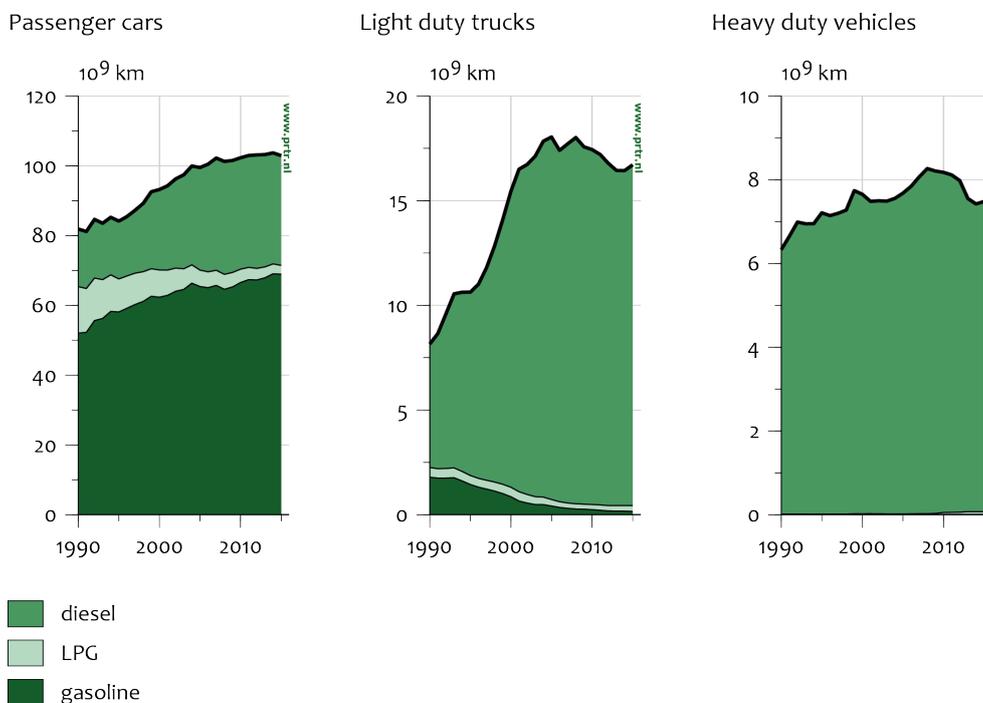


Figure 4.2 Kilometres driven per vehicle and fuel type in the Netherlands

Passenger cars were responsible for 12% of total NO_x emissions in the Netherlands in 2015. NO_x emissions from passenger cars have decreased significantly throughout the time series: from 145 Gg in 1990 (24% of total NO_x) to 27 Gg in 2015. This decrease can mainly be attributed to the introduction of the (closed loop) three way catalyst (TWC), which led to a major decrease in NO_x emissions from gasoline passenger cars. NO_x emissions from gasoline passenger cars decreased by 93% between 1990 and 2015 even though traffic volumes increased by 32%. NO_x emissions from diesel-powered passenger cars increased from 16 Gg in 1995 to 25 Gg in 2007. This increase resulted from the major increase in the kilometres driven by diesel cars combined with less stringent emission standards and disappointing real-world NO_x emission performance from recent generations of diesel passenger cars. Since 2007, NO_x emissions from diesel cars have decreased somewhat to 19 Gg in 2015. Due to the decrease of NO_x emissions from gasoline passenger cars, NO_x has become mostly a diesel related issue. The share of gasoline in total NO_x emissions from passenger cars has decreased from 76% in 1990 to 27% in 2015, whereas the share of diesel has increased from 11% to 71% between 1990 and 2015. The introduction of the TWC for gasoline passenger cars also led to a major reduction of NMVOC and CO emissions. NMVOC exhaust emissions from gasoline passenger cars decreased from 84 Gg in 1990 to 13 Gg in 2015, whereas CO emissions decreased from 540 to 223 Gg. NMVOC and CO emissions from diesel and LPG-powered passenger cars also decreased significantly, but both are minor sources of NMVOC and CO. In 2015, passenger cars (not including evaporative NMVOC emissions)

were responsible for 9% of NMVOC emissions (down from 21% in 1990) and 40% of CO emissions (down from 52% in 1990) in the Netherlands. Passenger cars (source category 1A3bi, only including exhaust emissions) were responsible for 7% of PM_{2.5} emissions and 3% of PM₁₀ emissions in The Netherlands in 2015. PM₁₀ exhaust emissions from passenger cars have decreased by 85% between 1990 and 2015. Both emissions from gasoline and diesel cars have decreased significantly throughout the time series, resulting from the increasingly stringent EU emission standards for new passenger cars. Exhaust emissions in 2015 were 0.9 Gg, down 0.3 Gg (26%) from 2013. The continuing decrease of PM₁₀ and PM_{2.5} exhaust emissions in recent years is primarily caused by the increasing market penetration of diesel passenger cars equipped with diesel particulate filters (DPF). DPFs are required to comply with the Euro 5 PM emission standard, which entered into force at the start of 2011. DPFs entered the Dutch fleet much earlier though, helped by a subsidy that was instated by the Dutch government in 2005. In 2007, more than 60% of new diesel passenger cars were equipped with a DPF. Since 2008, the share of new diesel passenger cars with a DPF has been above 90%. PM_{2.5} exhaust emissions from passenger cars (and other road transport) are assumed to be equal to PM₁₀ exhaust emissions.

NH₃ emissions from passenger cars increased from 0.9 Gg in 1990 to 5.2 Gg in 2006, resulting from the introduction of the TWC. Since 2007, emissions have decreased to 4.0 Gg in 2015. The increase in vehicle kilometres driven since 2007 has been compensated by the introduction of newer generations of TWCs with lower NH₃ emissions per vehicle kilometre driven, resulting in a decrease of the fleet average NH₃ emission factor. Lead emissions from passenger cars decreased from 230 Mg in 1990 to 0.04 Mg in 2015 due to the phase-out of leaded gasoline.

Light-duty trucks (1A3bii)

The light-duty truck fleet in the Netherlands has grown 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 stabilized since. The number of vehicle kilometres driven varied between 17 and 18 billion between 2005 and 2011, decreased somewhat in 2012 and 2013 (-2% per year), and subsequently increased slightly in 2015 (+2%). These fluctuations in recent years can probably be attributed to the economic situation combined with the continuing impact of the changes in the fiscal scheme for privately owned light-duty trucks. The share of gasoline-powered trucks in the fleet has decreased steadily throughout the time series. In recent years, diesel engines have dominated the light-duty truck market, with shares of more than 98% of new-vehicles sales. Currently, more than 95% of the fleet is diesel-powered. NO_x emissions from light-duty trucks have fluctuated between 21 and 24 Gg since 1994. NO_x emissions in 2015 were 15% lower than in 1990 (19.9 Gg vs. 23.5 Gg), even though the number of vehicle kilometres driven has more than doubled in this time span. The tightening of 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 recent Euro-5 light-duty trucks, the fleet average NO_x emission factor for diesel light-duty trucks has been more or less stable in recent years. The share of light-duty trucks in total NO_x emissions in The Netherlands was approximately 9% in 2015.

The exhaust emissions of NMVOC and CO from light-duty trucks have decreased significantly throughout the time series. NMVOC emissions decreased from 11 Gg in 1990 to 0.6 Gg in 2015, whereas CO emissions decreased from 48 to 3.4 Gg over the same time period. The increasingly stringent EU emissions standards for both substances have led to a major (85-87%) decrease in the fleet average emission factors for both gasoline and diesel trucks between 1990 and 2015. Gasoline-powered trucks emit far more NMVOC and CO than diesel-powered trucks per vehicle kilometre driven; therefore, the decrease in the number of gasoline trucks has also contributed substantially to the decrease in NMVOC and CO emissions. Light-duty trucks currently are a minor source of both CO and NMVOC emissions, accounting for less than 1% of the national totals for both substances in 2015.

The exhaust emissions of PM₁₀ (and subsequently also of PM_{2.5}) from light-duty trucks decreased throughout the time series as well. The fleet average PM₁₀ emission factor has decreased consistently throughout the time series, but in earlier years this decrease was offset by the increase in vehicle kilometres driven. Diesel-powered trucks are dominant in the PM₁₀ exhaust emissions, with a share of over 99%. The average PM₁₀ exhaust emission factor for diesel-powered light-duty trucks has decreased by 9-12% annually in recent years due to the market penetration of diesel-powered light-duty trucks with a diesel particulate filter (DPF). Combined with the stabilisation of the amount of vehicle kilometres driven since 2005, PM₁₀ exhaust emissions decreased by 63% between 2005 and 2015. In 2015, light-duty trucks were responsible for 4% of PM₁₀ emissions and 7% of PM_{2.5} emissions in The Netherlands.

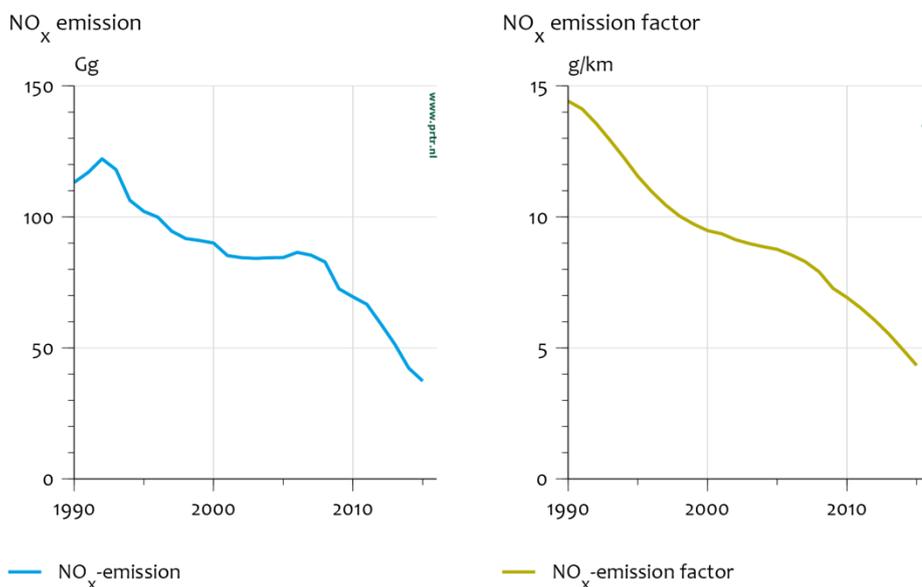


Figure 4.3 NO_x emissions and NO_x emission factors of heavy-duty vehicles in the Netherlands

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 31% between 1990 and 2008 (see Figure 4.2). The economic crisis has since led to a decrease in transport volumes: the total vehicle kilometres driven in 2015 was 10% lower than in 2008. Diesel dominates the vehicle fleet with a share of 99%.

Heavy-duty vehicles are a major source of NO_x emissions in The Netherlands with a share of 16% in the national total in 2015. NO_x emissions from heavy-duty vehicles decreased from 113 Gg in 1990 to 37 Gg in 2015 (see Figure 4.3). Emission totals have decreased significantly in recent years due to the combination of a decrease in vehicle mileages, as shown in Figure 4.1, and a decrease in the fleet averaged NO_x emission factor, as shown in Figure 4.2. The latter decreased by 65% between 1990 and 2015, mainly as a consequence of the 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 emission factor for heavy-duty vehicles has decreased significantly since 2008. The current generation of Euro-VI trucks that have entered the market since 2013 are fitted with a combination of Exhaust Gas Recirculation (EGR) and an SCR catalyst (Selective Catalytic Reduction) resulting in very low real-world NO_x emissions levels (Kadijk *et al.*, 2015).

NM VOC exhaust emissions decreased by 94%, from 16 Gg in 1990 to 1 Gg in 2015, whereas PM₁₀ and PM_{2.5} exhaust emissions decreased by 94%, from 7 Gg to 0.5 Gg. These decreases have also been caused by EU emission legislation. Heavy-duty vehicles were only a minor source

of NMVOC (0.7%) and PM₁₀ emissions (1.7%) in 2015. Their share in PM_{2.5} emissions was slightly higher at 3.5% of national totals.

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. They are a key source though for NMVOC and CO in both the 1990 and 2015 level assessment and in the trend assessment (CO only). Even though the number of vehicle kilometres driven increased by 83% between 1990 and 2015, exhaust emissions of NMVOC decreased significantly due to the increasingly stringent EU emissions standards for two-wheelers. NMVOC exhaust emissions decreased from 25 to 8.1 Gg between 1990 and 2015. Motorcycles and mopeds were responsible for 6% of NMVOC emissions in The Netherlands in 2015. CO emissions from motorcycles and mopeds increased from 45 to 56 Gg between 1990 and 2015. In 2014, motorcycles and mopeds were responsible for 10% of CO emissions in the Netherlands.

NO_x emissions increased from 0.4 to 0.9 Gg between 1990 and 2015, but the share of motorcycles and mopeds in NO_x emissions in the Netherlands was still small (0.4%) in 2015. The share in PM_{2.5} emissions was approximately 1% in 2015, with emissions decreasing from 0.4 to 0.1 Gg in the 1990-2015 timespan.

Gasoline 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 gasoline passenger cars. Gasoline passenger cars are by far the major source of evaporative NMVOC emissions from road transport in the Netherlands. Total evaporative NMVOC emissions decreased from 36 Gg in 1990 to 1.6 Gg in 2015 (see Figure 4.4). As a result, evaporative emissions are no longer a key source in the level assessment, accounting for only 1% of total NMVOC emissions in the Netherlands in 2015 (down from 7% in 1990).

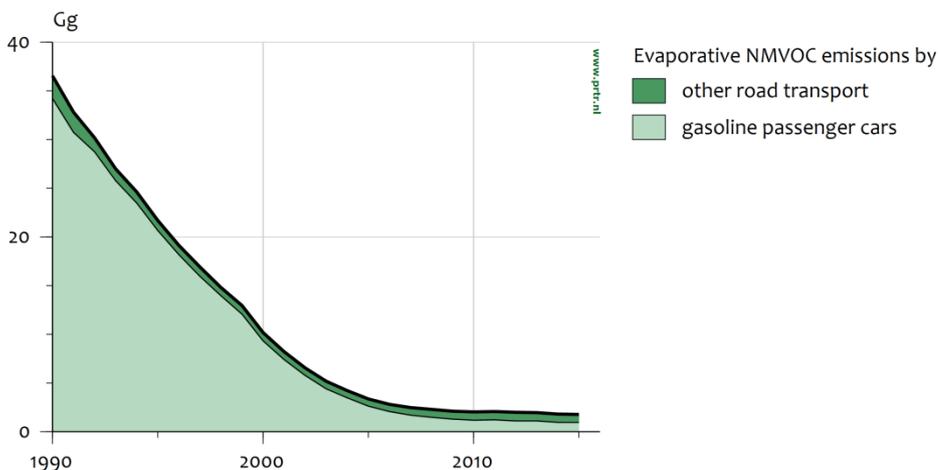


Figure 4.4 Emissions of NMVOC from evaporation by road transport in the Netherlands

PM emissions from tyre and brake wear and road abrasion (1A3bvi and 1A3bvii)

Automobile tyre and brake wear (1A3bvi) and Automobile road abrasion (1A3bvii) were key sources for PM₁₀ emissions in the Netherlands in 2015, being responsible for 5% and 4% of PM₁₀ emissions, respectively. PM₁₀ emissions from brake wear, tyre wear and road abrasion have increased throughout most of the time series, as shown in Figure 4.4, resulting from the increase in vehicle kilometres driven by light and heavy-duty vehicles. PM₁₀ emission factors were kept constant throughout the time series.

PM_{2.5} emissions were derived from PM₁₀ emissions using PM_{2.5}/PM₁₀ ratios of 0.2 for tyre wear and 0.15 for both brake wear and road surface wear. Therefore the trend in PM_{2.5} wear emissions is similar to the trend in PM₁₀ emissions. The share of tyre and brake wear (2%) and road abrasion (1%) in total PM_{2.5} emissions in The Netherlands is smaller than for PM₁₀.

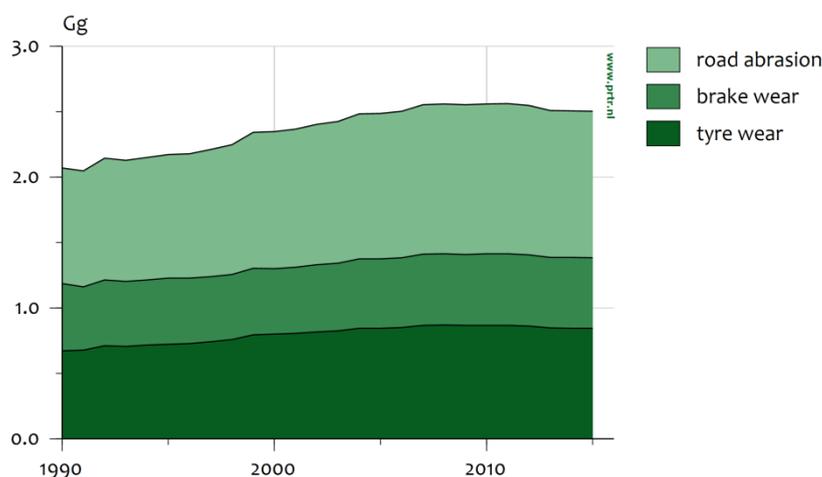


Figure 4.4 Emissions of PM₁₀ resulting from brake and tyre wear and road abrasion

4.3.4 Activity data and (implied) emission factors

The emissions from road transport were calculated using a Tier 3 methodology. Exhaust emissions of CO, NMVOC, NO_x, NH₃ and PM from road transport were calculated using statistics on vehicle kilometres driven and emission factors 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 for fuels used in road transportation. Resulting emission totals for CO, NMVOC, NO_x, NH₃ and PM were subsequently corrected for differences between fuel used and 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 by different vehicle types were derived from Statistics Netherlands.

Statistics Netherlands calculated total vehicle mileages per vehicle type using data on:

1. The size and composition of the Dutch vehicle fleet;
2. Average annual mileages for different vehicle types, and
3. The number of kilometres driven by foreign vehicles in the Netherlands.

Data on the size and composition of the Dutch vehicle fleet (1) were derived from RDW, which has information on all vehicles registered in the Netherlands, including vehicle weight, fuel type and year of manufacturing. The annual mileages for different types of road vehicles (2) were calculated from odometer readings from the national car passport corporation (NAP). The NAP database contains odometer readings from all road vehicles that have been to a garage for maintenance or repairs. Every year, Statistics Netherlands acquires the NAP database and uses this data combined with RDW-data on vehicle characteristics to derive average annual mileages for different vehicles types (age classes and fuel types). This methodology was applied to derive average annual mileages for passenger cars, light-duty and heavy-duty trucks and buses. The resulting mileages were corrected for the amount of kilometres driven abroad, using different statistics as described in Klein *et al.* (2017). Average annual mileages for motorcycles and mopeds were derived by Statistics Netherlands in 2013 using a survey among owners, as is described in more detail in Jimmink *et al.* (2014).

The vehicle kilometres driven in the Netherlands by foreign passenger cars (3) were estimated by Statistics Netherlands using different tourism related data, as described in Klein *et al.* (2017). Vehicle kilometres driven by foreign trucks were derived from statistics on road transportation in the Netherlands and in other EU countries, collected by Eurostat. The vehicle kilometres driven by foreign buses in the Netherlands were estimated by different national and international statistics on buses and tourism, such as the Dutch Accommodations Survey, the UK Travel Trends and the Belgian Travel Research (Reisonderzoek), as described in Molnár-in 't Veld & Dohmen-Kampert (2010).

For the emission calculations, a distinction was made between three road types: urban, rural and motorway. The road type distributions for different vehicle types were derived from Goudappel Coffeng (2010). In this study, a national transport model was used to estimate the distribution of vehicle kilometres driven on urban roads, rural roads and motorways, for passenger cars and light and heavy-duty trucks. Subsequently, data from number plate registrations alongside different road types throughout The Netherlands were used to differentiate these distributions according to fuel type and vehicle age. In general, it was concluded that the share of gasoline passenger cars on urban roads is higher than on motorways. Also, the fleet on motorways on average is younger than on urban roads. These differences can mainly be related to differences in average annual mileages: higher mileages in general result in higher shares of motorway driving in total mileages. The road type distribution for different vehicle categories is reported in detail in Klein *et al.* (2017).

Total fuel consumption per vehicle and fuel type, used for calculating SO_x emissions and emissions of heavy metals, was calculated by combining the data on vehicle kilometres driven per vehicle type with average fuel consumption figures (litre per vehicle kilometre driven). These figures on specific fuel consumption (litre/kilometre) were derived by TNO using insights from emission measurements and fuel-card data (Ligterink *et al.*, 2016).

Emission factors

The CO, NMVOC, NO_x and PM exhaust emission factors for road transport were calculated by TNO using the VERSIT+ model (Ligterink & De Lange, 2009). With the use of VERSIT+, emission factors can be calculated for different transport situations and scale levels. The emission factors follow from various analysis fed by different kinds of measuring data. VERSIT+ LD (light-duty) has been developed for light-duty vehicles, i.e. passenger cars and light-duty trucks. The model can be used to estimate emissions under specific transport situations. For the determination of the emission factors, the driving behaviour dependence and the statistical variation per vehicle has been investigated. Next the results have been used in a model with currently more than 50 light-duty vehicle categories for each of the emission components. The resulting model separates optimal driving behaviour and vehicle category dependencies.

VERSIT+ HD (heavy-duty) (Riemersma & Smokers, 2004) was used to predict the emission factors of heavy-duty vehicles (i.e. lorries, road tractors and buses). For older vehicles VERSIT+ HD uses input based on European measurement data. These data have been obtained with less realistic tests, meaning that in some cases only the engine has been tested and in other cases measurements have been executed with several constant engine loads and engine speeds (rpm). For newer vehicles (Euro-III – Euro-VI) measurement data are available which closer resemble the real-world use of the vehicles. These new data are based on realistic driving behaviour, both from on-road measurements and measurements on test stands, have been used in a model to represent emissions during standard driving behaviour. The emission factors for buses often originate from test stand measurements with realistic driving behaviour for regular service buses.

For the determination of the emission factors for heavy-duty vehicles, the PHEM model was used which has been developed by the Graz University of Technology, using also measurement data from TNO. For pre-Euro-III the emission factors are still based on this model. Euro-III and later emission factors are based on in-house on-road measurements (Ligterink *et al.*, 2012). The input is, just as for VERSIT+ LD, composed of speed-time diagrams which make the model suitable for the prediction of emissions in varying transport situations. In VERSIT+ HD the most important vehicle and usage characteristics for emissions are determined. For Euro-V the actual payload of a truck is important for the NO_x emission as the operation of the SCR relies on a sufficient high engine loads. The average payloads of the trucks in the Netherlands were derived from on-road measurements on motorways (Kuiper & Ligterink, 2013). The usage of trailers was also collected from this data. Moreover, PM emissions also have a strong correlation with payload and

the resulting engine load, which is taken into account in the emission factors (Stelwagen & Ligterink, 2015).

Over the years, for most vehicle categories many measurement data have become available, which means that the reliability of VERSIT+ in determining emission factors is relatively high. However, individual vehicles can have large deviations from the average. TNO has even ascertained large variations of the measured emissions between two sequential measurements of the same vehicle. This is not the result of measurement errors, but of the great susceptibility of the engine management system, especially on petrol and LPG vehicles, to variations in how the test cycle is conducted on the dynamometer. Moreover, diesel emission control systems also show a great sensitivity to variations in test circumstances. It has been key to ensure that the emissions correspond to the on-road results. VERSIT+ is used to predict emissions in specific transport situations, the commercial software EnViVer links the emission model to traffic simulations, but can also be used to predict emission factors on a higher level of aggregation. VERSIT+ takes into account additional emissions during the cold start of the vehicles. The additional emissions are expressed in grams per cold start. Data on the number of cold starts is derived from the Dutch Mobility Survey (MON); see also Klein *et al.* (2017). The effects of vehicle aging on emission levels are also incorporated in VERSIT+, using data from the in-use compliance programme that TNO runs for the Dutch Ministry of Infrastructure and the Environment. A detailed overview of the emission factors per vehicle type and road type is provided in Klein *et al.* (2017).

Emissions of SO₂ and heavy metals (and CO₂) are dependent on fuel consumption and fuel type. These emissions were calculated by multiplying fuel consumption with fuel and year specific emission factors (grams per litre of fuel). The emission factors for SO₂ and heavy metals were based on the sulphur, carbon and heavy metal contents of the fuels, as described in Klein *et al.* (2017). It is assumed that 75% of the lead is emitted as particles and 95% of the sulphur is transformed to sulphur dioxide. The NH₃ emission factors for passenger cars were derived from a recent study by TNO (Stelwagen *et al.*, 2015), as is described in detail in the 2015 inventory report (Jimmink *et al.*, 2015).

NMVOC evaporative emissions are estimated using the methodology from the EEA Emission Inventory Guidebook (EEA, 2007). PM emission factors for brake and tyre wear and for road abrasion were derived from literature (Ten Broeke *et al.*, 2008; Denier van der Gon *et al.*, 2008; RWS, 2008). An overview of these emission factors is provided in Klein *et al.* (2017) as well.

Deriving fuel sold emissions for road transport

To derive fuel sold (FS) emissions from road transport, the fuel used (FU) emissions per fuel type are adjusted for differences between (estimated) fuel used by road transport in the Netherlands and fuel sold as reported by Statistics Netherlands. Figure 4.6 shows both the bottom-up estimates for fuel used (PJ) by road transport and reported fuel sold to road transport per fuel type for the 1990-2015 time series. For gasoline, the time series show good agreement in both the absolute

level and the trend, except for the 2011-2015 period where fuel sold decreased by 10% whereas fuel used decreased by only 1%. Part of this difference might be attributed to the use of preliminary data on vehicle kilometres travelled in the Netherlands to estimate fuel used. Since odometer readings from 2013 and 2014 are not yet available for the entire vehicle fleet, average annual mileages from different car types in 2014 are still preliminary estimates. Another explanation could be an increase in fuel tourism resulting from an increasing difference in fuel prices in the Netherlands compared to Belgium and Germany. The time series for diesel also show similar trends, but there is a larger difference in absolute levels, with fuel sold being substantially higher than fuel used. The difference between fuel used and fuel sold varies between 20 and 30 percent throughout the 1990-2013 period. Part of this difference might be attributed to the use of diesel in international freight transport, with modern trucks being able to drive >1000 kilometres on one single tank of diesel. Freight transport volumes in (and through) the Netherlands are substantial due to, among other things, the Port of Rotterdam being the largest port in the EU. With the Netherlands being a rather small country, it might very well be that a substantial part of the diesel fuel that is sold in the Netherlands for freight transport is actually used abroad. This could at least partially explain why substantially more diesel fuel is sold than is used by road transport in the Netherlands. It is unknown though to what extent this explains the differences between diesel fuel sold and used. Other possible explanations are that the diesel fuel is used for other purposes than road transport, such as mobile machinery. This seems unlikely though, because up until 2013 excise duties were higher for diesel used in road transport than diesel used for other purposes such as mobile machinery and rail transport. Fuel tourism does not seem to be a logical explanation for the differences, because fuel prices in the Netherlands are generally higher than in neighbouring countries. This holds especially for gasoline and to a smaller extent for diesel. In 2015, both fuel used and fuel sold remained at the same level as in 2014.

The time series for LPG also show similar trends, with both fuel used and fuel sold decreasing rapidly. For recent years of the time series, the level of energy use also shows good agreement, but for earlier years, differences are larger.

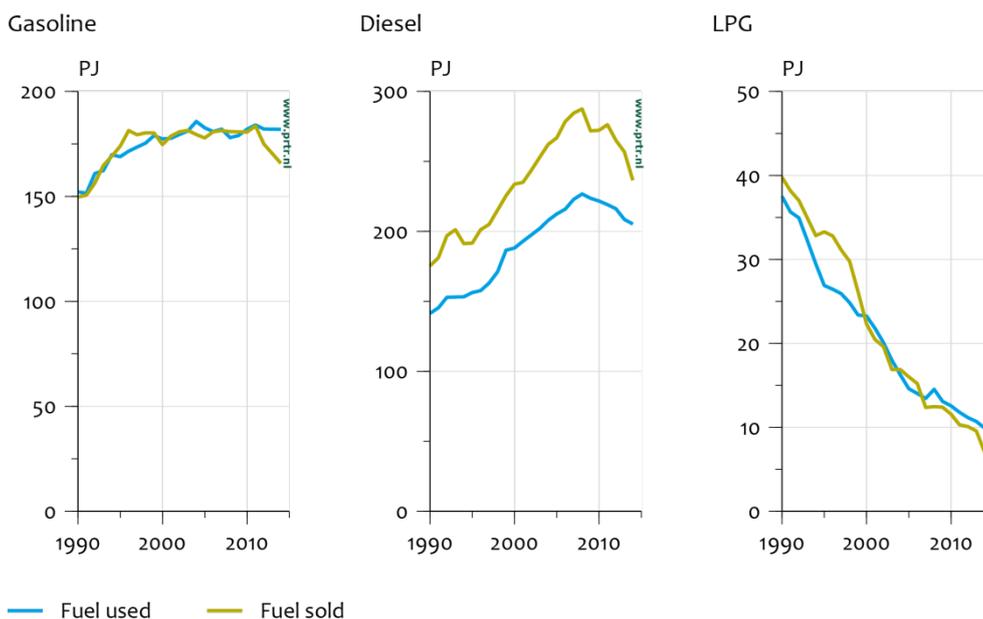


Figure 4.6 Fuel used vs. fuel sold trends, for gasoline, diesel and LPG fuelled road transport in the Netherlands

Because fuel sold emissions are estimated using a generic correction on the 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 earlier years of the time series, as can be seen in Figure 4.7. NMVOC emissions in road transport mostly stem from gasoline vehicles. Since the difference between fuel used and fuel sold for gasoline is small, fuel used and fuel sold NMVOC emission totals do not differ much, as shown in Figure 4.7. 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.

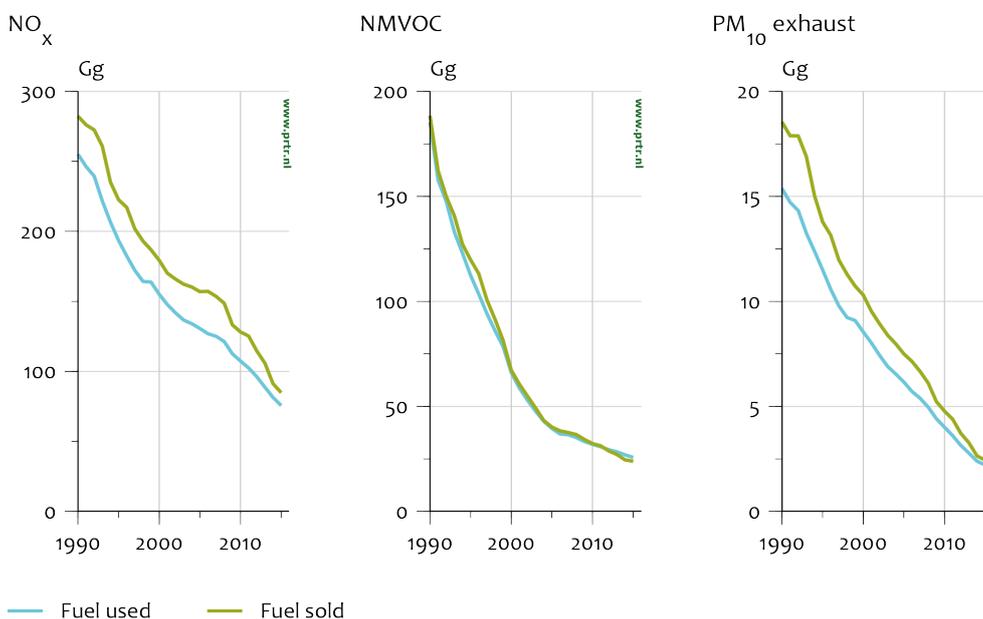


Figure 4.7 NO_x , NMVOC and PM_{10} exhaust emissions from road transport in the Netherlands based on fuel used and fuel sold

4.3.5 Methodological issues

The PM emission factors for brake and tyre wear and for road abrasion are rather uncertain due to a lack of measurements.

4.3.6 Uncertainties and time series consistency

In 2013, TNO carried out a study to improve the knowledge on uncertainties of pollutant emissions from road transport (Kraan *et al.*, 2014). Using a jackknife approach, the variation in the different input variables used for estimating total NO_x emissions from Euro-4 diesel passenger cars was examined, including emission behaviour of the vehicles, on-road driving behaviour and 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 if these results hold for more recent generations of (diesel) passenger cars. Test procedures have been improved in recent years, but the number of vehicles tested has decreased over the years.

In 2016, an expert workshop was organized to discuss and estimate the uncertainties in the activity data and emission factors used for the emission calculation for the transport sector. An overview of the uncertainties and underlying argumentation can be found in Dellaert & Dröge (2017).

Consistent methodologies were used throughout the time series.

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 to 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.

4.3.8 Source-specific recalculations

This year's submission includes new time-series for BC emissions from road transport, using insights from a recent study by TNO commissioned by the E-PRTR (Ligterink, 2017). The study gives an overview of recent research, including the results of a recent measurement programme on petrol vehicles with direct injection (GDI) and heavy-duty Euro-V trucks, culminating in a complete set of emission factors for all vehicle categories derived in the emission monitoring. In previous inventories, BC emissions from road transport (and other source categories within the transport sector) were calculated using preliminary EC/PM fractions estimated by Visschedijk (2014). The new emission factors for older vehicle types in general are lower than previously estimated, resulting in lower BC emissions in earlier years of the time series (Figure 4.7). Emissions decreased by approximately 30 percent in earlier years of the time series. In recent years of the time series differences are minimal.

BC emissions road transport

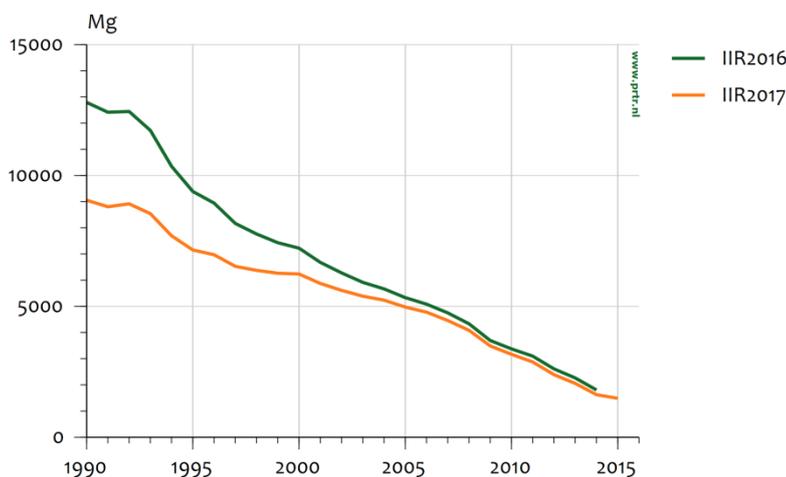


Figure 4.8. Total BC emissions by road transport in this year's and last year's inventory.

This year's submission includes new time-series for BC emissions from road transport, using insights from a recent study by TNO commissioned by the E-PRTR (Ligterink, 2017). The study gives an overview of recent research, including the results of a recent measurement programme on petrol vehicles with direct injection (GDI) and heavy-duty Euro-V trucks, culminating in a complete set of emission factors for all vehicle categories derived in the emission monitoring. In previous inventories, BC emissions from road transport (and other source categories within the transport sector) were calculated using preliminary EC/PM fractions estimated by Visschedijk (2014). The new emission factors for older vehicle types in general are lower than previously estimated, resulting in lower BC emissions in earlier years of the time series (Figure 4.8). Emissions decreased by approximately 30 percent in earlier years of the time series. In recent years of the time series differences are minimal.

4.3.9 *Source-specific planned improvements*

For next year's inventory TNO will perform a study on the road type distribution of different types of road vehicles. This should improve the knowledge of the (differences in the) composition of the vehicle fleet on urban roads, rural roads and highways.

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, generated at stationary power plants. Emissions resulting from electricity generation for railways are not included in this source category. This source category only covers the exhaust emissions from diesel-powered rail transport in the Netherlands. 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 due to wear, which result from friction and spark erosion of the current collectors and the overhead contact lines. This results, among other things, in emissions of particulate matter, copper and lead from trains, trams and metros.

4.4.2 *Key sources*

Railways are a key source for emissions of lead in the 2015 level assessment, accounting for 3% of Pb emissions in the Netherlands in 2015.

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 both 1990 and 2015. Between 1990 and 2000, diesel fuel consumption by railways increased from 1.2 to 1.5 PJ due to an increase in freight transport. Since 2001, fuel consumption has fluctuated around 1.4 PJ. Transport volumes have increased since 2001, especially in freight transport, but this has been compensated by the ongoing electrification of rail transport. In 2015, diesel fuel consumption by rail transport increased by 18% (0.2 PJ) to 1.4 PJ. 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 in the Netherlands are shown in Table 4.6. NO_x and PM₁₀ emissions from railways show similar trends to the diesel fuel consumption time series. NO_x emissions from railways fluctuated around 1.9 Gg in earlier years of the time series, and are around 1.8 Gg in 2015. PM₁₀ emissions have fluctuated around 0.07 Gg. Pb emissions have increased by 16% between 1990 and 2015. Pb emissions from railways result from wear of carbon brushes. Wear emissions were estimated based on 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 tonnes and 14% of the total copper emissions in the Netherlands. Emissions of other heavy metals are very low and are

therefore not included in Table 4.6. SO₂ emissions from railways have decreased by 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).

4.4.4 *Activity data and (implied) emission factors*

For calculating emissions from railways in the Netherlands a Tier-2 method was applied, using fuel sales data and country-specific emission factors. Statistics Netherlands reports data on fuel sales to the Dutch railways sector in the national Energy Balance. Since 2010, these fuel sales data are derived from Vivens, a co-operation of rail transport companies that purchases diesel fuel for the railway sector in the Netherlands. Before 2010, diesel fuel sales to the railways sector were obtained from the Dutch Railways (NS). The NS used to be responsible for the purchases of diesel fuel for the entire railway sector in the Netherlands.

Emission factors for CO, NMVOC, NO_x and PM₁₀ for railways were derived by the PBL Netherlands Environmental Assessment Agency in consultation with the NS. Emission factors of NH₃ were derived from Ntziachristos & Samaras (2000). The emission factors for railways have not been updated recently and therefore are rather uncertain.

PM₁₀ emissions due to wear of overhead contact lines and carbon brushes from railways are calculated using a study by NS-CTO (1992) on the wear of overhead contact lines and carbon brushes of the collectors on electric trains. For trams and metros, the wear of the overhead contact lines has been assumed identical to railways. The wear of current collectors has not been included, because no information was available on this topic. Carbon brushes, besides copper, contain 10% lead and 65% carbon. Based on the NS-CTO study, the percentage of particulate matter in the total quantity of wear debris was estimated at 20%. Because of their low weight, these particles probably remain airborne. It is estimated that approximately 65% of the wear debris ends up in the immediate vicinity of the railway, while 5% enters the 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.

Table 4.6 Trends in emissions from 1A3c Railways

Year	Main Pollutants				Particulate Matter				Other	Priority Heavy Metals
	NO _x	NMVOG	SO _x	NH ₃	PM _{2.5}	PM ₁₀	TSP	BC	CO	Pb
	Gg	Gg	Gg	Gg	Gg	Gg	Gg	Gg	Gg	Mg
1990	1.6	0.07	0.10	0.0003	0.05	0.06	0.06	0.02	0.26	0.22
1995	1.7	0.08	0.10	0.0003	0.06	0.06	0.06	0.02	0.27	0.26
2000	2.1	0.09	0.12	0.0004	0.06	0.07	0.07	0.03	0.32	0.28
2005	1.9	0.08	0.11	0.0003	0.06	0.06	0.06	0.02	0.29	0.27
2010	1.9	0.08	0.02	0.0003	0.06	0.06	0.06	0.02	0.29	0.29
2014	1.6	0.07	0.00	0.0003	0.05	0.06	0.06	0.02	0.26	0.27
2015	1.8	0.08	0.00	0.0003	0.06	0.06	0.06	0.03	0.30	0.25
1990-2015 period ¹⁾	0.23	0.01	-0.10	0.0000	0.01	0.01	0.01	0.00	0.04	0.03
1990-2015 period ²⁾	14%	16%	-99%	15%	16%	16%	16%	16%	15%	16%

¹⁾ Absolute difference in Gg

²⁾ Relative difference to 1990 in %

4.4.5 Methodological issues

Emission factors for railways have not been updated recently and therefore are rather uncertain.

4.4.6 Uncertainties and time series consistency

In 2016, an expert workshop has been organized to discuss and estimate the uncertainties in activity data and emission factors used for transport. An overview of the uncertainties and underlying argumentation can be found in Dellaert & Dröge (2017). Consistent methodologies were used throughout the time series for railways.

4.4.7 Source-specific QA/QC and verification

Trends in fuel sales data have been compared with trends in traffic volumes. The trends in both time series show fairly good agreement, although agreement has been less good in recent years due to the increased electrification of diesel rail transport in the Netherlands.

4.4.8 Source-specific recalculations

There was an error in the IIR2016 reported emissions of Pb, Cu and PM₁₀ due to wear and abrasion of overhead contact lines. This error has been corrected, leading to lower rail emissions of PM₁₀, Pb and Cu, shown in Figure 4.9.



Figure 4.9. PM_{10} , Pb and Cu emissions by railways road transport in this year's and last year's inventory.

4.4.9 Source-specific planned improvements

There are no source-specific planned improvements for railways. Emission factors remain uncertain but since railways are a small emission source and not a key source for any substance except for lead, updating the emission factors 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 (1A3dii) and international (1A3di(ii)) inland navigation in the Netherlands and from international maritime navigation (1A3di(i)). National inland navigation includes emissions from all trips that both depart and arrive in The Netherlands, whereas international inland navigation includes emissions from trips that either depart or arrive abroad. Only emissions on Dutch territory are reported. For maritime navigation this includes emissions on the Dutch continental shelf. All three categories include both passenger and freight transport. Emissions from international maritime navigation are reported as a memo item and are not part of the national emission totals. The emissions from recreational craft are reported under *Other mobile* (1A5b) but are described in this section as well.

4.5.2 Key sources

Both the source categories 1A3di(ii) *International inland waterways* and 1A3dii *National inland waterways* are key sources for NO_x, PM_{2.5} and BC emissions. The source category 1A5b *Other Mobile* is not a key source.

4.5.3 Overview of emission shares and trends

In total, national and international inland waterborne navigation combined was responsible for 12% of NO_x emissions and 6% of PM_{2.5} emissions in The Netherlands in 2015. With emissions from road transport decreasing rapidly, the share of inland waterborne navigation in national totals has increased throughout the time series. The share of inland waterborne navigation in national emissions of PM₁₀ (3.3%), NMVOC (0.9%), CO (1%) and SO₂ (0.04%) was small in 2015.

Emissions from international maritime navigation are not included in the national totals but maritime navigation is a major emission source in The Netherlands, with 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 102 Gg in 2015, up from 97 Gg in 2013 and higher than the combined NO_x emissions from all road transport in The Netherlands. PM₁₀ emissions amounted to 3.9 Gg in 2015. In contrast, recreational craft are only a small emission source with 2.3 Gg of NO_x, 0.9 Gg of NMVOC and 0.05 Gg of PM₁₀ in 2015.

Table 4.7 Trends in emissions from Inland shipping in the Netherlands (combined emissions of national and international inland shipping)

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	31	5.4	1.9	0.005	1.30	1.37	1.37	0.58	22
1995	28	5.6	1.9	0.005	1.32	1.39	1.39	0.58	23
2000	30	5.6	2.1	0.006	1.32	1.39	1.39	0.59	27
2005	28	4.9	2.0	0.006	1.14	1.20	1.20	0.50	29
2010	27	3.8	0.6	0.006	0.92	0.98	0.98	0.41	27
2014	29	2.9	0.0	0.006	0.89	0.95	0.95	0.40	27
2015	29	2.7	0.0	0.007	0.88	0.93	0.93	0.40	26
1990-2015 period ¹⁾	-2	-2.7	-1.9	0.001	-0.42	-0.44	-0.44	-0.18	4.0
1990-2015 period ²⁾	-7%	-50%	-99%	21%	-32%	-32%	-32%	-30%	18%

¹⁾ Absolute difference in Gg

²⁾ Relative difference to 1990 in %

The trends in emissions from inland shipping in the Netherlands are shown in Table 4.7. Since 2000, fuel consumption in inland navigation has fluctuated between 22 and 27 PJ. The economic crisis led to a decrease of transport volumes and fuel consumption in 2009. Since then, transport volumes have increased again, resulting in an increase in fuel consumption from 22 PJ in 2009 to 28 PJ in 2015, as is shown in Figure 4.10. Emissions of NO_x, CO, NMVOC and PM from inland

navigation have shown similar trends to the fuel consumption time series. Combined NO_x emissions from national and international inland navigation increased from 25 Gg in 2010 to 26 Gg in 2015. The introduction of emission standards for new ship engines (CCR stage I and II) has led to a small decrease in the fleet average NO_x emission factor (per kilogram of fuel) in recent years, but since fuel consumption increased significantly, total NO_x emissions still increased between 2009 and 2015.

SO₂ emissions from waterborne navigation have decreased by 98% between 2009 and 2015 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. Sulphur free diesel fuel was already introduced in 2009 in inland shipping in the Netherlands, therefore SO₂ emissions have 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 PM₁₀ emissions from waterborne navigation decreased by 0.04 Gg between 2009 and 2015.

Since fuel consumption by recreational craft has remained fairly constant in recent years, trends in emissions follow the trend in fleet average emission factors. The fleet average emission factors of most substances decreased slightly from 2014 to 2015, resulting in small decreases in emissions. PM₁₀, PM_{2.5} and CO emissions decreased by less than 1%. NO_x emissions showed a minor increase (0.6%) from 2014 to 2015.

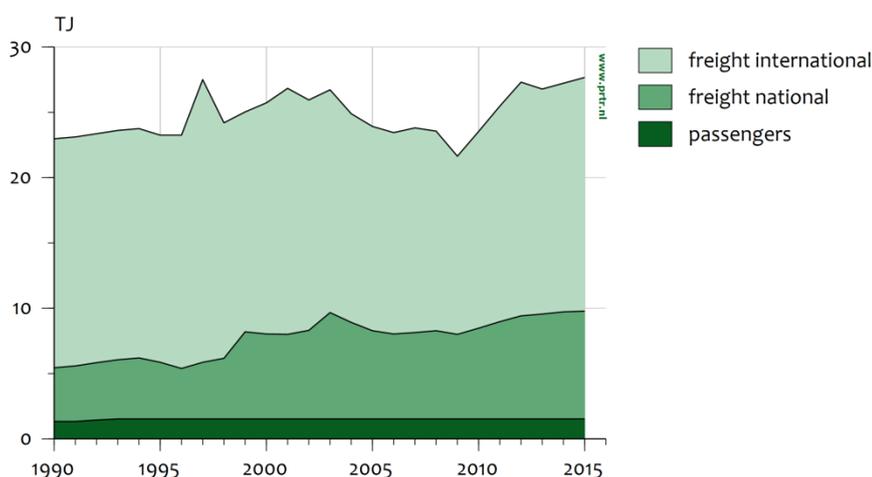


Figure 4.10 Fuel consumption in national and international inland shipping in the Netherlands

Energy use and resulting emissions from maritime navigation showed an upwards trend between 1990 and 2007. Since the start of the economic crisis, transport volumes decreased resulting in a reduction of energy use and emissions. This decrease was enhanced by *slow steaming*, resulting in lower energy use and thus further lowering emissions (MARIN, 2011). In 2015, total fuel consumption by maritime navigation on the Dutch part of the North Sea, the Dutch Continental Shelf (DCS),

remained about the same compared to 2014, whereas fuel consumption by maritime shipping on inland waterways increased by 9%. As a result, total NO_x emissions by maritime shipping on Dutch territory remained constant in 2015, while total PM₁₀ emissions decreased by 14%.

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 method. The methodology was developed as part of the *Emissieregistratie en Monitoring Scheepvaart (EMS)* project. The EMS-methodology distinguishes between 32 vessel classes. For each class, annual power demand (kWh) is calculated for all inland waterways in the Netherlands. A distinction is made between loaded and unloaded vessels. In addition, the average speed of the vessels has been determined (in relation to the water) depending on the vessel class and the maximum speed allowed on the route that is travelled. The general formula for calculating emissions is the following:

$$\text{Emissions} = \text{Number of vessels} * \text{Power} * \text{Time} * \text{Emission factor}$$

Data on the number of vessel kilometres per ship type were derived from Statistics Netherlands. The distribution of these kilometres over the Dutch inland waterway network was estimated using data from the IVS90 network that registers all ship movements at certain points (e.g. sluices) of the Dutch waterway network. The distribution was estimated during the development of the EMS-methodology and had been used since. In 2012, the distribution of vessel kilometres per ship type over the waterway network was re-estimated by TNO using a modelling approach.

Emissions from propulsion engines =

the sum of vessel classes, cargo situations, routes and directions of:

**{number of vessel passages times
average power used times
average emission factor times
length of route divided by speed}**

or

$$E_{v,c,b,r,s,d} = N_{v,c,b,r,d} \cdot Pb_{v,b,r} \cdot L_r / (V_{v,r,d} + V_r) \cdot EF_{v,s} \quad (1)$$

Where:

$E_{v,c,b,r,s,d}$ = Emission per vessel class, (kg)

$N_{v,c,b,r,d}$ = Number of vessels of this class on the route and with this cargo situation

sailing in this direction

$Pb_{v,b,r}$ = Average power of this vessel class on the route (kW)

$EF_{v,s}$ = Average emission factor of the engines of this vessel class (kg/kWh)

L_r = Length of the route (km)

$V_{v,r}$ = Average speed of the vessel in this class on this route (km/h)

V_r = Rate of flow of the water on this route (km/h), (can also be a negative value)

v,c,b,r,s,d = indices for vessel class, aggregated cargo capacity class, cargo situation, route, substance, and direction of travel, respectively

The formula in the text box is used for calculating the emission of substance (s) in one direction (d) specifically for one vessel class (v,c), carrying a cargo or not (b), on every distinct route (r) of the Dutch inland waterway network. The combination of the number of vessel movements, their power and their speed results in the total power demand (kWh). Emission factors are expressed in g/kWh. The emission factors depend on the engine's year of construction and are reported in Hulskotte & Bolt (2013). Fleet average emission factors are estimated using the distribution of engines in the fleet over the various year-of-construction classes. Due to a lack of data on the actual age distribution of the engines in the inland waterway fleet, a Weibull function is used to estimate the age distribution of the engines. The values of the Weibull parameters (κ and λ) have been derived from a survey, carried out by TNO among 146 vessels. The median age of the engines in the survey was 9.6 years and the average age was 14.9 years. The resulting fleet average emission factors throughout the time series are reported in Klein *et al.* (2017). 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 required for manoeuvring the vessel (bow propeller engines) and generating electricity for the operation of the vessel and the residential compartments (generators). Fuel consumption by auxiliary engines is estimated as 13% of fuel consumption of the main engines.

No recent information was available on the fuel consumption by passenger ships and ferries in the Netherlands, therefore fuel consumption data for 1994 were applied to all subsequent years of the time series. Emissions from recreational craft were calculated by multiplying the number of recreational craft (allocated to open motor boats/cabin motor boats and open sailboats/cabin sailboats) with the average fuel consumption per boat type times the emission factor per substance, expressed in emissions per engine type per quantity of fuel (Hulskotte *et al.*, 2005). The various types of boats are equipped with a specific allocation of engine types that determine the level of the emission factors. The applied emission factors are reported in Klein *et al.* (2017).

Since 2008, emissions from maritime shipping on the Dutch Continental Shelf and in the Dutch port areas are calculated annually by MARIN and TNO using vessel movement data derived from AIS (Automatic Identification System). Since 2005 all merchant ships over 300 Gross Tonnage (GT) are equipped with AIS. AIS transmits information about the position, speed and course of the ship every 2 to 10 seconds. Information about the ship itself, such as its IMO number, ship type, size and destination is transmitted every few minutes. Sailing speed of

the ship is an important factor in determining energy use and resulting emissions. Therefore, AIS data can be used to estimate energy consumption and emissions from maritime shipping bottom-up, taking into account specific ship and voyage characteristics.

To estimate emissions from a specific ship on Dutch waters, the IMO number of the ship is linked to a ship characteristics database that is acquired from Lloyd's List Intelligence (LLI). This database contains vessel characteristics, such as year of construction, installed engine power, service speed and vessel size, of more than 100.000 seagoing merchant vessels operating worldwide. Emission factors for each individual ship were determined by TNO using information on the year of build and the design speed of the ship, the engine type and power, the type of fuel used and, for engines build since 2000, the engines maximum revolutions per minute (RPM). Methodologies and resulting emissions for recent years are described in more detail in MARIN (2014).

4.5.5 *Methodological issues*

There was no recent data available on the fuel consumption in passenger ships and ferries. Also, the available data on the number of recreational crafts and their average usage rates are rather uncertain.

4.5.6 *Uncertainties and time series consistency*

In 2016, an expert workshop was organized to discuss and (re)estimate the uncertainties in the activity data and emission factors used for the emissions calculations for the transport sector. An overview of the uncertainties and underlying argumentation can be found in Dellaert & Dröge (2017). Consistent methodologies were used throughout the time series for inland waterborne navigation. For maritime navigation, AIS data have only become available since 2008. For earlier years in the time series, emission totals were estimated using vessel movement data from Lloyd's combined with assumptions on average vessel speeds (Hulskotte *et al.*, 2003).

4.5.7 *Source-specific QA/QC and verification*

There are no source-specific QA/QC or verification procedures for waterborne navigation.

4.5.8 *Source-specific recalculations*

There were no source-specific recalculations for waterborne navigation in this year's submission.

4.5.9 *Source-specific planned improvements*

TNO is currently performing a study to determine whether AIS data can also be used to calculate emissions from inland navigation on Dutch territory. In the current inventory, AIS data is only used for maritime navigation, but in recent years most inland ships have also been fitted with an AIS transponder. In theory, emissions from inland navigation can also be estimated using AIS data. The pilot study should determine whether or not AIS is a valuable option for inland navigation emission calculations.

4.6 Non-road mobile machinery (NRMM)

4.6.1 *Source category description*

Mobile machinery 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 most important deployment of NRMM in the Netherlands is in agriculture and construction. The largest volumes of fuel are used in tillage, harvesting and earthmoving. Furthermore, NRMM is used in nature and green maintenance, such as in lawn mowers, aerator machines, forest mowers and leaf blowers.

Emissions from NRMM were 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 latter source category is used for emissions from ground support equipment at airports.

4.6.2 *Key sources*

Mobile machinery in manufacturing industries and construction (1A2gvii) is a key source for NO_x, PM_{2.5} and BC in the 2015 level assessment. Source category 1A4bii Residential: household and gardening (mobile) is a key source of emissions of CO in both the 2015 level and the trend assessment, whereas source category 1A4cii Agriculture/forestry/fishing: off-road vehicles and other machinery is a key source for NO_x, PM_{2.5} and BC in the 2015 level assessment and for NO_x in the trend assessment. Source category 1A5b Other, mobile, which includes emissions from ground support equipment at airports, is no longer a key source.

4.6.3 *Overview of shares and trends in emissions*

NRMM was responsible for 12% of CO emissions, 9% of NO_x and PM_{2.5} and 5% of PM₁₀ emissions in the Netherlands in 2015. CO emissions mainly resulted from the use of gasoline equipment by households (lawn mowers) and for public green maintenance. NO_x, PM₁₀ and PM_{2.5} emissions were for the most part related to diesel machinery used in agriculture (tractors) and construction. LPG fork lift trucks were also a major source of NO_x emissions with a contribution of 13% in total NO_x emissions from NRMM in 2015.

Total energy use in NRMM has fluctuated between 38 PJ and 46 PJ throughout the time series. Energy use in 2015 decreased by 2.5% (1.1 PJ) compared to 2014, mainly due to a reduction in energy use by construction machinery. Since the start of the economic crisis, energy use by construction machinery decreased from 19.7 PJ in 2008 to 14.0 in 2015. Figure 4.11 shows total energy use within the different sectors where mobile machinery is applied. Construction and agricultural machinery were responsible for 76% of total energy use by NRMM in 2015. Diesel is the dominant fuel type, accounting for 91% of energy use in 2015. Gasoline and LPG had a share of 4% and 5% respectively.

LPG is used in the industrial sector (forklift trucks) and gasoline in the agricultural, construction and commercial/institutional sectors.

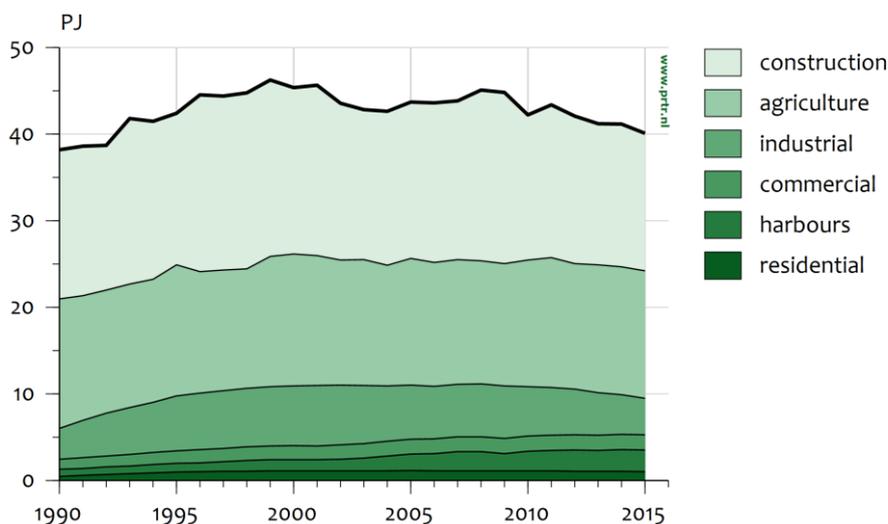


Figure 4.11 Fuel consumption in non-road mobile machinery in different sectors in the Netherlands

The trends in emissions from NRMM in the Netherlands are shown in Table 4.8. With the introduction of EU emissions standards for NRMM in 1999 and the subsequent tightening of the emission standards in later years, NO_x emissions from NRMM have steadily decreased, as is shown in Figure 4.12. Since 1999, NO_x emissions have decreased by 58%, whereas fuel consumption has only decreased by 14%. NO_x emissions from gasoline-and LPG-powered machinery have steadily increased throughout the time series. In 2015, gasoline and LPG machinery had a combined share of 15% in total NO_x emissions, whereas in 1990 their combined share was only 5%. CO emissions have also increased throughout the time series.

Table 4.8 Trends in emissions from non-road mobile machinery in the Netherlands

Year	Main Pollutants				Particulate Matter				Other
	NO _x	NMVOG	SO _x	NH ₃	PM _{2.5}	PM ₁₀	TSP	BC	CO
	Gg	Gg	Gg	Gg	Gg	Gg	Gg	Gg	Gg
1990	37	8.0	3.0	0.008	3.6	3.8	3.8	1.8	37
1995	41	8.4	3.0	0.009	3.1	3.3	3.3	1.6	54
2000	43	8.0	3.2	0.010	2.8	2.9	2.9	1.4	58
2005	35	6.1	3.1	0.009	2.3	2.4	2.4	1.2	54
2010	26	4.4	0.3	0.009	1.6	1.7	1.7	0.8	51
2014	21	3.4	0.0	0.009	1.2	1.3	1.3	0.6	49
2015	19	3.1	0.0	0.009	1.1	1.2	1.2	0.5	48
1990-2015 period ¹⁾	-18	-5.0	-3.0	0.000	-2.5	-2.6	-2.6	-1.3	11
1990-2015 period ²⁾	-49%	-62%	-99%	2%	-69%	-69%	-69%	-70%	30%

¹⁾ Absolute difference in Gg

²⁾ Relative difference to 1990 in %

Emissions of most other substances have decreased significantly throughout the time series. For PM₁₀ and NMVOC, this can be attributed to the EU NRMM emission legislation as well. SO₂ emissions have decreased due to the EU fuel quality standards reducing the sulphur content of the diesel fuel used by non-road mobile machinery. Since 2011, the use of sulphur free diesel fuel is required in NRMM. Consequently, SO₂ emissions have reduced significantly.

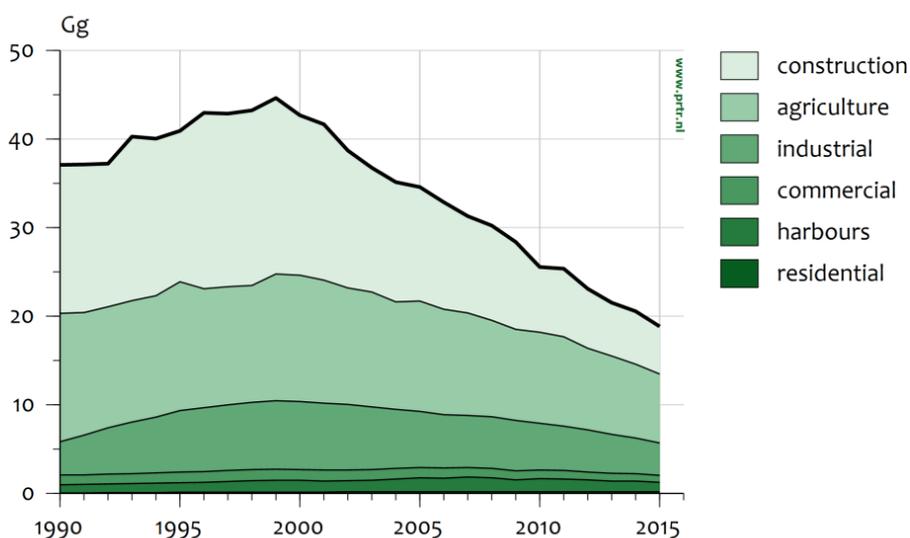


Figure 4.12 NO_x emissions by non-road mobile machinery in different sectors in the Netherlands

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, developed by TNO (Hulskotte & Verbeek, 2009). The so-called EMMA model uses sales data and survival rates for different types of machinery to estimate the active NRMM fleet in any given year. Combined with assumptions on the average use (annual operating hours) and the specific fuel consumption per hour of operation for the different types of machinery, total annual fuel consumption by NRMM is estimated. The methodology used in the EMMA model is similar to the methodology used in the EPA NON-ROAD USA model by the US Environmental Protection Agency (EPA), as described in Harvey *et al.* (2003). Emission factors were originally taken from a similar model TREMOD-MM (Lambrecht *et al.*, 2004) and partially updated with data taken from Helms *et al.* (2010).

Annual sales data for the different types of NRMM are derived from trade organization such as BMWT and Federatie Agrotechniek. Fuel consumption and resulting emissions of CO, NO_x, PM and VOC are calculated using the following formula:

Emission = Number of machines x hours x Load x Power x Emission factor x TAF-factor

In which:

- Emission = Emission or fuel consumption (grams)
- Number of machines = the number of machines of a certain year of construction with emission factors applicable to the machine's year of construction
- Hours = the average annual running hours for this type of machinery
- Load = the average fraction of full power used by this type of machinery
- Power = the average full power for this type of machinery (kW)
- Emission factor = the average emission factor or specific fuel consumption belonging to the year of construction (related to emission standards, in grams/kWh)
- TAF factor = adjustment factor applied to the average emission factor to correct the deviation from the average use of this type of machine due to varying power demands.

The TNO report on the EMMA model (Hulskotte & Verbeek, 2009) provides the emission factors of the various technologies and the different stages in the European emission standards. The emission factors are linked to the different machine types per sales year. Emissions of SO₂ were calculated based on total fuel consumption and sulphur content per fuel type as provided in Klein *et al.* (2017). Emission factors for NH₃ were derived from Ntziachristos & Samaras (2000).

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 the LEI research institute of Wageningen University and Research Centre. Fuel consumption by agricultural contractors was derived from the trade organization 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 was consequently added to the fuel consumption by construction machinery as reported by EMMA. EMMA overestimates total energy use in agriculture because in the model all agricultural machinery is reported under the agricultural sector, whereas in reality some agricultural machinery (e.g. tractors) is used in construction.

The resulting fuel consumption in construction was subsequently adjusted to take into account the impact of economic fluctuations. Because EMMA is based on sales data and assumptions on the average

annual use of the machinery, it is not able to properly take into account cyclical effects that do not only lead to fluctuations in the sales data, but also in the usage rates of the machinery (i.e. the annual operational hours). The latter effect is not included in the model; therefore the EMMA results were adjusted based on economic indicators from Statistics Netherlands for the specific sectors where the machinery was used. The adjusted EMMA results were used to calculate emissions from non-road mobile machinery. The resulting fuel consumption (energy use) 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 Klein *et al.* (2016).

The 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, provided by KLM Royal Dutch Airlines. KLM is responsible for refuelling and maintenance of the equipment at Schiphol Airport and therefore has precise knowledge on the types of machinery used and the amount of energy used per year. These data have been used to derive emission estimates. The resulting emissions have also been used to derive an average emission factor per MTOW at Schiphol Airport, which was subsequently used to estimate emissions at regional airports.

4.6.5 *Methodological issues*

The current methodology to estimate emissions from NRMM could be improved regarding:

1. The diesel used in the construction sector is liable to relatively strong economic fluctuations. At present the correction for this phenomenon takes place using economic indicators derived from Statistics Netherlands instead of physical indicators. It could be investigated if there are enterprises or institutions that have figures of diesel consumption at their disposal.
2. There is a lack of input data for several types of machinery and sectors. In the garden sector and private households weakly founded or extrapolated figures have been used to estimate the size of the fleet.
3. The application of generic survival rates for all types of machinery might have led to declinations 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 a considerable improvement of the reliability of the emission figures.
4. The effect of varying engine loads on emissions has hardly been examined. For some types of machinery, it is of great importance to have a better understanding on the influence on the emissions. A specific measurement programme for investigating the effect of transient engine loads in the machine's daily practice could lead to a far better foundation of the emission data.

4.6.6 *Uncertainties and time series consistency*

In 2016, an expert workshop was organized to discuss and (re)estimate the uncertainties in the activity data and emission factors used for the emission calculations for the transport sector. An overview of the

uncertainties and underlying argumentation can be found in Dellaert & Dröge (2017). The EMMA model was used for calculating fuel consumption and emissions for the time series since 1994. For earlier years there were no reliable machinery sales data available. Fuel consumption in 1990 was derived from estimates from Statistics Netherlands, while fuel consumption in 1991, 1992 and 1993 was derived by interpolation.

4.6.7 *Source-specific QA/QC and verification*

There are no source-specific QA/QC and verification procedures for non-road mobile machinery.

4.6.8 *Source-specific recalculations*

In this year's submission the emissions from mobile pumping engines and electricity generators have been added to the inventory. Mobile electricity generators are used in (road) construction, in industry and at public events.

Total diesel fuel consumption by pumping engines was estimated at 0.2-0.3 PJ during the time series. Diesel consumption in mobile electricity generators was estimated at 1.9 PJ in 1990, increasing to 2.5 PJ in 2015. NO_x emissions were estimated at 2.3 Gg in 1990 and 1.6 Gg in 2015, whereas PM₁₀ and PM_{2.5} emissions were estimated at 0.3 Gg in 1990 and 0.15 Gg in 2015. Since all equipment is diesel fuelled, CO and NMVOC emissions are small. The emissions from mobile pumping engines have been reported under source category 1A2gii 'Mobile combustion in manufacturing industries and construction'. The emissions from mobile electricity generators have been distributed over source categories 1A2gii and 1A4aii.

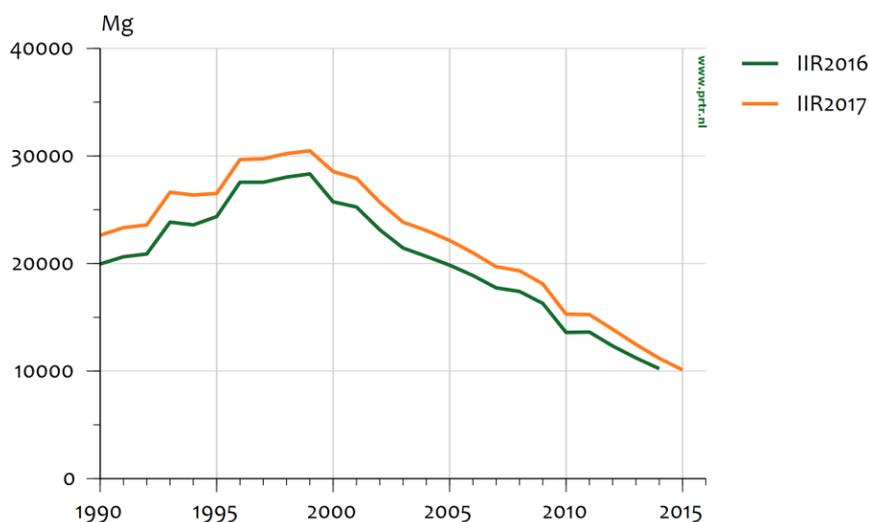
In addition to including these machinery categories in the calculations, the data on machine power specifications has been improved. The calculation now uses data on the power specifications of the machines sold instead of a more generic figure available for all machine types. This recalculation leads to different fuel consumption and emissions for a number of machine types across the NRMM categories for the complete time series. The changes are most significant for mobile machinery in the residential sector (1A4bii), where 2014 NO_x emissions decreased 5% compared to the previous submission.

Furthermore, the calculation for machinery at container terminals has been improved. At several container depots, only empty containers are handled. A lower energy requirement per twenty feet equivalent unit (TEU) container has been used for the handling of empty containers, leading to lower fuel use and emissions over the complete time series. The calculation is explained in Dellaert (2016).

The recalculations of NRMM emissions resulted in higher emissions for almost all components than previously reported from mobile sources in manufacturing industries and construction (1A2gvii), commercial & institutional sectors (1A4aii) and residential use (1A4bii). Figure 4.13 shows total emissions of NO_x and PM_{2.5} from these three source categories as reported in last year's and in this year's inventory. NO_x

emissions are approximately 10 to 15 percent higher than reported in last year's inventory, whereas PM_{2.5} emissions are 14-25 percent higher.

NO_x emissions non road mobile machinery



PM_{2.5} emissions non road mobile machinery

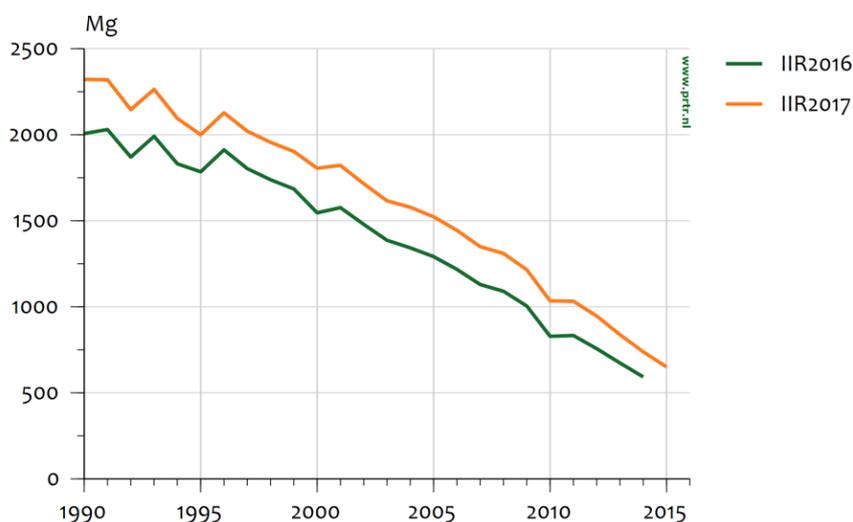


Figure 4.13 NO_x and PM_{2.5} emissions from non-road mobile machinery.

4.6.9 Source-specific planned improvements

There are no source-specific planned improvements for NRMM.

4.7 National fishing

4.7.1 Source category description

The source category 1A4ciii 'National fishing' covers emissions from fuel consumption to cutters operating within national waters, including the Dutch part of the Continental Shelf.

4.7.2 Key sources

National fishing is not a key source in the emission inventory.

4.7.3 Overview of emission shares and trends

National fishing is a small emission source in the Netherlands. In 2015, national fishing was responsible for 2% of total NO_x and BC emissions and 1% of PM_{2.5} emissions. The contribution to the national totals for other substances was less than 1%. Fuel consumption by national fishing has been decreasing since 1995, as is shown in Figure 4.14. This is in line with the decrease in the number of cutter vessels and the installed engine power in the cutter fleet (as reported by Statistics Netherlands).

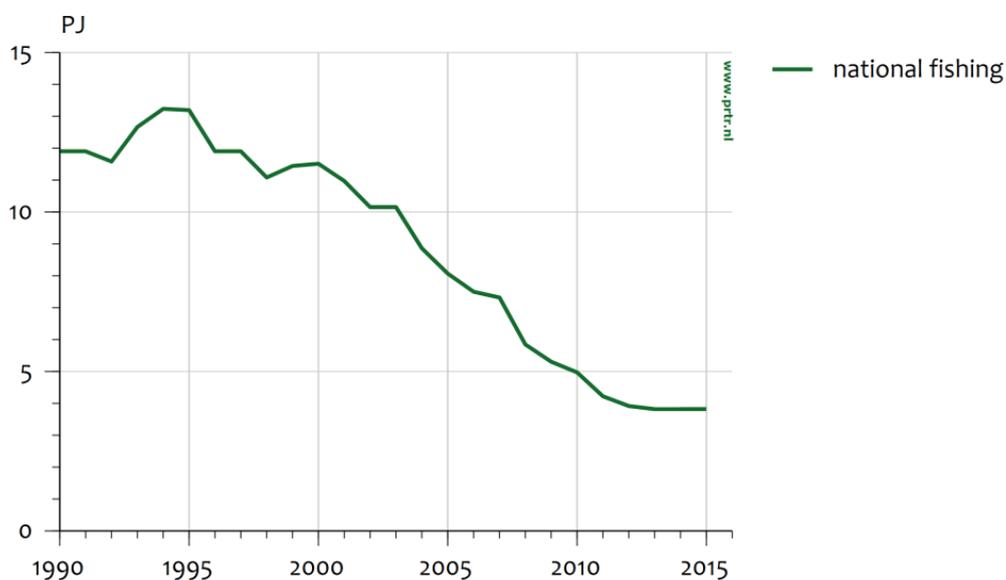


Figure 4.14 Fuel consumption by the fishing fleet in the Netherlands

The trends in emissions from national fishing are shown in Table 4.9. Since the emission factors were kept constant throughout the time series, emissions from national fishing show similar trends to fuel consumption. NO_x emissions decreased from 16.5 to 5.3 Gg between 1990 and 2014, whereas PM₁₀ emissions decreased from 0.39 to 0.13 Gg. SO₂ emissions decreased by over 99% due to the use of sulphur-free diesel fuel.

Table 4.9: Trends in emissions from National Fishing in the Netherlands

Year	Main Pollutants				Particulate Matter				Other
	NO _x	NMVOG	SO _x	NH ₃	PM _{2.5}	PM ₁₀	TSP	BC	CO
	Gg	Gg	Gg	Gg	Gg	Gg	Gg	Gg	Gg
1990	16.5	0.7	1.0	0.003	0.37	0.39	0.39	0.17	2.23
1995	18.2	0.8	1.1	0.003	0.41	0.43	0.43	0.18	2.47
2000	15.9	0.7	0.9	0.003	0.36	0.38	0.38	0.16	2.16
2005	11.2	0.5	0.6	0.002	0.25	0.26	0.26	0.11	1.51
2010	6.9	0.3	0.1	0.001	0.15	0.16	0.16	0.07	0.93
2014	5.3	0.2	0.0	0.001	0.12	0.13	0.13	0.05	0.71
2015	5.3	0.2	0.0	0.001	0.12	0.13	0.13	0.05	0.71
1990-2015 period ¹⁾	-11.2	-0.5	-1.0	-0.002	-0.25	-0.27	-0.27	-0.11	-1.52
1990-2015 period ²⁾	-68%	-68%	-100%	-68%	-68%	-68%	-68%	-68%	-68%

¹⁾ Absolute difference

²⁾ Relative difference to 1990 in %

4.7.4 Activity data and (implied) emission factors

Fuel consumption in fishing was derived from calculations based on vessel movements. These calculations were performed by LEI research institute and reported in annual reports called 'Visserij in Cijfers'. Fuel consumption is calculated using the following formula:

Fuel taken on board = the sum of hp-days x fuel consumption per hp per day per vessel,

HP-days stands for the number of days a vessel spends at sea multiplied by the amount of horsepower of the vessel. With the help of data from VIRIS, a database from LEI containing log data from individual vessels, the ports of departure and arrival and the number of days at sea have been ascertained for each vessel for each fishing trip. When determining where fuel is taken on board, it has been assumed that for all fishing trips where the ports of departure and arrival were both in the Netherlands, fuel was taken on board in the Netherlands. Furthermore, vessels are assumed always to refuel after completion of a fishing trip.

The applied emission factors for NO_x, CO, NMVOG and PM₁₀ were derived from Hulskotte & Koch (2000), whereas the SO₂ emission factors were derived from Van der Tak (2000). Emission factors for NH₃ were derived from Ntziachristos & Samaras (2000).

4.7.5 Methodological issues

Since there were no fuel sales data available specifically for national fishing, fuel consumption was calculated based on vessel movements. This method is rather uncertain. Also, the emission factors for fishing vessels have not been updated recently and therefore are rather uncertain.

4.7.6 Uncertainties and time series consistency

In 2016, an expert workshop was organized to discuss and (re)estimate the uncertainties in the activity data and emission factors used for the

emission calculations for the transport sector. An overview of the uncertainties and underlying argumentation can be found in Dellaert & Dröge (2017). Consistent methodologies were used throughout the time series for national fishing.

4.7.7 *Source-specific QA/QC and verification*

Trends in total fuel consumption in cutter fishery, as reported by LEI, were compared with trends in the cutter fishing fleet in the Netherlands and the installed engine power on the fleet. Both trends show good agreement.

4.7.8 *Source-specific recalculations*

There are no source-specific recalculations for national fishing.

4.7.9 *Source-specific planned improvements*

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

5 Industrial Processes and Product Use (NFR 2)

5.1 Overview of the sector

Emissions from this 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 those on the energy sector. Fugitive emissions in the energy sector (i.e. not related to fuel combustion) are included in NFR sector 1B.

The Industrial Processes and Product Use (NFR 2) sector consists of the following 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, transportation 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 in which sources belong to 2G and 2L, 2G is included in 2D3i (Other solvent and product use) and 2L in 2H3 (Other industrial processes).

Table 5.1 gives an overview of the emissions from the Industrial Processes and Product use (NFR 2) sector.

Table 5.1 Overview of emission totals from the Industrial Processes & Product Use (NFR 2) sector

Year	Main Pollutants				Particulate Matter		
	NO _x	NMVOC	SO _x	NH ₃	TSP	PM ₁₀	PM _{2.5}
	Gg	Gg	Gg	Gg	Gg	Gg	Gg
1990	5.2	215	10.0	5.4	50	30	15
1995	3.3	154	2.8	5.2	35	19	9.8
2000	1.9	111	1.5	4.0	18	12.1	6.2
2005	0.6	89	1.0	3.6	16	11.2	5.5
2010	0.5	89	0.9	2.6	15	10.5	5.2
2014	0.7	78	0.8	2.2	15	9.7	4.4
2015	0.7	77	0.9	2.2	15	9.7	4.4
1990–2015 period ¹⁾	-4.4	-138	-9.1	-3.3	-35	-20	-10.7
1990–2015 period ²⁾	-86%	-64%	-87%	-60%	-71%	-67%	-71%

Year	Priority Heavy Metals			POPs	
	Pb	Cd	Hg	DIOX	PAHs
	Mg	Mg	Mg	g I-Teq	Mg
1990	67	0.9	1.2	63	13
1995	67	0.7	0.8	49	4.5
2000	24	0.8	0.4	21	0.4
2005	27	1.5	0.4	19	0.4
2010	32	1.0	0.2	17	0.3
2014	7	0.4	0.1	13	0.1
2015	6	0.4	0.1	13	0.2
1990–2015 period ¹⁾	-61	-0.5	-1.1	-50	-13
1990–2015 period ²⁾	-91%	-53%	-88%	-80%	-99%

¹⁾ Absolute difference in Gg

²⁾ Relative difference to 1990 in %

More than 55% of the total NMVOC emissions in the Netherlands originates from the Industrial Processes and Product use (NFR 2) sector.

5.1.1 Key sources

The key sources of this sector are discussed in sections 5.2 to 5.6. Because the TSP and Cd time series of most key sources were incomplete, they were not included in sections 5.2 to 5.6. Incomplete time series will be repaired, as much as possible, in future submissions.

5.1.2 Activity data and (implied) emission factors

Industrial Processes

Data on production levels were derived from Statistics Netherlands. Up to 2007, implied emission factors were determined (see section 5.1.3).

Product Use

The Activity data and (implied) emission factors of the product use categories are included in 5.5, Solvents and product use.

5.1.3

*Methodological issues***Industrial Processes**

The emission totals of categories and subcategories consist of the sum of the data from individual facilities complemented with the emissions from the non-reporting (small and medium-sized) facilities. Depending on the availability of data on emissions from individual companies, one of the following methods was used:

Method 1-IP

Up to 2007, the emissions from non-reporting facilities were calculated as follows:

$$\text{Em non_IF} = \text{IEF} * (\text{TP} \text{ -/- } \text{P_IF})$$

where IEF = the implied emission factor; TP = Total production (Production Statistics, Statistics Netherlands); and P_IF = Production of individual facilities (Production Statistics, Statistics Netherlands)
The implied emission factors were calculated as follows:

$$\text{IEF} = \text{Em IF} / \text{P_IF}$$

where Em_IF = the sum of emissions from individual facilities (since 1999, most of the emissions from individual facilities were derived from the Annual Environmental Reports (AER))

Since 2007, due to a lack of production figures, emissions from non-reporting facilities have been calculated as follows:

$$\text{Em non_IF} = \text{Em_IF}_{(n)} / \text{Em_IF}_{(n-1)} * \text{Em non-IF}_{(n-1)}$$

where n = year

Method 2-IP

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

$$\text{Em non_IF} = \text{IEF} * (\text{TP} \text{ -/- } \text{P_IF})$$

where IEF = the implied emission factor; TP = Total production in (sub)category (Production Statistics, Statistics Netherlands); and P_IF = Production in individual facilities (Production Statistics, Statistics Netherlands)

The implied emission factors were calculated as follows:

$$\text{IEF} = \text{Em IF} / \text{P_IF}$$

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

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

$$\text{Em Total (sub)category}_{(n)} = \text{Em Total (sub)category}_{(n-1)} * [\text{PI}_{(n)} / \text{PI}_{(n-1)}]$$

where n = year, and PI = production indices (Statistics Netherlands)

Product Use

The Methodological issues of the product use categories are included in 5.5, Solvents and product use

5.1.4 *Uncertainties and timeseries consistency*

No accurate information was available for assessing the uncertainties about the emissions from this sector's sources. Consistent methodologies – except for TSP and Cd – were used throughout the time series for the sources in this sector.

5.1.5 *Source-specific QA/QC and verification*

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

5.1.6 *Source-specific recalculations*

In comparison to the previous submission several emissions were re-allocated from 1A to 2H2 and detailed information about these re-allocations can be found in section 5.5.

5.1.7 *Source-specific planned improvements*

Industrial processes

The CO time series from 2D3i will be corrected in the next submission. Furthermore, the incomplete TSP and Cd time series will be repaired, where possible, in future submissions.

Product use

There are no source-specific improvements planned for this part of the sector.

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 (please specify in the IIR)

Emissions from lime production (2A2) were included in the subcategory of food and drink process emissions (2H2).

Because of allocation problems, the emissions from 2A5a, 2A5b and 2A5c were reported in the category of other mineral products (2A6). Only emissions from glass production (2A3) and cement production (2A1) could be reported separately, because emissions in this category could be derived from the environmental reports by the corresponding companies.

5.2.2 Key sources

The key sources of this category are presented in Table 5.2.

Table 5.2. Key sources of Mineral products (2A)

	Category / Subcategory	Pollutant	Contribution to total of 2015 (%)
2A3	Glass production	Pb	11.4
2A6	Other Mineral Products	PM ₁₀ /PM _{2.5}	4.1/2.8

5.2.3 Overview of emission shares and trends

Table 5.3 gives an overview of the emissions from the key sources of this category.

Table 5.3. Overview of emission 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}
Unit:	Mg	Gg	Gg
Year			
1990	7.3	2.0	0.9
1995	6.5	1.6	0.7
2000	2.9	1.0	0.3
2005	1.4	1.0	0.3
2010	0.8	1.1	0.4
2014	1.0	1.1	0.4
2015	1.0	1.1	0.4

From 1990 to 2015, Pb emissions from 2A3 decreased from 7.3 to 1.0 Mg. This reduction is mainly caused by the implementation of technical measures.

The most important source of PM₁₀ and PM_{2.5} emissions in 2A6 is the ceramic industry (Production of bricks, roof tiles, etc). As a result of the implementation of technical measures the PM₁₀ emission from 2A6 decreased from 2.0 Gg in 1990 to 1.1 Gg in 2015 and the PM_{2.5} emissions from 0.9 Gg to 0.4 Gg.

5.2.4 Methodological issues

Method 2-IP was used for estimating the emissions from Glass production (2A3) and Other mineral products (2A6).

5.3 Chemical industry (2B)

5.3.1 Source-category description

This category comprises emissions related to 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 (please specify in the IIR)
- 2B10b Storage, handling and transport of chemical products (please specify in the IIR)

Adipic acid (included in 2B3) and calcium carbide (included in 2B5) are not produced in the Netherlands. No emissions were reported under categories 2B1 and 2B2 (only the greenhouse gases CO₂ and N₂O have been reported there). Because of allocation problems and confidential reasons, all emissions from the chemical industry (2B) were allocated to the category of chemical industry: other (2B10a).

5.3.2 Key sources

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

Table 5.4 Key sources of Chemical industry(2B)

Category / Subcategory		Pollutant	Contribution to total of 2015 (%)
2B10a	Chemical industry: Other	NMVOG	3.3
		PM ₁₀ /PM _{2.5}	4.2/6.2

5.3.3 Overview of emission shares and trends

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

Table 5.5 Overview of emission from the key sources of the Chemical industry(2B)

NFR Code:	2B10a		
NFR NAME:	Chemical industry: Other		
Pollutant:	NMVOG	PM₁₀	PM_{2.5}
Unit:	Gg	Gg	Gg
Year			
1990	33	4.1	2.46
1995	18	3.0	1.9
2000	13	1.2	0.8
2005	7.9	1.2	0.9
2010	5.7	1.3	1.0
2014	5.6	1.2	0.8
2015	5.5	1.1	0.8

From 1990 to 2015, NMVOG emissions decreased from 33 Gg to 5.5 Gg and PM₁₀ emissions decreased from 4.1 Gg to 1.1 Gg. These reductions

were mainly caused by the implementation of technical measures. Due to a major incidental emission there was a jump in 2012.

5.3.4 *Methodological issues*

Method 1-IP was used for estimating the emissions from other chemical industry (2B5a).

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 (please specify in the IIR)
- 2C7d Storage, handling and transport of metal products

Emissions from storage and handling by companies with main activities other than those above are assumed to be included in the relevant categories of this NFR sector.

5.4.2 *Key sources*

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

Table 5.6. Key sources of Metal production (2C)

Category / Subcategory		Pollutant	Contribution to total of 2015 (%)
2C1	Iron and Steel Production	PM ₁₀ /PM _{2.5}	4.8/6.1
		Pb	40.0
		Hg	13.0
2C5	Lead production	Hg	9.7
2C6	Zinc production	Pb	13.0

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.

The energy-related emissions are included under combustion emissions (category 1A2a) and fugitive emissions under category 1B2.

Table 5.7 provides an overview of the process emissions from the key source iron and steel production (category 2C1).

Table 5.7. Overview of emissions from the iron and steel production (2C1)

NFR Code:	2C1					
NFR NAME:	Iron and steel production					
Pollutant:	PM10	PM2,5	Pb	Hg	Dioxin	PAH's
Unit:	Gg	Gg	Mg	Mg	g I-Teq	Mg
Year						
1990	9.1	5.8	56	0.4	23	1.64
1995	4.8	3.1	58	0.3	26	1.62
2000	2.0	1.5	19	0.1	1.40	0.08
2005	1.7	1.1	23	0.2	1.40	0.06
2010	1.5	1.0	30	0.2	1.72	0.08
2014	1.2	0.8	3.4	0.1	0.16	0.06
2015	1.3	0.8	3.5	0.1	0.27	0.07

In addition to PM₁₀, PM_{2.5}, Pb and Hg (the key source pollutants), iron and steel production is also responsible for 1% of the total in dioxins and for 1% of all PAH emissions in the Netherlands. Most types of emissions from this source decreased during the 1990–2000 period. These reductions were mainly caused by the implementation of technical measures. Over the 2000–2010 period, emissions remained rather stable. Because of the replacement of electrostatic filters and the optimisation of some other reduction technologies at Tata Steel, most of the emissions decreased after 2010. Dioxin emission fluctuations were mainly caused by the varying process conditions.

Aluminium production (2C3)

Aluminium production (category 2C3) is responsible for 0.14% 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). Anode and primary aluminium producer Zalco was closed in 2011 and Aldel was closed at the end of 2013. Aldel made a restart under the name Klesch Aluminium Delfzijl by the end of 2014.

Table 5.8 provides an overview of the PAH emissions from aluminium production (category 2C3).

Table 5.8. Overview of PAH emissions from aluminium production (2C3)

NFR Code:	2C3
NFR NAME:	Aluminium production
Pollutant:	PAHs
Unit:	Mg
Year	
1990	6.909
1995	1.664
2000	0.128
2005	0.132
2010	0.108
2011	0.290
2012	0.001
2013	0.006
2014	0.006
2015	0.024

Between 1990 and 2000, PAH emissions decreased from 7 Mg in 1990 to less than 0.13 Mg in 2000. These reductions were mainly caused by the implementation of technical measures.

During the 2012-2014 period, PAH emissions decreased further to 0.006 Mg in 2014, These reductions were mainly caused by:

- the closure of one of the anode production plants ;
- installation of three modern fume treatment plants at the other production plant.

For these reasons, aluminium production (category 2C3) is no longer considered a key source of PAHs.

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

In 2015 the restart under the name Klesch Aluminium Delfzijl resulted in an increase of the PAH emissions to 0.024 Mg.

Lead production(2C5) and zinc production(2C6)

Because of the decreased Pb and Hg emissions from 2C1(Iron and steel production), lead production(2C5) is now a key source for Hg and Zinc production(2C6) for Pb. The Hg emissions from lead production(2C5) remained rather stable since 2012 while the Pb and Zn emissions from zinc production(2C6) have increased sharply after 2013. The reason for these increases is not known at this moment. Before next submission the Netherlands will try to find an explanation for this sharp increase.

5.4.4 Methodological issues

Method 1-IP was used for estimating the emissions from iron and steel production (2C1), aluminium production (2C3), lead production (2C5) and zinc production (2C6). In cases without a complete registration for the four individual PAHs, a set of specific factors was used for calculating

the emissions of the other, missing individual PAHs. These factors were obtained from the study by Visschedijk et al. (2007).

5.5 Solvents and product use (2D)

5.5.1 Source-category description

Solvents and product use consist of 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, since no activity data was available. The emissions from chemical products (category 2D3g) were included in the category of chemical industry (2B).

More than 40% of the total NMVOC emissions in the Netherlands originates from Solvents and product use (2D).

5.5.2 Key sources

The key sources of this category are presented in Table 5.10.

Table 5.10 Key sources of Solvents and product use (2D)

	Category / Subcategory	Pollutant	Contribution to total of 2015 (%)
2D3a	Domestic solvent use including fungicides	NMVOC	15.0
2D3d	Coating applications	NMVOC	14.0
2D3i	Other solvent use	NMVOC	7.1
		PM ₁₀ /PM _{2.5}	4.5/9.2
		DIOX	58.0

5.5.3 Overview of emission shares and trends

Table 5.11 gives an overview of the emissions from the key sources of this category.

Table 5.11 Overview of emission from key sources of Solvents and product use (2D)

NFR Code:	2D3a	2D3d	2D3i			
NFR NAME:	Domestic solvent use including fungicides	Coating applications	Other solvent use			
Pollutant:	NMVOG	NMVOG	NMVOG	PM ₁₀	PM _{2.5}	Dioxin
Unit:	Gg	Gg	Gg	Gg	Gg	g I-Teq
Year						
1990	12	93	15	1.9	1.9	25
1995	15	67	13	1.8	1.8	23
2000	17	41	11	1.8	1.8	20
2005	18	26	11	1.5	1.5	18
2010	20	28	11	1.5	1.5	15
2014	20	20	10	1.2	1.2	13
2015	21	19	10	1.2	1.2	13

Domestic solvent use including fungicides (2D3a)

The emission sources in this key source are:

- Cosmetics (and toiletries)
- Cleaning agents
- Car products
- Others

Figure 5.1 shows the trend in NMVOC emissions from the sources of Domestic solvent use including fungicides (2D3a).

NMVOC emissions from Domestic solvent use including fungicides (2D3a)

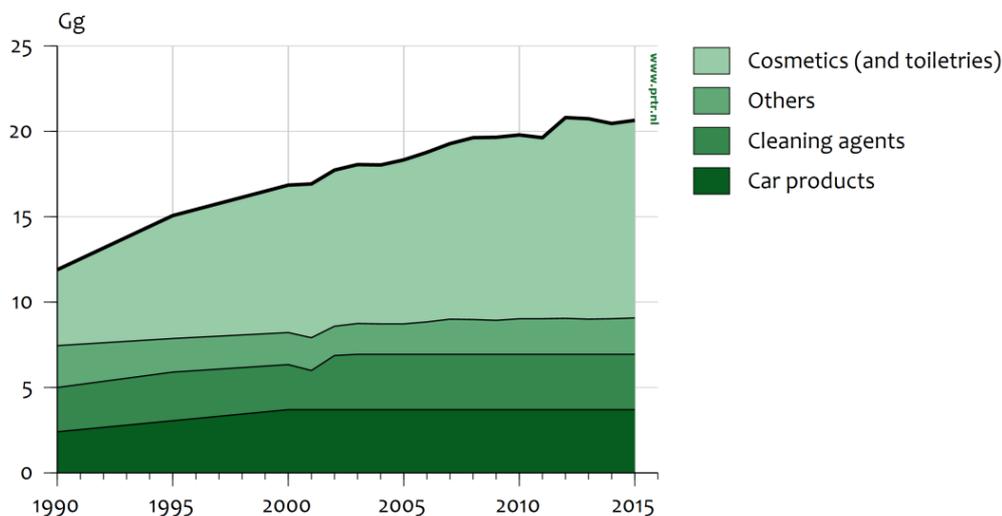


Figure 5.1 NMVOC emissions from sources of Domestic solvent use including fungicides (2D3a)

During the period 1990-2015, NMVOC emissions increased from 12 Gg in 1990 to 21 Gg in 2015. This was mainly the result of the increase in the consumption of cosmetics.

Coating applications (2D3d)

The emission sources in this key source are:

- Industrial paint applications
- Domestic use
- Construction and buildings
- Car repairing
- Boat building

Figure 5.2 shows the trend in NMVOC emissions from the sources of Coating applications (category 2D3d) over the 1990–2015 period.

NMVOC emissions from Coating applications (2D3d)

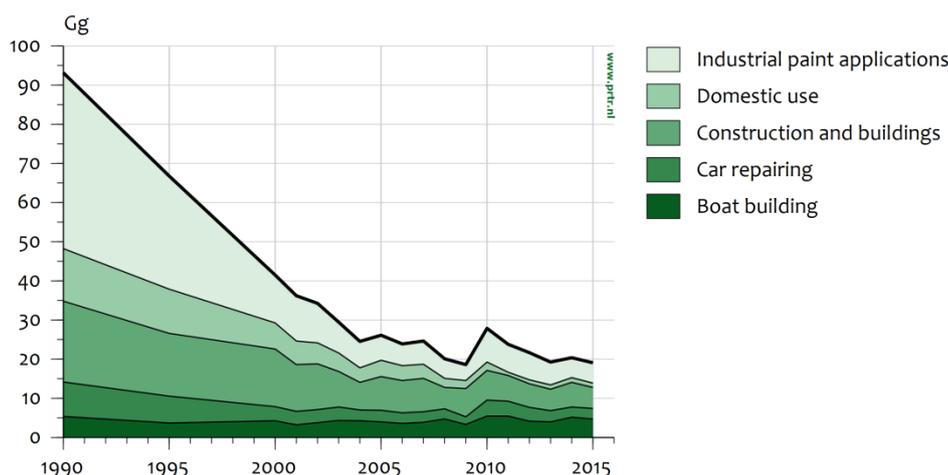


Figure 5.2 NMVOC emissions from sources of Coating applications (2D3d)

Mainly due to the lower average NMVOC content of the paints used, NMVOC emissions from Coating applications (2D3d) 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 repairing and the industry generally showed a modest recovery.

Because Car repairing and the Industry are market segments with high NMVOC levels, the total NMVOC emissions increased to 28 Gg in 2010. During the period 2010-2013 the paint consumption decreased again, which resulted in a decline of the NMVOC emissions to 19 Gg in 2013. A slight increase of the paint consumption has led to an increase in the NMVOC emissions of 1 Gg in 2014. In 2015 a lower NMVOC content of the paints resulted in a decrease of the NMVOC emissions.

Other solvent use (2D3i)

As already mentioned in 5.1 the 2016 Guidebook is not clear in which sources belong to 2G. Therefore 2G is included in 2D3i.

The most important NMVOC sources are cleaning agents and refrigerants. NMVOC emissions in this category decreased from 15 Gg in 1990 to 10 Gg in 2015. 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 13 g I-TEQ in 2015.

The most important source of PM₁₀ and PM_{2.5} emissions (76% of the emissions) in 2D3i is Smoking of cigarettes. As a result of the drop in the number of cigarettes smoked, the emission of 2D3i decreased from 1.9 Gg in 1990 to 1.2 Gg in 2015.

5.5.4 *Activity data and (implied) emission factors***Domestic solvent use including fungicides (2D3a)**

Sales data of 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 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). The total paint consumption decreased from 197 kton in 1990 to 153 kton in 2015 and the NMVOC content from 30% in 1990 to almost 13% in 2011. During the 2012-2014 period the NMVOC content remained rather stable. In 2015 the NMVOC content decreased further to 12%.

Other solvent use (2D3i)

Sales data of 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 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***Domestic solvent use including fungicides (2D3a)**

Total NMVOC emissions per product 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 air by the NMVOC content of the product.

Coating applications (2D3d)

NMVOC emissions from paint use were calculated from national statistics on annual paint sales (of paint that was both produced and sold within the Netherlands), provided by the Dutch Paint and Ink Producers Association (VVVF) and VVVF estimations on imported paints. The VVVF, through its members, directly monitors NMVOC in domestically produced paints, and estimates the NMVOC content in imported paints. Estimates have also been made for the use of flushing agents and the reduction

effect of afterburners. For more information, see methodology report ENINA (ENINA, 2016).

Other solvent use (2D3i)

Total NMVOC emissions per product 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 air by the NMVOC content of the product.

5.5.6 *Source-specific recalculations*

Coating applications (2D3d)

Some errors were detected and corrected for several years. This has resulted in small NMVOC emission changes during the 2000-2014 period.

5.6 Other Production Industry (2H)

5.6.1 *Source-category description*

This category comprises emissions related to the following sources:

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

5.6.2 *Key sources*

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

Table 5.13 Key sources of Other Production Industry (2H)

	Category / Subcategory	Pollutant	Contribution to total of 2015 (%)
2H2	Food and beverages industry	NMVOC	2.9
		PM ₁₀ /PM _{2.5}	6.8/2.6
2H3	Other industrial processes	NMVOC	7.3
		PM ₁₀ /PM _{2.5}	9.9/5.3
		Pb	5.3

5.6.3 *Overview of emission shares and trends*

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

Table 5.14 Overview of emission from the key sources of Other Production Industry (2H)

NFR Code:	2H2		2H3			
NFR NAME:	Other industrial processes					
Pollutant:	PM₁₀	PM_{2.5}	NMVOC	PM₁₀	PM_{2.5}	Pb
Unit:	Gg	Gg	Gg	Gg	Gg	Mg
Year						
1990	4.3	0.8	25	5.4	1.6	0.34
1995	2.3	0.4	13	3.1	0.8	0.28
2000	1.8	0.3	6	3.2	0.9	0.16
2005	1.8	0.3	10	2.7	0.7	0.004
2010	1.6	0.3	11	2.6	0.7	0.004
2014	1.7	0.3	10	2.4	0.6	0.02
2015	1.7	0.3	10	2.5	0.7	0.46

Food and beverages industry (2H2)

From 1990 to 2015, PM₁₀ emissions decreased from 4.3 to 1.7 Gg. These reductions were mainly caused by the implementation of technical measures.

Other industrial processes (2H3)

The 2H3 subcategory in the Dutch PRTR includes emissions from the storage and handling of bulk products and from many other different activities. Only companies with 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 the above are assumed to be included in the relevant categories of this NFR sector.

From 1990 to 2015, NMVOC emissions decreased from 25 Gg to 10 Gg. The contribution of storage and handling of liquid bulk products was 15 Gg in 1990 and 8 Gg in 2015.

Figure 5.3 shows the trend in PM₁₀ emissions from storage and handling of dry bulk products over the 1990–2015 period.

PM₁₀ emissions from the storage and handling of dry bulk products

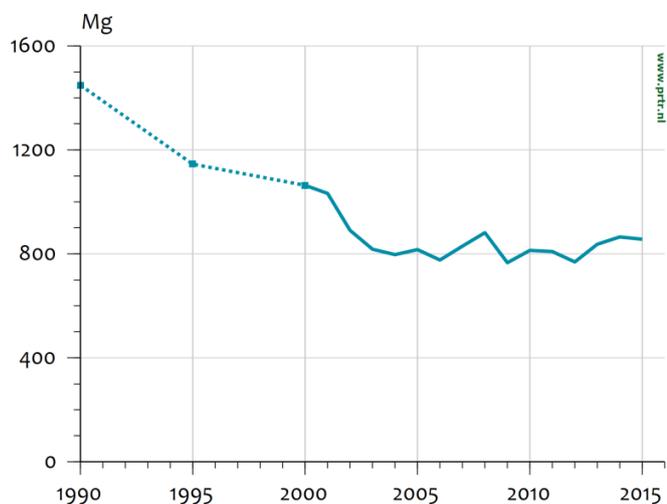


Figure 5.3 Storage and handling of dry bulk products: trend and emissions of PM₁₀

PM₁₀ emissions decreased from 5.4 Gg to 2.5 Gg during the 1990–2015 period. The contribution of storage and handling of dry bulk products was 1.4 Gg in 1990 and 0.9 Gg in 2015. Reductions in NMVOC and PM₁₀ emissions were mainly caused by the implementation of technical measures. After 2005, PM₁₀ emission fluctuations were caused by the varying amounts of handling products.

By the addition of a new company to the list of individual companies lead(Pb) emissions increased in 2015.

5.6.4 Methodological issues

Method 2-IP was used for estimating the emissions from the production of food and drink (category 2H2).

Method 1-IP was used for estimating particulate matter (PM) emissions from storage and handling of 2H3; Method 2-IP was used for estimating all other emissions of 2H3.

5.6.5 Source-specific recalculations

Food and beverages industry (2H2)

As a result of a reallocation of some sources from 1A2e to 2H2 NMVOC, TSP, PM₁₀ and PM_{2.5} emissions have been changed for the whole time series.

Other industrial processes (2H3)

Due to a reallocation of some sources from 1A1a, 1A4ai and 1A2gviii to 2H3 NMVOC, TSP, PM₁₀ and PM_{2.5} emissions have been changed for the whole time series.

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 of '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
- 3I Agriculture other

The Netherlands did not allocate emissions to category 3I. As field burning of agricultural residues is prohibited by law, emissions in category 3F did not occur. This Informative Inventory Report (IIR) focuses on emissions of ammonia (NH₃), nitrogen oxides (NO_x), non-methane volatile organic compounds (NMVOC), particulate matter (PM₁₀, PM_{2.5}) and zinc (Zn) from the NFR source categories 3B Manure management and 3D Crop production and agricultural soils. Emissions of the greenhouse gases methane (CH₄), nitrous oxide (N₂O) and carbon dioxide (CO₂) from the agricultural sector were reported in the annual National Inventory Report (NIR). All emissions were calculated according to the methods described in Vonk *et al.* (2016).

In 2015 the agricultural sector was responsible for 88% of all NH₃ emissions in the Netherlands. Emissions of NO_x from animal housing and manure storage contributed to 2% of the national total. In accordance with the EMEP Guidebook NO_x emissions from applied manure, inorganic fertilizer and manure produced during grazing were reported as memo-items under category 11C natural emissions. NMVOC emissions from the handling of manure were not estimated; NMVOC emissions from crop production played a minor role in the national total (0.1%).

Agriculture accounted for 24% of the national PM₁₀ emission. Animal houses produce a relatively large amount of PM₁₀ compared to PM_{2.5}. Therefore the contribution of PM_{2.5} from agriculture to the national total is only 5%. Although zinc is not a priority heavy metal emissions from drift following pesticide use are reported for completeness.

The Netherlands used an N-flow model to calculate N-emissions. Figure 6.1 presents a schematic overview of NH₃ and NO_x emissions from NFR sectors 3B and 3D, in relation to the N-flows.

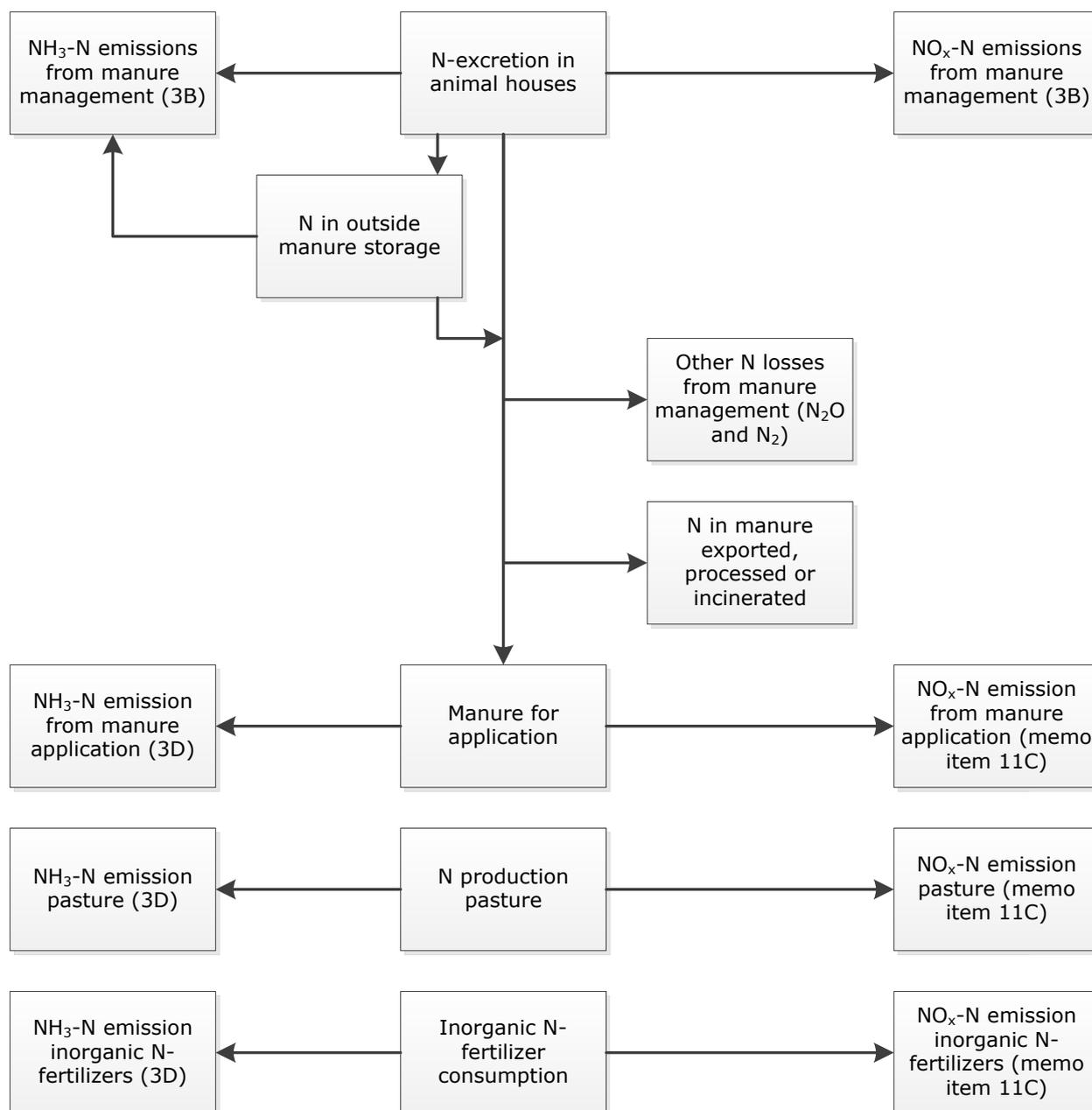


Figure 6.1 Nitrogen flows in relation to NH_3 and NO_x emissions

6.1.1 Key sources

According to the key source analysis the four main key sources for NH_3 emission from agriculture were:

- 3Da2a Animal manure applied to soils
- 3B1a Dairy cattle
- 3B3 Swine
- 3Da1 Inorganic N-fertilizers

To explain more than 80% of the national total NH_3 emission according to EMEP requirement, the NFR categories 3B1b Non-dairy cattle and 3B4gi Laying hens needed to be included in the key source analysis.

The NFR category 6A Other is also a key source and contributed 6% to the national total. Sector 6A included the emissions from privately owned horses and from application of inorganic N-fertilizer, animal manure and compost outside agriculture. Calculation methods for these emissions are similar to the methods described in this chapter.

For PM₁₀ emissions from agriculture the key source were:

- 3B4gi Laying hens
- 3B4gii Broilers
- 3B3 Swine
- 3Dc Farm-level agricultural operations including storage, handling and transport of agricultural products

For emissions of PM_{2.5} and NO_x the agricultural sector contained no key sources.

6.1.2 Trends

NH₃ emissions decreased between 1990 and 2015, with a significant reduction in the first few years of the time-series. A ban on surface spreading of manure was enforced in 1991, making it mandatory to incorporate manure into the soil either directly or shortly after application. To a large extent, this reduced the emission of NH₃ from the application of animal manure. In addition, it became mandatory to cover manure storages. More recently the introduction of low-emission housing of animals further decreased ammonia emissions.

Maximum application standards for manure and fertilizer and systems of production rights promoted efficiency. For example, milk quota led to increased feeding of maize to dairy cattle to increase production per cow. Increased production per animal led to a decrease in animal numbers and consequently lower emissions. Another example was the ongoing improvement in nutritional management where a reduction of dietary crude protein resulted in lower N excretions per animal, and consequently reduced NH₃ emissions.

The N excreted by animals decreased considerably between 1990 and 2015, while the amount of manure exported or incinerated increased fivefold. Other N losses from animal housing and nitrogen in manure outside agriculture also increased, leading to 26 percent less nitrogen in manure to be applied on agricultural soils. Since the other N losses from animal housing also comprised washing liquid of air scrubbers which was used as an inorganic N-fertilizer, some emissions shifted to category 3D Crop production and agricultural soils. The same applied for nitrogen in manure used outside agriculture, as those emissions were allocated to category 6A Other. Since most of the NH₃ emissions originated from the agricultural sector, the decreasing trend in NH₃ emission from agriculture also showed in the decreasing trend of the national total.

Particulate matter

Although PM emissions for most animal categories decreased slightly over the 1990–2015 period due to decreased animal numbers, the PM emissions in laying hens almost quadrupled for PM₁₀ and more than doubled for PM_{2.5}. This was caused by a shift from battery cage systems with liquid manure to ground housing or aviary systems with solid

manure and higher associated emission factors for PM₁₀ and PM_{2.5}. This graduate transition between 1990 and 2012 was initiated by a ban on battery cage systems in 2012.

6.2 Manure management

6.2.1 *Source category description*

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

- 3B1a Dairy cattle
- 3B1b Non-dairy cattle
- 3B2 Sheep
- 3B3 Swine
- 3B4a Buffalo
- 3B4d Goats
- 3B4e Horses
- 3B4f Mules and asses
- 3B4gi Laying hens
- 3B4gii Broilers
- 3B4giii Turkeys
- 3B4giv Other poultry
- 3B4h Other animals

Animals in the category 3B4a (Buffalo) did not occur in the Netherlands. Emissions from the category 3B4giv (Other poultry) included the emissions from ducks. Under category 3B4h (Other animals) rabbits and furbearing animals were being reported. Contrary to previous IIR-reports, emissions from pets were reported in category 6A Other from IIR2017 onwards.

Emissions resulting from the application of animal manure or during grazing were considered to be related to land use and are not reported under 3B Manure management, but included in 3D Crop production and agricultural soils.

6.2.2 *Key sources*

Within sector 3B dairy cattle (NFR category 3B1a) had the largest contribution to NH₃ emissions with 15% of the national total. Swine (NFR category 3B3, 11%), non-dairy cattle (NFR category 3B1b, 8%) and laying hens (NFR category 3B4gi, 6%) were also NH₃ key sources.

Within sector 3B laying hens (NFR category 3B4gi) were the largest source for PM₁₀ emissions, with 11% of the national total. Broilers (NFR category 3B4gii; 5%) and swine (NFR category 3B3; 4%) were also key categories for PM₁₀. For emissions of PM_{2.5} and NO_x the agricultural sector contained no key sources.

6.2.3 *Overview of emission shares and trends*

Table 6.1 presents an overview of emissions of the main pollutants NO_x and NH₃, together with the emissions of PM₁₀ and PM_{2.5} originating from sector 3B Manure management.

Table 6.1 Emissions of main pollutants and particulate matter from sector 3B
Manure management

Year	Main Pollutants		Particulate Matter	
	NO _x	NH ₃	PM _{2.5}	PM ₁₀
	Gg	Gg	Gg	Gg
1990	3.7	99	0.4	4.1
1995	3.7	97	0.4	4.1
2000	3.0	77	0.4	4.6
2005	2.8	65	0.4	4.6
2010	3.0	64	0.5	5.2
2014	3.1	55	0.5	5.6
2015	3.2	55	0.5	5.7
1990-2015 period ¹⁾	-0.6	-44	0.1	1.6
1990-2015 period ²⁾	-15%	-44%	14%	39%

¹⁾ Absolute difference in Gg

²⁾ Relative difference to 1990 in %

Between 1990 and 2015, NH₃ emissions from manure management reduced by 44%. Higher production rates per animal and restriction by quotas resulted in a decreasing trend in animal numbers of cattle, sheep and swine. N excretions per animal decreased in the time series due to lower dietary crude protein for all animal categories except cattle. Furthermore NH₃ emissions decreased due to the increased share of low-emission housing. As NO_x emissions were also influenced by the above mentioned developments, NO_x emissions decreased with 15% from 1990 to 2015.

PM emissions from animal housing showed an increasing trend in the time series which is caused mainly by the increased share of solid manure housing systems in poultry. The increased available floor space per animal added to this effect.

6.2.4 Activity data and (implied) emission factors

Basic input data include animal numbers as determined by the annual agricultural census (see the summary in Table 6.2, and Van Bruggen *et al.* (2017) for a full overview of subcategories and years). For horses, an estimated 300 000 additional animals were included in the inventory, to account for privately owned animals. The emissions of NH₃ and PM resulting from the Manure management of these animals were calculated using NEMA, but were reported under the source category Other (6A).

Table 6.2 Animal numbers in 1990-2015 (x 1,000)

Animal type	1990	1995	2000	2005	2010	2013	2014	2015
Cattle	4,926	4,654	4,069	3,797	3,975	3,999	4,068	4,134
<i>dairy cattle</i>	1,878	1,708	1,504	1,433	1,479	1,553	1,572	1,622
<i>non-dairy cattle</i>	3,048	2,946	2,565	2,364	2,497	2,446	2,496	2,512
Sheep	1,702	1,674	1,305	1,361	1,130	1,034	959	946
Swine	13,915	14,397	13,118	11,312	12,255	12,212	12,238	12,603
Goats	61	76	179	292	353	413	431	470
Horses ¹	70	100	117	133	141	129	126	117
Mules and asses	NO	NO	NO	NO	1	1	1	1
Poultry	94,902	91,637	106,517	95,190	103,371	99,370	104,685	108,558
<i>laying hens</i>	51,592	45,734	53,078	48,418	56,500	53,477	56,019	57,656
<i>broilers</i>	41,172	43,827	50,937	44,496	44,748	44,242	47,020	49,107
<i>turkeys</i>	1,052	1,207	1,544	1,245	1,036	841	794	863
<i>other poultry</i>	1,086	869	958	1,031	1,087	810	853	932
Other animals	1,340	951	981	1,058	1,261	1,342	1,324	1,404

¹ excluding privately owned horses

Source: CBS, 2017

Animal numbers were distributed over the various housing types using information from the agricultural census. If required, additional data from environmental permits was used (Van Bruggen *et al.*, 2017). For instance, the agricultural census only gave implementation grades of abatement techniques in a very general manner (e.g. floor/cellar adaptation or air scrubber). Further subdivision was possible with detailed information from environmental permits.

N-emission calculations

Emissions of NH₃ and NO_x from animal manure in animal houses and storage were calculated using the National Emission Model for Agriculture (NEMA) at a Tier 3 level. The N excretions per animal were calculated annually by the Working group on Uniformity of calculations of Manure and mineral data (WUM). The historic data were recalculated in 2009 (CBS, 2012a) and supplemented yearly by means of the publication series 'Dierlijke mest en mineralen' (Animal manure and minerals, in Dutch) ensuring consistency.

The total ammonia nitrogen (TAN) in manure was estimated using faecal digestibility of the N in various feed components within the rations. From N excretion data the TAN-excretion per housing type and corresponding NH₃ emission factor was calculated, taking into account mineralisation and immobilisation. The Tier 1 default N₂O emission factors from the IPCC 2006 Guidelines were applied for both N₂O and NO_x emissions, following research from Oenema *et al.* (2000) that set the ratio of these losses to 1:1. According to this same study, N₂ losses were set to a factor 5 (solid manure) or 10 (liquid manure) of the N₂O/NO_x factors, all expressed as percentages of the total N available.

NH₃ emissions and other N losses of N₂O, NO_x and N₂ from animal housing were calculated and subtracted from the excreted N. The amount of manure that was stored and the corresponding NH₃ emissions from storage were calculated. The sum of emissions from both animal

housing and manure storage per livestock type were reported under their respective subcategories in sector 3B Manure management. After subtracting all N losses during manure management, the net export and processing and incineration of manure, the amount of N available for application was calculated (as used for calculating emissions from manure application and from grazing, allocated to sector 3D).

The NH₃ emission per animal reduced for all animal species due to improved efficiency. However, in cattle this effect was countered by an increased living space per animal which resulted in a net increase in cattle IEF. Although living space per animal was also increased in swine and poultry, emission reduction techniques like air scrubbers and manure drying more than countered the effect. The fluctuating N-content of grass silage caused yearly changes in the IEF of cattle. Implied emission factors for NH₃ emissions in sector 3B Manure management were calculated for the main NFR categories and presented in Table 6.3.

Table 6.3 Implied emission factors for NH₃ from sector 3B Manure management (in kg NH₃/animal)

Animal type	1990	1995	2000	2005	2010	2013	2014	2015
Cattle	6.6	6.7	5.7	6.3	6.7	6.5	7.1	7.1
- dairy cattle	11.6	11.8	9.6	11.4	11.8	10.9	11.7	11.7
- non-dairy cattle	3.5	3.7	3.4	3.2	3.7	3.7	4.2	4.1
Sheep	0.4	0.4	0.4	0.2	0.1	0.1	0.1	0.1
Swine	3.5	3.4	2.7	2.2	1.9	1.2	1.1	1.1
Goats	1.6	1.6	1.4	1.2	1.2	1.1	1.2	1.3
Horses ¹	4.5	4.5	4.5	4.3	4.0	4.0	4.0	4.0
Mules and asses	NO	NO	NO	NO	2.8	2.8	2.8	2.8
Poultry	0.17	0.18	0.16	0.15	0.13	0.11	0.10	0.10
- laying hens	0.19	0.20	0.19	0.17	0.16	0.15	0.15	0.14
- broilers	0.13	0.13	0.11	0.11	0.07	0.05	0.04	0.04
- turkeys	0.80	0.79	0.72	0.61	0.60	0.64	0.61	0.62
- other poultry	0.31	0.30	0.28	0.25	0.21	0.20	0.19	0.19
Other animals	0.40	0.38	0.32	0.28	0.22	0.22	0.23	0.24

¹ excluding privately owned horses

NO_x emissions from denitrification processes in animal manure were not considered as a source when the National Emission Ceiling (NEC) was set. However, the NO_x emissions from animal housing and storage were included in the national total, as they were deemed non-natural.

Particulate matter

Emissions of PM₁₀ and PM_{2.5} from agriculture mainly consisted of animal skin, manure, feed and bedding particles originating from animal housings. The general input data used for these calculations were animal numbers and housing systems taken from the annual agricultural census and environmental permits.

Country specific emission factors for PM emissions from animal housing were derived from a measurement programme conducted by Wageningen UR Livestock Research. For several livestock categories and animal housing types, PM₁₀ and PM_{2.5} emissions were determined and consequently published in the 'Fijnstofemissie uit stallen' series ('Dust

emission from animal houses', in Dutch with English summary and available through www.asg.wur.nl). For housing types not included in the studies, emission factors were estimated on housing characteristics and space per animal proportional to the studied housing types. Where emission factors had to be derived within animal categories (e.g. laying hens under and over 18 weeks of age), the excreted amount of phosphorus was used. An overview of the resulting emission factors was presented in Vonk *et al.*, 2016. Implied emission factors for PM₁₀ and PM_{2.5} were given in Table 6.4 and Table 6.5.

Table 6.4 Implied emission factors for PM₁₀ from sector 3B Manure management (in g PM₁₀/animal)

Animal type	1990	1995	2000	2005	2010	2013	2014	2015
Cattle	85	83	78	79	78	79	79	80
- dairy cattle	115	115	115	120	124	125	126	127
- non-dairy cattle	67	64	57	54	51	50	50	50
Sheep	NE							
Swine	113	112	112	110	104	83	81	77
Goats	19	19	19	19	19	19	19	19
Horses ¹	220	220	220	220	220	220	220	220
Mules and asses	NO	NO	NO	NO	160	160	160	160
Poultry	22	23	26	32	35	42	41	40
- laying hens	15	16	23	34	39	53	52	50
- broilers	27	27	27	27	27	26	26	26
- turkeys	100	98	95	95	95	95	95	95
- other poultry	105	105	105	105	105	105	105	105
Other animals	4	5	5	6	7	7	6	6

¹ excluding privately owned horses

Table 6.5 Implied emission factors for PM_{2.5} from sector 3B Manure management (in g PM_{2.5}/animal)

Animal type	1990	1995	2000	2005	2010	2013	2014	2015
Cattle	24	23	22	22	21	22	22	22
- dairy cattle	32	32	32	33	34	35	35	35
- non-dairy cattle	19	18	16	15	14	14	14	14
Sheep	NE							
Swine	6	6	6	5	5	4	4	4
Goats	6	6	6	6	6	6	6	6
Horses ¹	140	140	140	140	140	140	140	140
Mules and asses	NO	NO	NO	NO	100	100	100	100
Poultry	2	2	3	3	3	3	3	3
- laying hens	1	1	2	2	2	3	3	3
- broilers	2	2	2	2	2	2	2	2
- turkeys	47	46	45	45	45	45	45	45
- other poultry	5	5	5	5	5	5	5	5
Other animals	2	2	3	3	3	3	3	3

¹ excluding privately owned horses

6.2.5 Uncertainties and timeseries consistency

A propagation of error analysis on NH₃ emissions was performed in 2015. Using reassessed uncertainty estimates of input data (CBS, 2012) and expert judgement, an uncertainty of 16% in the total NH₃ emission from sector 3B Manure management was calculated. Including the emissions in sector 3D Crop production and agricultural soils, the

combined uncertainty in NH₃ emission from the agriculture sector was 20%. A Monte Carlo-analysis on uncertainties is planned for 2017.

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

6.2.6 *Source-specific QA/QC and verification*

This source category is covered in Chapter 1, under general QA/QC procedures.

6.2.7 *Source-specific recalculations*

In previous IIR reports the emissions of turkeys and ducks were included in the emissions of broilers. In line with the UNECE stage 3 review of the IIR2015, these emissions were reported separately in the IIR2017, in their specific NFR categories 3B4giii (turkeys) and 3B4giv (other poultry).

For PM an error was corrected in the emission factor of horses and mules and asses. In the calculation of swine emissions also an error was corrected. In total these corrections led to a net increase of 1% in PM₁₀ and 1% in PM_{2.5} in 2014.

6.2.8 *Source-specific planned improvements*

An update of the emission factors for NH₃ emissions from poultry housing is planned in sector 3B manure management for the next submission. Furthermore, a study on the TAN excretion of cattle will be performed in 2017 which may lead to adjustments of all N-emissions from cattle.

6.3 Crop production and agricultural soils

6.3.1 *Source category description*

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

- 3Da1 Inorganic N-fertilizers
- 3Da2a Animal manure applied to soils
- 3Da2b Sewage sludge applied to soils
- 3Da2c Other organic fertilizers 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

Emissions within the categories 3Db and 3Dd do not occur in the Netherlands. Category 3Dc contains PM emissions from the use of inorganic N-fertilizers and pesticides, the supply of concentrate feed to farms, haymaking and crop harvesting. NMVOC emissions are allocated to category 3De and zinc emissions to category 3Df.

6.3.2 Key sources

Within sector 3D animal manure applied to soils (3Da2a) was the largest key source for NH₃ emissions with 30% of the national total. Inorganic N-fertilizers (3Da1) also was a key source of NH₃ with a contribution of 9%.

Within sector 3D farm-level agricultural operations including storage, handling and transport of agricultural products (3Dc) was a key source for PM₁₀ emissions at 2% of the national total. For emissions of PM_{2.5} and NO_x the agricultural sector contained no key sources.

6.3.3 Overview of shares and trends in emissions

Table 6.6 presents an overview of emissions of the main pollutants NH₃, NMVOC and NO_x, together with the particulate matter fractions PM₁₀ and PM_{2.5} and the other heavy metal Zn that originated from sector 3D crop production and agricultural soils (3D).

Table 6.6 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
	NO _x	NMVOC	NH ₃	PM _{2.5}	PM ₁₀	Zn
	Gg	Gg	Gg	Gg	Gg	Mg
1990	0.3	0.2	250	0.1	0.8	0
1995	0.4	0.2	112	0.1	0.8	0
2000	0.4	0.2	84	0.1	0.8	0
2005	0.4	0.2	72	0.1	0.8	6.8
2010	0.3	0.2	53	0.1	0.8	4.5
2014	0.3	0.2	56	0.1	0.7	4.4
2015	0.3	0.2	56	0.1	0.7	4.4
1990-2015 period ¹⁾	0.0	0.0	-194	0.0	0.0	4.4
1990-2015 period ²⁾	16%	12%	-78%	-3%	-4%	

¹⁾ Absolute difference in Gg

²⁾ Relative difference to 1990 in %

N-emissions

Emissions of NH₃ decreased with 78% between 1990 and 2015, with an initial sharp 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). Also the use of inorganic N-fertilizer decreased during the time series, following policies aimed at reducing the nutrient supply to soils.

NO_x emissions from sector 3D were not accounted for under the NEC. Therefore emissions from animal manure application, inorganic N-fertilizer use and grazing were reported as a memo item under the category of Other natural emissions (11C, see also section 6.2.3). Only NO_x emissions from sewage sludge and compost were reported under category 3D. Increased amounts of applied compost and decreased amounts of applied sewage sludge resulted in an overall increasing trend in NO_x emissions.

Particulate matter

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

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

N-emission calculations

For N-emission calculations in sector 3D activity data were calculated from N-excretion from sector 3B minus N-emissions from housing and storage. After subtracting the N in manure removed from agriculture (either exported or incinerated), the remaining N was allocated to pasture and arable land. Implementation grades of application techniques were derived from the agricultural census. The associated NH₃ emission factors were reported in Vonk *et al.* (2016). NO_x emissions related to manure and fertilizer application and grazing of animals were calculated using the EMEP default factor and reported as memo item in category 11C. For compost use and sewage sludge application also NO_x emissions were calculated using the default EMEP emission factor and reported in sector 3D.

Ammonia emissions from the use of inorganic N-fertilizers were calculated using data on the amount of inorganic N-fertilizer used in agriculture. Several types of inorganic N-fertilizer were distinguished – each with a specific NH₃ emission factor. These emission factors were used in NEMA to calculate NH₃ emissions from inorganic N-fertilizers. In recent years the amount of applied urea fertilizer increased and a growing share is coated with urease inhibitors to reduce NH₃ emissions, and/or is applied with NH₃ low-emission techniques. To account for this development, additional subcategories of urea fertilizer were specified for the 1990-2015 time series, in addition to the methodology report of Vonk *et al.* (2016). The used subgroups and the emission factors for each subgroup have been published in Van Bruggen *et al.* (2017).

Calculations of NH₃ emissions from crop residues and crops ripening were based on activity data from the agricultural census. Emission factors originated from research of De Ruijter *et al.* (2013).

Implied emission factors for sector 3D in kg NH₃/kg N supply were calculated for the NFR categories as depicted in Table 6.7. Implied emission factors for animal manure and sewage sludge application dropped considerably between 1990 and 1995 due to mandatory incorporation into the soil. The reduction in emission from urine and

dung deposited by grazing animals was mainly explained by less grazing cattle.

Table 6.7 Implied emission factors for NH₃ from 3D Crop production and agricultural soils (in kg NH₃/kg N supply)

Emission source	1990	1995	2000	2005	2010	2013	2014	2015
Application of inorganic N-fertilizers	0.04	0.04	0.04	0.05	0.04	0.04	0.05	0.05
Application of animal manure	0.54	0.20	0.19	0.19	0.14	0.13	0.14	0.13
Application of sewage sludge	0.29	0.08	0.09	0.10	0.10	0.09	0.10	0.10
Application of other organic fertilizers (compost)	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
Urine and dung deposited by grazing animals	0.09	0.09	0.04	0.04	0.03	0.03	0.03	0.03
Crop residues	0.09	0.09	0.07	0.05	0.06	0.06	0.06	0.05
Crop ripening	NA							

Particulate matter

Small sources of PM₁₀ and PM_{2.5} emissions reported under category 3D were application of inorganic N-fertilizers and pesticides, the supply of concentrate feed to farms and haymaking. For calculations of PM emissions both EMEP default and country specific emissions factors were applied. PM from other agricultural processes (e.g. the supply of concentrate feed to farms, use of pesticides and haymaking) was estimated using fixed amounts (Van der Hoek, 2002). Crop harvesting was calculated based on acreage from the agricultural census and EMEP default emission factors. An overview was given in Table 6.8.

Table 6.8 Emission factors for PM₁₀ and PM_{2.5} from 3D Crop production and agricultural soils

Emission factor (kg/ha)	PM ₁₀	PM _{2.5}
Wheat	1.49	0.21
Barley	1.25	0.17
Rye	1.15	0.15
Oats	1.78	0.25
Other crops	0.25	0.02
Added estimate (ton/year)	PM ₁₀	PM _{2.5}
Haymaking	6	1.2
Supply of concentrates	90	18
Supply and use of fertilizers	105	21
Use of pesticides	125	25

6.3.5 Uncertainties and timeseries consistency

A propagation of error analysis on NH₃ emissions was performed in 2015. Using reassessed uncertainty estimates of input data (CBS, 2012) and expert judgment, an uncertainty of 31% was calculated for NH₃ emissions following animal manure application, 16% for inorganic N-fertilizer use and 100% for grazing emissions. Total uncertainty in the ammonia emissions from sector 3D Crop production and agricultural soils then amounts to 30%. Including the emissions in sector 3B Manure management, the combined uncertainty in NH₃ emission from agriculture is 20%. A Monte Carlo-analysis on uncertainties is planned for 2017.

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

6.3.6 *QA/QC and verification*

This source category is covered in Chapter 1, under general QA/QC procedures.

6.3.7 *Recalculations*

In recent years ammonia emissions after application of inorganic N-fertilizers increased due to an increased amount of urea fertilizer applied to soils. The fertilizer industry developed new inorganic urea fertilizers with special coatings to reduce N-losses. Additionally application methods changed which reduced ammonia emissions from urea fertilizer. In 2016 a study was performed on the emission factors of these new urea fertilizers. Within NEMA more subcategories of urea fertilizer were specified. The used subgroups and emission factors of each subgroup have been published in an annex to Van Bruggen *et al.* (2017).

The NH₃ emissions from inorganic fertilizers were recalculated for the whole time series. As the share of low-emission urea fertilizers increased in recent years the emission reduction from implementation of the new emission factors was largest in recent years. The recalculation led to a decrease of about 4 Gg from 2008 onwards (from 13.6 to 10.2 Gg NH₃ in 2014). As NEMA was also used to calculate the emissions from the use of fertilizers by consumers and private parties, emissions in sector 6A were also recalculated leading to a decrease of 0.3 Gg NH₃ in 2014.

In the previous submission activity data for sewage sludge and compost use in 2014 were not yet available. Therefore the activity data of 2013 was copied to 2014. As activity data for sewage sludge and compost in 2014 became available, emissions of these sources were recalculated for 2014.

6.3.8 *Planned improvements*

The current inventory report only included NO_x emissions from housing and storage in the reported national totals. NO_x emissions from the application of inorganic N-fertilizer or animal manure and manure produced on pasture were also assessed, but were reported as a memo item under the category of natural emissions (11C). This categorisation will be reconsidered as soon as emission ceilings also account for these emission sources.

Newly applied techniques for manure processing such as anaerobic digestion and separation of manure are currently studied. The share of processed manure in the Netherlands is increasing. A new methodology to estimate emissions (or emission reductions) from processing of manure is planned to be implemented in the next submission.

7 Waste (NFR 5)

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 from this source category comprise those from landfills and from extracted landfill gas. Since the extracted landfill gas is mostly used for energy purposes, these emissions are allocated to the energy sector (source category Other Stationary (1A5a)).

Composting and anaerobic digestion (5B)

Emissions from this source category comprise those from facilities for composting and/or fermenting of separately collected organic waste for composting and/or biogas production. During processing relevant emissions of NH₃, SO_x and NO_x occur. The produced biogas is used for energy purposes, these emissions are allocated to the energy sector (source category Small combustion (1A4)).

Waste incineration (5C)

Emissions from this source category comprise from municipal, industrial, hazardous and clinical waste incineration, 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 sector on energy (source category Public electricity and heat production (1A1a)).

NO_x and SO_x emissions from cremations (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 annual environmental reports by individual treatment plants/companies. WWTPs produce methane, amongst others. Around 80% of this methane is captured and is either used in energy production or is flared. For this reason, the WWTP emissions are reported under the source category Commercial/Institutional: Stationary (1A4ai).

Other waste (5E)

The emissions from the Other waste source category comprise those from "Waste preparation for recycling and Scrap fridges/freezers".

7.1.1 Key sources

There are no relevant key sources in the Waste sector.

7.1.2 Overview of shares and trends in emissions

An overview of the trends in emissions is shown in Table 7.1. Emissions coming from the waste sector are low. This is mainly because most emissions coming from incineration are reported under the Energy sector.

Emissions have reduced since 1990 for most pollutants. However, with the exception of NMVOC all pollutants show lower emissions in 1990. For NH₃ this is mainly caused by an increase of industrial composting of household organic waste in the years 1990-1994. For all other pollutants this is caused by a combination of increased activity and gradual implementation of abatement technology.

Table 7.1 Overview of emission totals in the Waste sector (NFR 5)

Year	Main Pollutants		Particulate Matter			Heavy Metals/POPs	
	NMVOC	NH ₃	TSP	PM _{2.5}	PM ₁₀	Hg	DIOX
	Gg	Gg	Gg	Gg	Gg	Mg	g I-Teq
1990	1.5	0.05	0.006	0.006	0.006	0.06	0.00
1995	1.3	0.31	0.013	0.010	0.012	0.07	0.30
2000	1.0	0.32	0.007	0.007	0.007	0.10	0.27
2005	0.7	0.34	0.006	0.006	0.006	0.09	0.25
2010	0.5	0.25	0.003	0.003	0.003	0.05	0.09
2014	0.4	0.23	0.003	0.001	0.001	0.01	0.02
2015	0.4	0.22	0.004	0.001	0.001	0.01	0.02
1990-2015 period ¹⁾	-1.1	0.19	-	-0.005	-0.005	-0.04	0.02
1990-2015 period ²⁾	-73%	417%	-33%	-83%	-83%	79%	-

¹⁾ Absolute difference

²⁾ Relative difference to 1990 in %

7.1.3 Methodological issues

There are no specific methodological issues.

7.1.4 Uncertainties and timeseries consistency

No accurate information was available for assessing uncertainties on emissions from sources in this sector.

7.1.5 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.

7.1.6 Source-specific recalculations

There were no source-specific recalculations in this sector.

7.1.7 Source-specific planned improvements

There are no source-specific planned improvements.

7.2 Solid waste disposal on land (5A)

7.2.1 Source-category description

The source category of Solid waste disposal on land (5A) comprises the direct emissions from landfills and from captured landfill gas. Extracted landfill gas is mainly used as an energy source and a relative small amount is flared. As such the emissions from this source are included in the energy sector (source category Other Stationary (1A5a)).

In this source category all waste landfill sites in the Netherlands are included that have been managed and monitored since 1945, and concerns both historical and current public landfill, plus waste landfill sites on private land. These waste sites are considered to be responsible for most of the emissions from this source category.

The total amount of landfill gas produced in the Netherlands is calculated using a first-order degradation model which calculates the degradation of DOC (degradable organic carbon) in the waste. From this the amount of methane is calculated using a methane conversion factor (table 7.2). It is assumed that 10% of the non-extracted methane will be oxidized in the top layer of the landfill.

Tabel 7.2 Input parameters used in the landfill degradation model.

Parameter	Parameter values	References
Oxidation factor (OX)	0.1 (10%)	[Coops <i>et al.</i> , 1995]
f = fraction of degradable organic carbon (DOCf)	0.58 From 1945 through 1989; from 2000 reducing to 0.5 in 2005; thereafter constant 0.5	[Oonk <i>et al.</i> , 1994] [Rijkswaterstaat 2014]
Degradable speed constant k	0.094 From 1945 through 1989 (half-life time 7.5 yr); from 1990 reducing to 0.0693 in 1995; thereafter constant 0.0693 (half-life time 10 yr); from 2000 reducing to 0.05 in 2005; thereafter constant 0.05 (half-life time 14 yr)	[Oonk <i>et al.</i> , 1994] [Rijkswaterstaat 2014]
DOC(X) = concentration of biodegradable carbon in waste that was dumped in year x	132 kg C/ton dumped waste from 1945 through 1989; from 1990 linear reducing to 125 kg C/ton in 1995; 120 kg/ton in 1996 and 1997 and after 1997 determined annually by Rijkswaterstaat.	Based on [De Jager <i>et al.</i> , 1993], determined by [Spakman <i>et al.</i> , 1997] and published in [Klein Goldewijk <i>et al.</i> , 2004]
F (fraction of CH ₄ in landfill gas)	0.6 from 1945 through 2000; from 2000 reducing to 0.5 in 2005; thereafter constant 0.5	[Oonk <i>et al.</i> , 1994] [Rijkswaterstaat 2014]
MCF(x) = Methane correction factor for management	1	

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

With regard to the direct emission of landfill gas, only NMVOCs are of relevance under the Convention on Long-Range Transboundary Air Pollution (CLRTAP). The individual compounds that form NMVOCs mainly originate from volatile organic compounds that were dumped in the past as part of the waste. A small part is produced as a by-product during biodegradation of organic materials within the waste. The direct NMVOC emissions from landfills were calculated based on fractions of individual compounds in the landfill gas (table 7.3).

7.2.2 *Overview of shares and trends in emissions*

NMVOC emission levels related to this source category are relatively low (with 1.45 Gg and 0.36 Gg in 1990 and 2015, respectively). Therefore, shares and trends in these emissions are not elaborated here.

7.2.3 *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 emission factors used is given in table 7.3.

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 weighing bridges. Since 2005, landfill operators are obliged to register their waste on the basis of EURAL codes (EC-Directive 75/442/EEG).

Table 7.3 Landfill gas emission factors

Compound	Emission factor and unit		Emitted landfill gas
	Combusted landfill gas		
	Flared	Gas engine	
Total hydrocarbons (incl. methane)			0.407415 kg/m ³
Hydrocarbons (C _x H _y)	0.27% hydrocarbons	6 g/m ³	
Dioxins	0.9E ⁻⁹ g/m ³	0.3E ⁻⁹ g/m ³	
SO ₂ (based on all sulphur)			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 C _x H _y – 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 ₂ S			100 mg/m ³

7.3 Composting and anaerobic digestion (5B)

7.3.1 Source-category description

The source category of Composting and anaerobic digestion (5B) comprises emissions from the following categories:

5B1 Composting

5B2 Anaerobic digestion at biogas facilities

Emissions from this source category comprise from facilities for composting and/or fermenting of separately collected organic waste for composting and/or biogas production. During processing emissions of NH₃, SO_x and NO_x occur.

As of 1994 it's a statutory requirement for communities in the Netherlands to collect all biodegradable organic waste (i.e. garden waste, horticulture waste and household waste from fruits and vegetables) separately from other domestic waste. The main part of the organic waste is composted on an industrial scale and a small part is turned into biogas through anaerobic digestion.

During composting and fermentation, biodegradable and other organic waste is converted into compost and/or biogas. These processes are carried out in enclosed facilities (halls, tunnels and/or fermentation tanks), allowing waste gases to be filtered through a biobed before being emitted to the air. The material in the biobed is renewed periodically.

The processes for organic horticulture waste are carried out mostly in open air, in rows which are regularly shifted to optimise aeration. The domestic organic waste that is processed in an anaerobic digester results in biogas that is used in energy production. This source category (5B2) is included in the energy sector (source category of Small combustion (1A4)).

7.3.2 *Overview of shares and trends in emissions*

NH₃, NO_x and SO₂ emission levels related to this source category are relatively low (for 1990 respectively 0.05 Gg, 0.0 Gg and 0.0 Gg and for 2015 respectively 0.220 Gg, 0.101 Gg and 0.004 Gg). Therefore, shares and trends in these emissions are not elaborated here.

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

The emission factors used come from sparse literature about emissions from composting and/or fermenting separated biodegradable and other organic waste. It appears that there is hardly any monitoring conducted at the biobed reactors, or the literature cannot be considered relevant due to the clearly differing operational methods used in the Netherlands.

Emission factors for composting and fermentation of biodegradable 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).

The following emission factors have been used:

- NH₃ from fermentation, 2.3 g/Mg of biodegradable and other organic waste;
- NO_x from fermentation, 180 g/Mg of biodegradable and other organic waste;
- SO₂ from fermentation, 10.7 g/Mg of biodegradable and other organic waste.

The processed amount of other organic waste is based on the declared amount with the Landelijk Meldpunt Afvalstoffen (LMA), the hotline for national waste transport. A few wastestreams are selected, these are LoW-codes 020103, 020107 and 200020, and with the treatment composting. Table 7.4 gives an overview of the amounts composted.

LMA has no information on amounts of other organic waste for the years before 2010. Therefore, the amounts for the period 1996-1999 are estimated based on the amounts in 2010-2012 and set to 250 000 Mg/year. Just as the separate collection of biodegradable waste, the other organic waste also started in the '90's thus the amount is assumed null Mg in 1990 and increased linear to 1996 when the estimated amount is 250 000 Mg. From 2000 onwards there is a slow decrease in the processed amounts of organic household waste. This is regarded to be an effect of a smaller share of garden waste in the total amount, due to the increase in paved surface of home gardens.

Table 7.4 Overview of composted organic waste

Year	Amounts of composted organic wastes (Gg)		
	Horticulture	Household (garden, fruit and vegetable)	Total
1990	0.0	228	46
1995	2 057	1 454	313
2000	2 475	1 568	320
2005	2 784	1 367	338
2010	2 437	1 220	254
2014	2 145	1 357	228
2015	2 077	1 357	220

7.4 Waste incineration (5c)

7.4.1 Source-category description

The source category of 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 generated heat from waste incineration is used to produce electricity and heating. These categories, therefore, are reported under the energy sector (source category Public electricity and heat production (1A1a)) and if used as fuel under the subsequent Industry category.

Emissions from cremations (category 5C1bvi) originate from the incineration of human remains (process emissions) and from combustion emissions. The emissions of the natural gas used are reported under the energy sector (source category of Commercial and institutional services (1A4ai)). There is no incineration of carcasses and slaughter waste in the Netherlands. Carcasses and slaughter waste are processed to reusable products, amongst others biofuels. Because of a ban on both other (5C1bvi) and open waste burning (5C2), these emission sources are considered not to occur in the Netherlands.

7.4.2 Key sources

The relevant substances that are emitted during the cremation of human remains are mercury, dioxin, PM₁₀ and PM_{2.5}. Up to 2010, cremations were a relevant key source for Hg. Since 2012, all cremation centres comply with the Dutch Atmospheric Emissions Guideline (NeR) and are equipped with technological measures to reduce emissions. As a result, cremations are no longer a key source.

7.4.3 Overview of shares and trends in emissions

Emission levels in this source category are relative low. Therefore, shares and trends in these emissions are not elaborated here.

7.4.4 Emissions, activity data and (implied) emission factors

Activity data

The number of cremations in the Netherlands is publicised, online, by the Dutch National Association of Crematoria (LVC), on www.lvc-online.nl (LVC, 2017).

Table 7.5 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*
2011	135 741	78 594	59	86**
2012	140 813	83 379	59	100
2013	141 245	86 018	61	100
2014	139 223	85 493	61	100
2015	147 134	93 177	63	100

* Interpolation using year 2011

** Calculation based on an accurate list of crematoria under the NeR (LVC, 2017)

Emission factor for mercury

The emission factor for mercury is based on the amalgam sales combined with results from model (KUB) calculations of the emission factor for mercury per age category (Coenen, 1997).

All the mercury in the amalgam is assumed to become volatilized during cremation and subsequently emitted together with the flue gas, if no NeR measures are in place. The emission factors 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, emission factors have been linearly interpolated.

Implementation of NeR measures have been shown to lead to a significant reduction in mercury emissions. Measurements that were taken, when in compliance with the NeR, resulted in concentrations of between 0.001 and 0.004 mgHg/m³ (Elzenga, 1996). Based on this result, an emission factor of 0.1 gHg/cremation (0.05 mgHg/m³ fume) was assumed when in compliance with the NeR.

Emission factor for TSP, PM₁₀ and PM_{2.5}

When no emission reduction measures were in place, an emission factor of 100 g TSP/cremation was 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/m³ (~13 g TSP/cremation), and at the crematorium in Bilthoven concentrations of less than 0.7 mg TSP/m³ were measured. For facilities with NeR measures in place, calculations were done under the assumption of an emission level of 10 g TSP/cremation.

PM₁₀ 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.

Emission factor for dioxins

For crematoria without NeR measures in place, an emission factor 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/m³ (0.052 ug I-TEQ/cremation) and 0.013 ng I-TEQ/m³ (0.028 ug I-TEQ/cremation). However, in Germany, the current limit (Verordnung über Anlagen zur Feuerbestattung; Bundes-Immissionsschutzverordnung 27 (27th BImSchV)) for installations equipped with filters is 0.1 ng I-TEQ/m³ (or 0.2 ug I-TEQ/cremation).

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

7.5 Waste-water handling (5D)

WWPTs produce methane, amongst others. 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).

7.6 Other waste (5E)

7.6.1 *Source-category description*

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

- Sludge spreading;
- Waste preparation for recycling;
- Scrap fridges/freezers.

Sludge spreading

WWTPs produce sewage sludge. In the Netherlands, when this sewage sludge meets the legal environmental quality criteria, it can be used as fertilizer in agriculture. The emissions from this source are, in line with the guidebook, reported under "Sewage sludge applied to soils (3Da2b)".

The remainder of the sewage sludge is recycled or incinerated. To minimize the costs of transport, the sewage sludge is mechanical dried at the WWTP. The dried sludge is then transported to one of the waste recycle/incineration plants. The emissions from this source are included in "Municipal waste incineration (5C1a)" and reported in the sector on energy (source category Public electricity and heat production (1A1a)).

The process for 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 possibilities for drying sewage sludge in special designed greenhouses using solar energy and/or residual heat from combustion processes.

Waste preparation for recycling

Waste preparation for recycling happens mainly at individual companies that process waste to turn it into new base materials.

Scrap fridges/freezers

Fridges and freezers that have been written off are collected separately and sent to specialized recycling companies. During the recycling process, a small amount of NMVOCs is emitted from the fridges and freezers insulating layer.

7.6.2 *Overview of shares and trends in emissions*

Emission levels in this source category are relative low. Therefore, shares and trends in these emissions are not elaborated here.

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

Waste preparation for recycling

Data on the emissions from the process of waste preparation for recycling were based on environmental reports by large industrial companies. Where necessary, extrapolations were made to emission

totals per industry group, using either both implied emission factors and production data or those based on environmental reports in combination with specific emission factors (as described in section 5.1.3 under Methodological issues).

Scrap fridges/freezers

When recycling scrapped fridges/freezers a small amount of NMVOC (as dichlorodifluoromethane (CFC12), used as blowing agent) will emit from the insulation material. In the calculations, an emission factor of 105 gr CFC12 per recycled fridge/freezer was used.

Since 2010 data on the numbers of scrapped fridges/freezers were 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. The monitoring reports are publicised online, on www.wecycle.eu. In the past, these data were supplied by the NVMP (Dutch Foundation Disposal Metalelectro Products). The NVMP has 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.

8 Other

This includes emissions from privately owned horses (stable and storage only), human transpiration and respiration, and from manure sold and applied to private properties or nature areas. Also, the emissions from pet animals are included.

Category 6A describes a key source for the following components: NH₃ (8.6%) as percentage of national total in 2015.

Reallocation

Compared to last year's inventory, the emissions from pet animals have been re-allocated from 3B4h to 6A. For NH₃ this amounts to about 1.5 Gg in 2015.

Recalculation

After recommendation by a scientific audit (Sutton *et al.*, 2015) the NH₃ emission factor for human transpiration and breathing has this year been updated by a more realistic value. The new emission factor is equal to the largest value in the range of emission factors for transpiration and breathing from Sutton *et al.* (2000). The difference between the old and the new emission factor can be explained by the fact that the new emission factor takes into account that only part of the ammonia in the sweat volatilizes. This resulted in a lower emission factor than used in the previous IIR. As a consequence emissions of human transpiration for the whole time series decreased by more than 3 Gg from about 5 Gg to about 1.5 Gg.

9 Recalculations and other changes

9.1 Recalculations of certain elements of the IIR2016

Compared to the IIR2016 (Jimmink *et al.*, 2016), several methodological changes were implemented in the Pollutant Release and Transfer (PRTR) system:

9.2 Improvements

9.2.1 *Included improvements*

During the compilation of the IIR2016 minor errors were detected, which have been repaired in the IIR2017. The following significant improvements were carried out during the improvement process of the Dutch PRTR:

- As every year, emission factors in the road transport sector were recalculated based on the updated VERSIT+ LD model (Ligterink & De Lange, 2009).
- Update of the model for the calculation of emissions from non-road transport.
- Update of the model for the calculation of civil aviation (LTO) emissions.
- Update of emission factors in the railways sector
- Update of NH₃ emission factor fertilizers
- Update of NH₃ emission factor human transpiration and breathing (6A)

9.2.2 *Planned improvements*

In 2015 the IIR and NFR-tables were subjected to a stage 3 review. This resulted in several findings by the review team. To address these issues, the inventory sector-experts were consulted regarding the necessary actions.

The issues dealing with technical aspects of the inventory are mostly corrected in this inventory report. The remaining actions with respect to content will be prioritised and planned for implementation in the inventories of 2017 and 2018. Appendix 2 gives a quick view on the planning regarding the actions on the issues from the stage 3 review.

9.3 Effects of recalculations and improvements

Tables 9.1 to 9.3 give the changes in total national emission levels for the various compounds, compared to the inventory report of 2016.

Table 9.1 Differences in total national emission levels between current and previous inventory reports, for the years 1990, 2000, 2010 and 2014

National total		NO_x (as NO₂) Gg NO₂	NMVO C Gg	SO_x (as SO₂) Gg SO₂	NH₃ Gg	PM_{2.5} Gg	PM₁₀ Gg	TSP Gg	BC Gg	CO Gg
1990	IIR 2016	603.1	489.5	193.1	372.1	50.2	73.5	97.0	16.7	1143.5
	IIR 2017	603.9	489.8	193.3	368.8	50.8	74.0	97.4	13.1	1143.2
Difference	absolute	0.8	0.4	0.1	-3.3	0.6	0.4	0.4	3.6	-0.3
	%	0.1%	0.1%	0.1%	-0.9%	1.3%	0.6%	0.4%	-22%	0.0%
2000	IIR 2016	419.0	242.6	73.3	181.5	27.6	42.3	50.8	10.5	752.4
	IIR 2017	420.5	243.5	73.4	177.9	27.9	42.5	51.0	9.6	751.6
Difference	absolute	1.5	0.9	0.3	-3.6	0.4	0.2	0.2	-0.9	-0.8
	%	0.4%	0.4%	0.1%	-2.0%	1.3%	0.5%	0.4%	-8.2%	-0.1%
2010	IIR 2016	299.5	165.1	33.8	140.4	16.2	29.8	36.6	5.4	680.8
	IIR 2017	299.7	165.2	33.9	134.9	16.5	30.0	36.8	5.3	675.4
Difference	absolute	0.2	0.0	0.1	-5.5	0.3	0.2	0.2	0.1	1.8
	%	0.1%	0.0%	0.2%	-3.9%	2.2%	0.5%	0.5%	-1.9%	0.3%
2014	IIR 2016	234.8	143.1	29.1	133.8	12.7	26.4	34.5	3.5	570.8
	IIR 2017	234.1	142.7	29.1	127.4	13.1	26.6	34.6	3.4	562.6
Difference	absolute	-0.7	-0.4	0.1	-6.4	0.4	0.2	0.2	-0.1	-8.2
	%	-0.3%	-0.3%	0.2%	-4.8%	3.1%	0.7%	0.5%	-2.3%	-1.4%

The changes in NH₃ emissions originate from the recalculations of the inorganic N-fertilizer application emissions in the agricultural sector and from an updated emission factor for NH₃ from human breathing and transpiration (included in 6A). The increase in PM_{2.5} emissions is mostly caused by a recalculation in Other chemical industry (2B10a) and the non-road mobile machinery. The decrease in BC emissions can be explained by a recalculation in road transport, mostly light and heavy duty vehicles.

Changes in the 2014 figures are also the result of using improved activity data for that year.

Table 9.2 Differences in the total national emission level between the current and previous inventory reports for the years 1990, 2000, 2010 and 2014 (metals)

National total		Pb	Cd	Hg	As	Cr	Cu	Ni	Se	Zn
		Mg								
1990	IIR 2016	333.6	2.1	3.6	1.3	11.8	46.1	74.9	0.4	224.1
	IIR 2017	331.6	2.1	3.6	1.3	11.8	36.8	73.2	0.4	224.1
Difference	absolute	-2.0	0.0	0.0	0.0	0.0	-9.3	-1.6	0.0	0.0
	%	-0.6%	0.0%	0.0%	0.0%	0.0%	-20%	-2.2%	-	0.0%
2000	IIR 2016	29.2	1.0	1.1	0.9	5.0	51.4	18.7	0.5	95.4
	IIR 2017	27.3	1.0	1.1	0.9	5.0	39.9	18.6	0.5	95.4
Difference	absolute	-1.9	0.0	0.0	0.0	0.0	-12.2	0.0	0.0	0.0
	%	-6.5%	0.0%	0.0%	0.1%	0.0%	-24%	-0.1%	0.0%	0.0%
2010	IIR 2016	39.2	2.6	0.6	0.6	3.8	57.6	2.1	1.5	109.8
	IIR 2017	37.5	2.6	0.6	0.6	3.8	45.2	2.1	1.5	102.4
Difference	absolute	-1.7	0.0	0.0	0.0	0.0	-12.3	0.0	0.0	-7.4
	%	-4.2%	0.0%	0.0%	0.8%	0.1%	-21%	0.0%	0.1%	-6.7%
2014	IIR 2016	10.2	0.6	0.5	0.7	3.5	54.6	1.8	0.8	127.0
	IIR 2017	9.0	0.6	0.5	0.7	3.5	42.6	1.8	0.8	116.6
Difference	absolute	-1.2	0.0	0.1	0.0	0.0	-12.0	0.0	0.0	-10.4
	%	-12%	0.1%	15.9%	0.2%	0.4%	-22%	0.0%	0.0%	-8.2%

The decrease in Pb emissions is caused by updated emission factors for Railways and International aviation. The decrease in Cu emissions is also caused by the changes made in the calculation for Railways. The decrease of Zn emissions originates from an updated emission factor for waste combustion in the public electricity and heat production sector.

Table 9.3 Differences in the total national emission level between the current and previous inventory reports for the years 1990, 2000, 2010 and 2014 (PCDD/F, PAHs and HCB)

National total		PCDD/ PCDF (dioxines/ furanes)	PAHs				
			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 2016	742.4	12.5	15.2	11.2	10.0	20.1
	IIR 2017	742.5	5.2	7.9	4.0	2.8	20.3
Difference	absolute	0.1	-7.2	-7.4	-7.2	-7.3	0.2
	%	0.0%	-58.0%	-48.4%	-64.4%	-72.3%	1.0%
2000	IIR 2015	31.0	1.8	1.7	0.9	0.9	31.0
	IIR 2016	31.0	1.8	1.7	0.9	0.8	31.0
Difference	absolute	0.0	-0.1	-0.1	-0.1	-0.1	0.0
	%	0.1%	-3.9%	-3.9%	-7.6%	-8.4%	0.1%
2010	IIR 2015	31.3	1.6	1.6	0.8	0.8	31.3
	IIR 2016	31.3	1.6	1.6	0.8	0.8	31.3
Difference	absolute	0.0	0.0	0.0	0.0	0.0	0.0
	%	0.1%	-0.3%	-0.1%	-0.7%	-0.5%	0.1%
2012	IIR 2015	24.9	1.6	1.5	0.8	0.8	24.9
	IIR 2016	24.9	1.6	1.5	0.8	0.8	24.9
Difference	absolute	0.0	0.0	0.0	0.0	0.0	0.0
	%	0.0%	-0.4%	-0.2%	-0.9%	-0.5%	0.0%

All changes shown in Table 9.3 for PCDD/F and PAH are due to recalculations of combustion emissions in the transport sector. Exception is an error correction in the PAH emission for the 1A1c category for the years 1990 to 1998, which proved to be overestimated in the latest IIR.

Changes in the 2014 figures are also the result of using improved activity data for that year.

10 Projections

This chapter consists of descriptions (per source sector) of general methods (models), data sources and assumptions used for estimating projected emissions as reported in Annex IV, Table 2a, of the Dutch CLRTAP submission.

The emission projections (Table 10.1) presented here consist of an update of air pollutant projections as presented in the National Energy Outlook (NEV) study by Schoots *et al.* (2016). An overview of the historical and projected total emissions for the Netherlands per pollutant is given in Table 10.1.

The update of the projections cover:

- A recalculation of NH₃-emissions from fertilizer application and drain water discharges from air scrubbers used in emission housing for livestock. Both in the historical series and the projections the emission factor for urea from fertilizer application and drain water discharges has been changed. As a consequence, projected ammonia emissions in 2020 and 2030 are reduced by more than 5 Gg compared to the previous projections by Schoots & Hammingh (2015).

The basic assumptions for the calculation of ammonia emissions from fertilizer and drainage water: Use of urea is split by type of urea (regular, liquid or inhibitor) and method of application (superficial or injection) each with its own emission factor. Previously, all urea has been considered as of type regular and method superficial. Emissions associated with the other types of urea injection are much lower.

- The emission factor for the application of drain water has been lowered from about 4% (the average for NH₃-N fertilizer) to a specific factor of 1.8% for drain water.
- A downwards adjusted emission factor for ammonia from human transpiration and respiration. Both in the historical series as well as the projections the emission factor has been lowered from 0.3 kg NH₃ per person per year to 0.083 kg NH₃ per person per year. The former Dutch factor was much higher than in many other countries. After conducting literature searches through the Emission Inventory project it was decided to replace the old factors (Van der Hoek, 1994) with those from a more recent study (Sutton *et al.*, 2000). As a consequence, ammonia emissions in 2020 and 2030 were about 4 Gg lower compared to the previous projections.
- The emission projections for transport were adjusted to take new EU and national policies into account. This includes the Stage V emission standards for non-road mobile machinery and the RDE legislation for light-duty vehicles. In Schoots & Hammingh (2015) both were included as additional measures, but both have since

been agreed upon and are now included in both policy scenarios based on the agreements reached in the EU.

- The emissions projections for road transport are estimated using a fuel used (FU) approach based on projected growth in vehicle kilometres driven derived from the national transport model. As is described in section 4.3.4, reported emission totals for road transport should be on the basis of fuel sold (FS). As such, the FU emission totals are adjusted to correct for differences between fuel used and fuel sold. As is shown in Figure 4.6, the difference between fuel used and fuel sold for both gasoline and diesel has changed in recent years. These changes have been studied in further detail in Geilenkirchen *et al.* (2017), which has led to lower projected differences between fuel used and fuel sold (approximately 5 percentage points) and as such lower projected FS emission totals for road transport.

Table 10.1 Historical and projected emissions from the Netherlands, calculated based on fuel sold (RIVM, 2017; Schoots *et al.*, 2016)

Pollutant/year	Historical					NEC	Projected (WM)		Projected (WAM)	
	1990	2000	2005	2010	2015	2010	2020	2030	2020	2030
SO ₂ Gg	193	73	64	34	30	50	30	30	30	30
NO _x Gg	604	420	369	300	228	260	178	132	177	130
NH ₃ Gg	369	178	156	135	128	128	117	109	117	109
NMVOG Gg	490	244	181	165	139	185	144	146	143	145
PM ₁₀ Gg	74	43	35	30	26	NA	28	27	28	27
PM _{2.5} Gg	51	28	22	17	13	NA	11.0	10.0	10.4	9.6

General approach - methods and general assumptions

The NEV describes developments in the Dutch energy system from 2000 to the present, as well as expectations until 2035. The NEV takes into account the position of the Netherlands in the north-west European energy market and the international development of energy prices. Energy demand and supply, greenhouse gas emissions, the contribution of energy activities to the national product and employment are all taken into consideration. This NEV thus provides an evidence base for political decision-making as well as the public debate on energy.

The vision of the future reflected in the NEV is a representation of the most plausible developments in economics, demography, prices, markets, technology and policy by 1 May 2016. The NEV provides forecasts for two different policy scenarios, taking into account both policies implemented by the Dutch government and measures and activities of other parties in society. The 'existing measures' scenario is based on actual, officially published measures and binding agreements. The 'with additional measures' scenario takes a further step and covers public, planned measures and agreements that had not yet been officially established by 1 May 2016, but were specific enough to be included in the calculations.

Physical developments determine emissions

Starting from a macro-economic point-of-view, the production and consumption of goods and services are estimated. These are then translated to physical developments (e.g. kilometres driven, tons of steel production). In turn, these physical developments determine emissions, taking into account expected technological changes, such as energy-efficiency improvement, or a fuel mix change in power plants.

The NEV uses bottom-up analyses to construct the Dutch energy system balances, both historical as well as projected up to 2030. The developments in the various public and economic sectors are tracked, that lead to energy demand and/or production. This enables the mapping of all energy flows. This is done, as much as possible from the quantitative development of the activities itself, like the production of electricity and goods, the use of appliances, the heating of buildings and the kilometres driven.

Historical data are collected by Statistics Netherlands (CBS) from company questionnaires and registrations from mains operations and governments. For future projections expected changes are calculated based on assumed economical, demographic and energy market developments. If possible, established, announced and proposed projects from both governments and other societal actors have been accounted for.

From expected activity levels the appropriate energy use and consequently the needed energy production can be calculated. Technological developments play an important role in this, especially concerning the improvement of energy efficiency and changes in the fuel mix used for electricity production.

In turn, from the energy use CO₂ emissions are calculated. Emissions of other greenhouse gases and air polluting gases are derived from the relevant activity levels.

The NEV uses a combination of models for various parts of the energy system, in which data is exchanged mutually. Jointly, the models lead to a complete and consistent energy balance for the Netherlands. As a brief explanation on the used models and correspondingly used assumptions, some background documents have been made available. Together with a 'frequently asked questions' section, they are available at the [NEV-website](#).

11 Spatial distributions

11.1 Background for reporting

In 2017 the Netherlands reports geographically distributed emissions and LPS data to the UNECE LRTAP Convention for the years 1990, 1995, 2000, 2005, 2010 and 2015. Emission data are disaggregated to the standard EMEP grid with a resolution of 7km x 7km. Reporting is mandatory for the following air pollutants: SO_x, NO_x, NH₃, NMVOC, CO, PM₁₀, PM_{2.5}, Pb, Cd, Hg, DIOX, PAH and HCB. Guidelines for reporting air emissions on grid level are given in UNECE (2009). 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 (UNECE, 2009). These aggregations can be achieved through the aggregation of the spatially resolved (mapped) detailed NFR sectors.

The gridded emission data of the 2017 reporting is available at the Central Data Repository (CDR) at the EIONET website.

11.2 Methodology for disaggregation of emission data

All emissions in the Dutch PRTR are linked with a spatial allocation. For every spatial allocation category, a factsheet is available: <http://www.emissieregistratie.nl/ERPUBLIEK/misc/Documenten.aspx?ROOT=\Algemeen%20%28General%29\Ruimtelijke%20toedeling%20%28Spatial%20allocation%29>.

Such a 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 institutes concerned. Furthermore an Excel sheet is available which can be used to link emission, emission source, allocation and factsheet.

Three methods are used for spatial allocation of emission sources:

- 1 direct linkage to location;
- 2 model calculation;
- 3 estimation through 'proxy data';

The first category applies only to large point sources of which both the location and the emissions are known. This concerns all companies required by Dutch law to report their air and water emissions by means of Annual Environmental Reports (AER), combined with data concerning waste water treatment plants (RWZIs). Altogether, this category encloses almost three thousand sources.

Some examples of the second method, spatial distributions based on model calculations are:

- Ammonia from agriculture
- Particulate matter (PM₁₀) 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 third and largest group of emissions is spatially allocated by proxy data. Examples of these allocation keys are population and housing density, vehicle kilometres (roads, shipping routes, railways), land cover and number of employees per facility.

11.3 Maps with geographically distributed emission data

Examples of combinations of the three methods can be seen in the maps below, based on the latest reporting data from the Netherlands Pollutants Release and Transfer Register (2014, <http://www.emissieregistratie.nl/ERPUBLIEK/bumper.en.aspx>). The selected air pollutants are ammonia (NH₃), sulphur dioxide (SO₂), nitrogen dioxide (NO_x) and fine particulates (PM_{2.5}). Figures 11.1-11.4 show the geographically distributed emissions for these air pollutants. Even from the spatial allocation at a national level, specific patterns from the major sectors are recognizable.

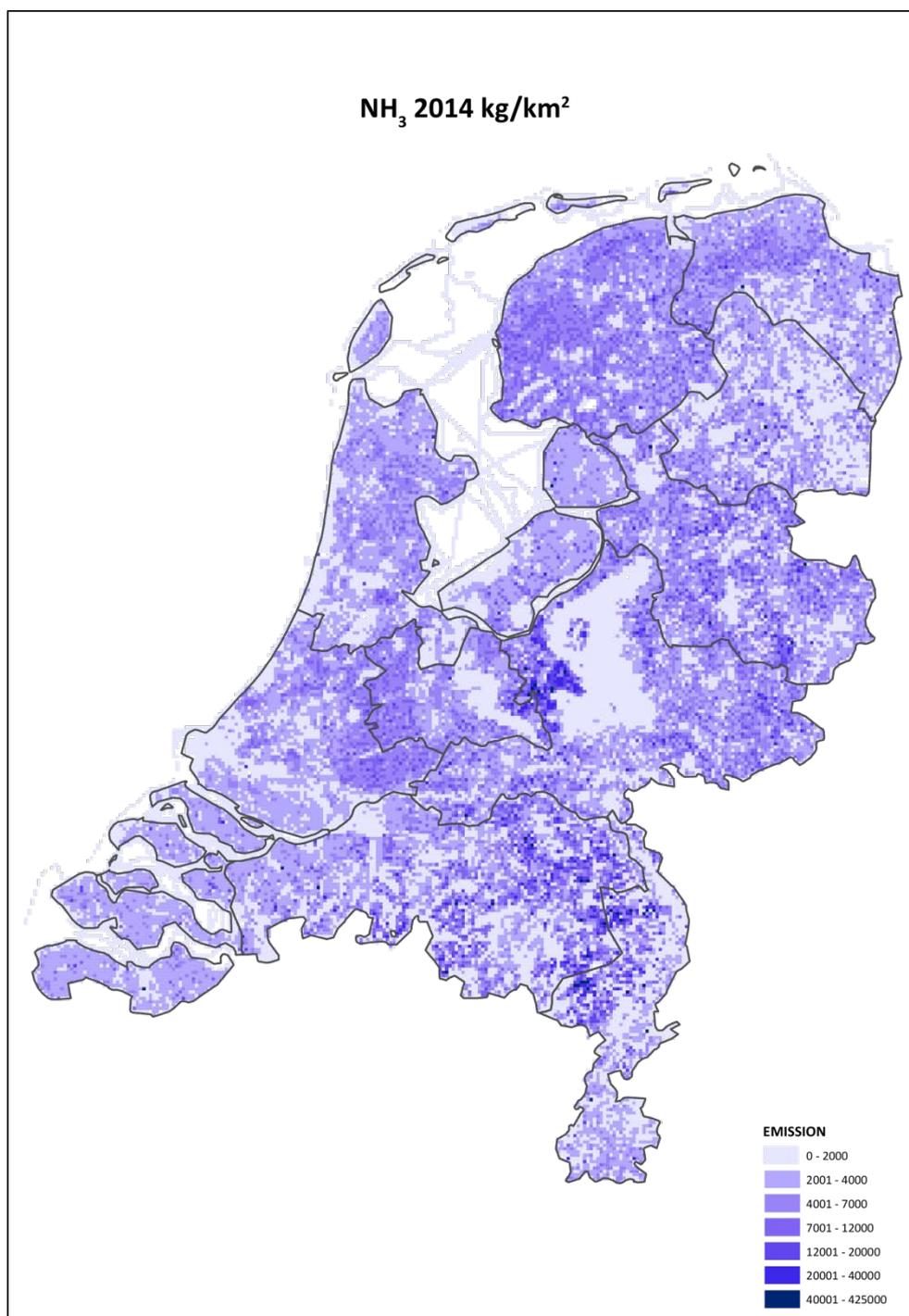


Figure 11.1 Geographical distribution of NH₃ emissions in the Netherlands in 2014

The agricultural sector is the major contributor to the national total NH₃ emission. Emissions of NH₃ are mainly related to livestock farming and especially to the handling of manure. Emissions of NH₃ are therefore related to storage and spreading of manure as well as emissions from stables (Van Bruggen, *et al.*, 2017). Some inland shipping routes are visible as burning of fossil fuels also releases NH₃. Compared to other sectors however the emission quantities are small.

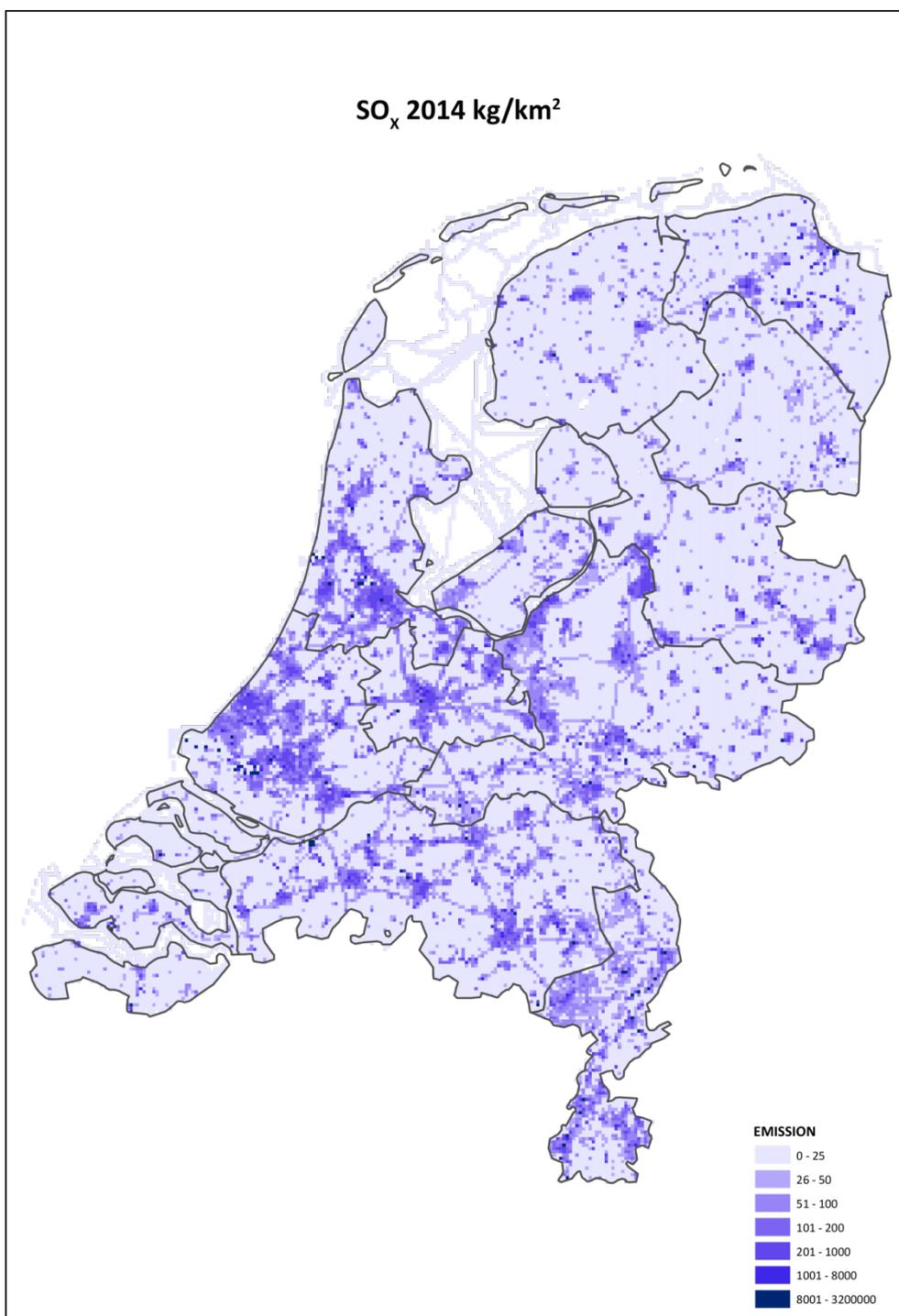


Figure 11.2 Geographical distribution of SO_x emissions in the Netherlands in 2014

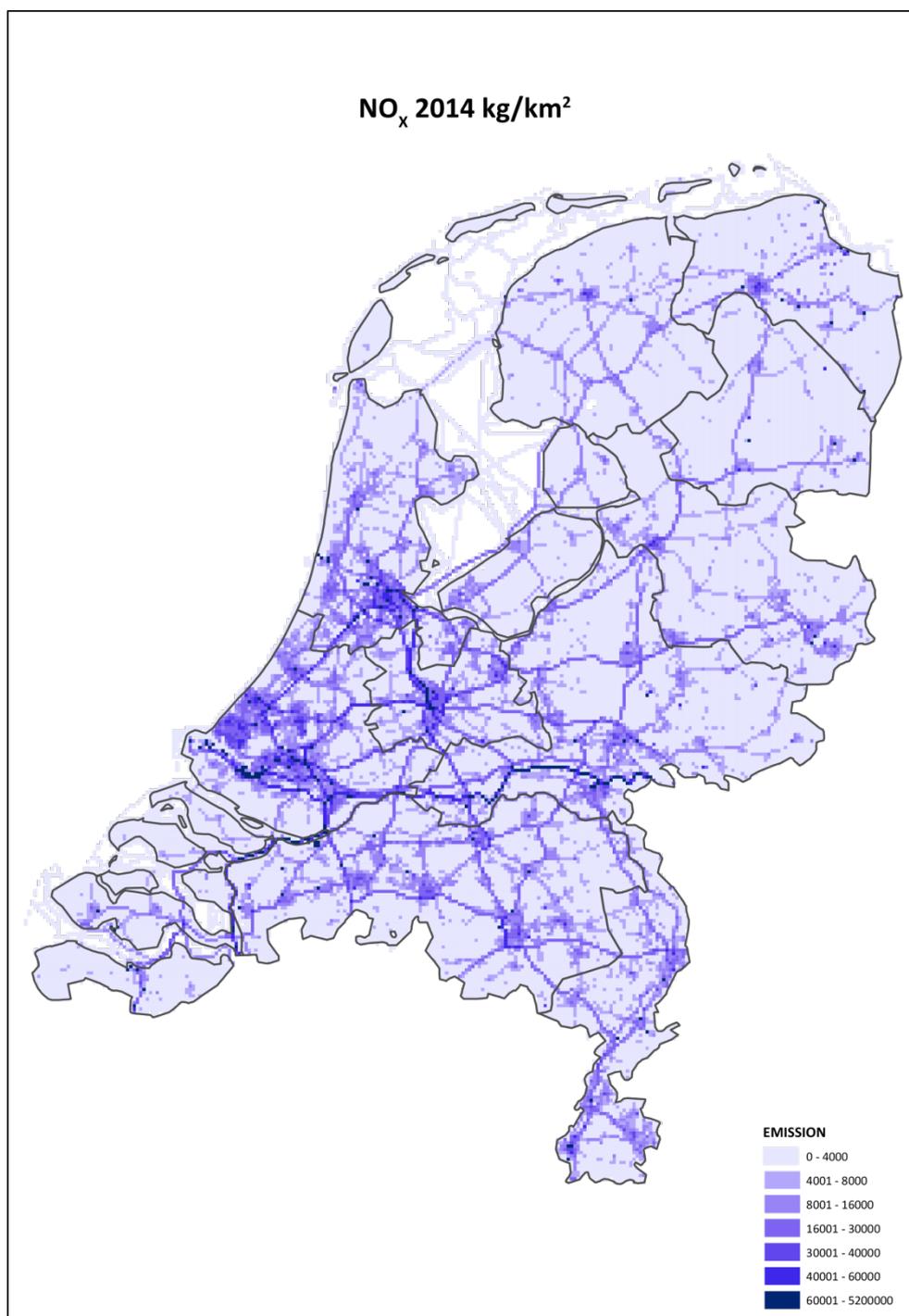


Figure 11.3 Geographical distribution of NO_x emissions in the Netherlands in 2014

Both SO₂ and NO_x are predominantly emitted by transport: cities, main roads and shipping routes are therefore clearly visible. Inland shipping routes are more visible on the SO_x emission map as more reduction measures were taken in other sectors compared to inland shipping.

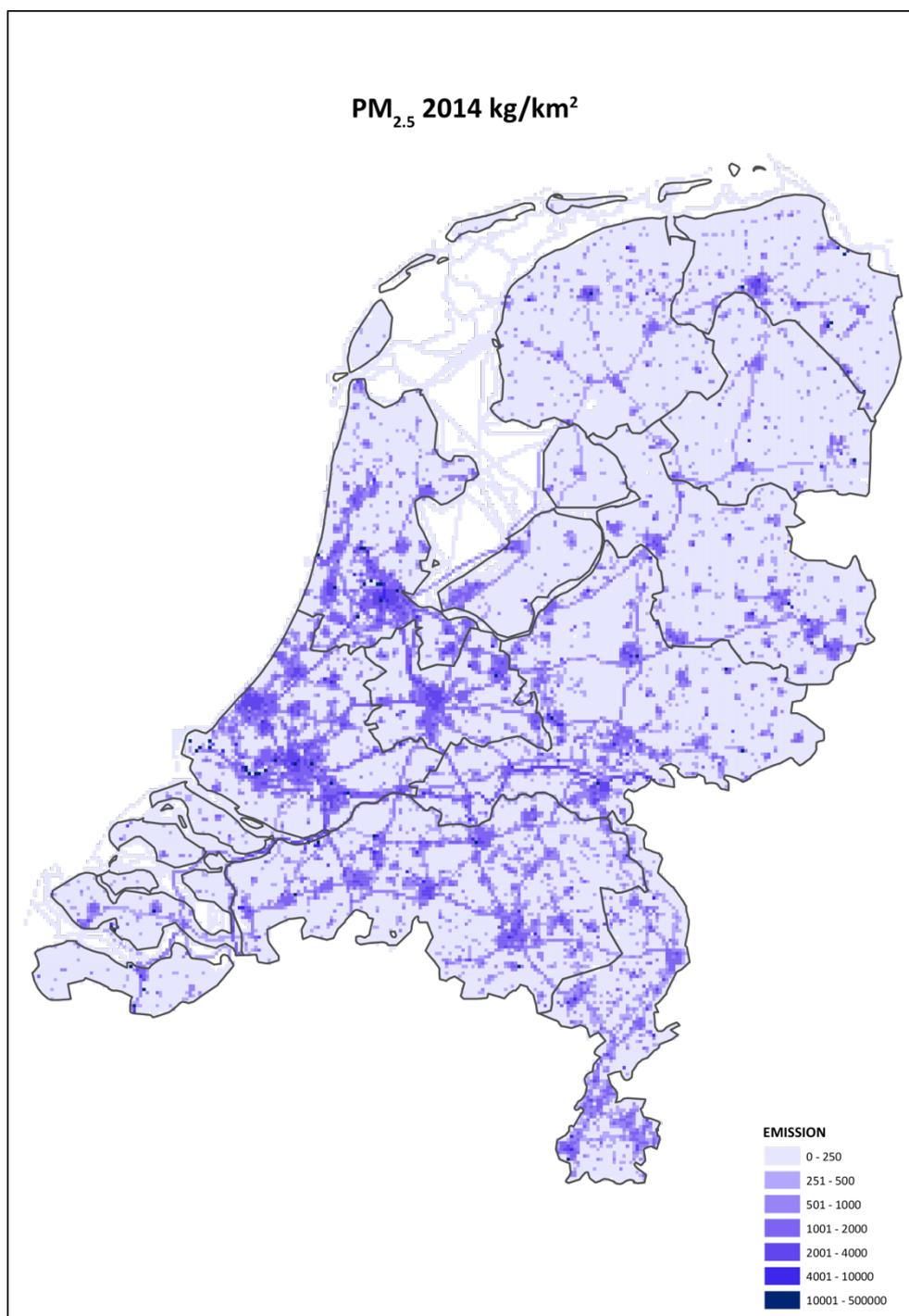


Figure 11.4 Geographical distribution of PM_{2.5} emissions in the Netherlands in 2014

Finally, the map of fine particulate matter shows a pattern in which cities, agriculture, main roads and shipping routes can be recognized. This is due to the fact that residential heating, agricultural animal housing, road traffic and shipping, are main sources of particulate matter.

References

- AFS (2013). HESSQ jaarverslag 2012. Aircraft Fuel Supply B.V.
- Agrawal, H., A.A. Sawant, K. Jansen, J.W. Miller & D.R. Cocker III (2008). Characterization of chemical and particulate emissions from aircraft engines. *Atmospheric Environment* 42, p. 4380-4392.
- Asselt, M.B.A. van (2000). Perspectives on Uncertainty & Risk. The PRIMA Approach to Decision Support. PhD thesis, Maastricht University, Maastricht.
- Bremmer, H.J., L.M. Troost, G. Kuipers, J. de Koning & A.A. Sein (1993). Emissies van dioxinen in Nederland. RIVM/TNO rapportnummer 770501003, National Institute for Public Health and the Environment/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.V. Oude Voshaar, S.M. van der Sluis, G.L. Velthof & J. Vonk (2017). Emissies naar lucht uit de landbouw in 2015. Berekeningen met het model NEMA. WOT-technical report (in prep.) WOT Natuur & Milieu, Wageningen (in Dutch).
- CBS (2012). Uncertainty analysis of mineral excretion and manure production. Statistics Netherlands, The Hague/Heerlen.
- CBS (2012a). Standardised calculation methods for animal manure and nutrients. Standard data 1990-2008. Statistics Netherlands, The Hague/Heerlen.
- CBS (2017). Landbouw; gewassen, dieren, grondgebruik en arbeid op nationaal niveau. Statistics Netherlands, Den Haag/Heerlen/Bonaire. Available: <http://statline.cbs.nl/Statweb/publication/?DM=SLNL&PA=81302ned&D1=387-427,470-502&D2=0,5,10,13-16&HDR=G1&STB=T&VW=T> (in Dutch).
- Coenen, P.W.H.G. (1997). Onderzoek naar de kwikemissies van crematoria en beschikbare reinigingstechnieken, Tauw Milieu Rapport R3517616.W02/BWH, 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).
- Dellaert, S.N.C. (2016). Emissions of mobile machinery at Dutch container terminals. TNO report TNO 2016 R10160, TNO, Utrecht.
- Dellaert, S.N.C. & R. Dröge (2017). Uncertainty of the NO_x, SO_x, NH₃, PM₁₀, PM_{2.5}, EC_{2.5} and NMVOC emissions from transport. In preparation.
- Dellaert, S.N.C. & J.H.J. Hulskotte (2017). Emissions of air pollutants from civil aviation in the Netherlands. TNO 2017 R10055.
- 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.
- Dröge, R. & H.M. ten Broeke (2012). Emissies van individuele industriële bedrijven. TNO report TNO-060-UT-2012-00756, TNO, Utrecht (in Dutch).
- EEA (2007). EMEP/EEA air pollutant emission inventory guidebook 2007. Technical guidance to prepare national emission inventories. EEA Technical report No 16/2007, European Environment Agency (EEA), Copenhagen, Denmark.
<http://www.eea.europa.eu/publications/EMEPCORINAIR5>.
- EEA (2013). EMEP/EEA air pollutant emission inventory guidebook 2013. Technical guidance to prepare national emission inventories. EEA Technical report No 12/2013, European Environment Agency (EEA), Copenhagen, Denmark.
<http://www.eea.europa.eu/publications/emep-eea-guidebook-2013>.
- EEA (2016). Air pollutant emission inventory guidebook. Part A. 6 Inventory management, improvement and QA QC, EEA, Copenhagen.
- Elzenga, J.G. (1996). Crematoria. RIVM report nr. 772414009, National Institute for Public Health and the Environment, Bilthoven (in Dutch).
- EMEP/EEA (2016). Air pollutant emission inventory guidebook. Part B. NFR 1.A.3.a., EEA, Copenhagen.
- ENINA (2016). Methodology report on the calculation of emissions to air from the sectors Energy, Industry and Waste. As used by the Dutch PRTR for the reporting of GHG (GHG) emissions under UNFCCC, Kyoto Protocol, EU Monitoring Mechanism Regulation (MMR) and EU Effort Sharing Decision (ESD) and for international reporting obligations of other pollutants under CLRTAP and the NEC Directive. RIVM Report 2016-0055, National Institute for Public Health and the Environment, Bilthoven.
- EPA (1985). Compilation of air pollutant emission factors. Volume II: Mobile sources. 4th edition, US Environmental Protection Agency, Research Triangle Park, North Carolina, USA.
- Geilenkirchen, G.P., M. 't Hoen & M. Traa (2017). Verkeer en vervoer in de Nationale Energieverkenning 2016, PBL, Den Haag (in Dutch).
- Gijlswijk, R. van, P.W.H.G. Coenen, T. Pulles & J.P. van der Sluijs (2004). Uncertainty assessment of NO_x, SO₂ and NH₃ emissions in the Netherlands. TNO report R 2004/100, TNO, Apeldoorn. Available:
<http://www.rivm.nl/bibliotheek/digitaaldepot/TNOreportRa2004.pdf>.

- Goudappel Coffeng (2010). Onderzoek naar de wegtype-verdeling en samenstelling van het wegverkeer. Final report, Goudappel Coffeng, Deventer (in Dutch).
- Harvey, C.A., P. Carey & J. Warila (2003). EPA's Newest Draft Nonroad Emission Inventory Model (NONROAD). 12th International Emission Inventory Conference, San Diego, California, USA.
- Hasselrot, A. (2001). Hurdy-Gurdy 1.0 with Database of 25 Turboprop Aircraft, a File Maker Solution. (Software on CD), FOI/FFA
- Helms, H., Lambrecht, U. & W. Knörr (2010), Aktualisierung des Modells TREMOD - Mobile Machinery (TREMOM-MM). UBA TEXTE 28/2010, Dessau-Rosslau, Germany (in German).
- Hoek, K.W. van der (1994). Berekeningsmethodiek ammoniakemissie in Nederland voor de jaren 1990, 1991 en 1992, RIVM report 773004003, National Institute for Public Health and the Environment, Bilthoven (in Dutch).
- Hoek, K.W. van der (2002). Uitgangspunten voor de mest- en ammoniakberekeningen 1999 tot en met 2001 zoals gebruikt in de Milieubalans 2001 en 2002, inclusief dataset landbouwemissies 1980-2001. RIVM report 773004013, National Institute for Public Health and the Environment, Bilthoven (in Dutch).
- Hulskotte, J.H.J. & W.W.R. Koch, (2000). Emissiefactoren zeeschepen. TNO-report TNO-MEP-R2000/221, TNO, Apeldoorn (in Dutch).
- Hulskotte, J., E. Bolt & D. Broekhuizen (2003). EMS-protocol emissies door verbrandingsmotoren van zeeschepen op het Nederlands Continentaal Plat, Adviesdienst Verkeer en Vervoer, Rotterdam (in Dutch).
- 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 Mobile Machines gebaseerd op machineverkoop in combinatie met brandstof Afzet (EMMA). TNO-report TNO-034-UT-2009-01782_RPT-ML, TNO, Utrecht (in Dutch).
- Hulskotte, J.H.J. & E. Bolt (2013). EMS-protocol emissies door binnenvaart: verbrandingsmotoren. TNO-report, TNO, Utrecht (in Dutch).
- Jansen, B.I. & R. Dröge (2011). Emissiemodel houtkachels. TNO report TNO-060-UT-2011-00314, TNO, Utrecht (in Dutch).
- Jimmink, B.A., H.M. ten Broeke, P.W.H.G. Coenen, R. Dröge, G.P. Geilenkirchen, A.J. Leekstra, C.W.M van der Maas, R.A.B. te Molder, C.J. Peek, J. Vonk & D. Wever (2014). Emissions of transboundary air pollutants in the Netherlands 1990-2012. Informative Inventory Report 2014. RIVM report 680355015/2014, National Institute for Public Health and the Environment, Bilthoven.
- Jimmink, B.A., P.W.H.G. Coenen, R. Dröge, G.P. Geilenkirchen, A.J. Leekstra, C.W.M. van der Maas, R.A.B. te Molder, C.J. Peek, J. Vonk & D. Wever (2015). Emissions of transboundary air pollutants in the Netherlands 1990-2013. Informative Inventory Report 2015. RIVM Report 2014-0166, National Institute for Public Health & the Environment, Bilthoven.

- Jimmink, B.A., P.W.H.G. Coenen, R. Dröge, G.P. Geilenkirchen, A.J. Leekstra, C.W.M. van der Maas, R.A.B. te Molder, C.J. Peek, J. Vonk & D. Wever (2016). Emissions of transboundary air pollutants in the Netherlands 1990-2014. Informative Inventory Report 2016. RIVM Report 2015-0210, National Institute for Public Health and the Environment, Bilthoven.
- Kadijk, G., N. Ligterink, & J. Spreen (2015) On-road NOx and CO2 investigations of Euro 5 Light Commercial Vehicles. TNO report TNO R10192, TNO, Delft.
- Klein, J., G. Geilenkirchen, J. Hulskotte, N. Duynhoven, R. de Lange, A. Hensema, P. Fortuin & H. Molnár-in 't Veld (2015). Methods for calculating the emissions of transport in the Netherlands. Task Force traffic and Transport of the National Emissions Inventory, Bilthoven.
- Klein, J., J. Hulskotte, N. Ligterink, H. Molnár & G. Geilenkirchen (2016). Methods for calculating the emissions of transport in the Netherlands. 2016, CBS, Den Haag.
- Klein, J., Hulskotte, H., Ligterink, N. Molnár, H. & Geilenkirchen, G. (2017), Methods for calculating the emissions of transport in the Netherlands. 2017, CBS, Den Haag.
- KLM (2016). APU emission factors. KLM, Amsterdam.
- Kok, H.J.G. (2014). Update NOx-emissiefactoren kleine vuurhaarden – glastuinbouw en huishoudens. TNO report 2014 R10584, TNO, Utrecht (in Dutch).
- Kraan, T.C., N.E. Ligterink & A. Hensema (2014). Uncertainties in emissions of road traffic: Euro-4 diesel NOx emissions as case study, TNO report TNO R11316, TNO, Delft.
- Kuiper, E. & N.E. Ligterink (2013), Voertuigcategorieën en gewichten van voertuigcombinaties op de Nederlandse snelweg op basis van assen-combinaties en as-lasten, TNO report TNO R12138, TNO, Delft (in Dutch).
- Kugele, A., F. Jelinek & R. Gaffal (2005). Aircraft particulate matter estimation through all phases of flight, Eurocontrol Experimental Centre, Brétigny sur Orge, France.
- Lambrecht, U., H. Helms, K. Kullmer & W. Knörr (2004). Entwicklung eines Modells zur Berechnung der Luftschadstoffemissionen und des Kraftstoffverbrauchs von Verbrennungsmotoren in mobilen Geräten und Maschinen. IFEU, Heidelberg, Germany (in German).
- Ligterink, N.E. & R. de Lange (2009). Refined vehicle and drivingbehaviour dependencies in the VERSIT+ emission model. TNO Science & Industry, Delft.
- Ligterink, N.E., L.A. Tavasszy, and R. de Lange (2012). A velocity and payload dependent emission model for heavy-duty road freight transportation. Transportation Research Part D 17, p. 487-491.
- Ligterink, N.E., P.S. van Zyl & V.A.M. Heijn (2016). SRM emission factors for CO2. TNO, Delft.
- Ligterink (2017) Elemental carbon emission factors of vehicles for Dutch air-quality assessments. TNO, Delft.
- LVC (2017). <http://www.lvc-online.nl/viewer/file.aspx?FileInfoID=172>
- MARIN (2011). MARIN's emission inventory for North Sea Shipping 2009: validation against ENTEC's inventory and extension with port emissions. MARIN, Wageningen.

- MARIN (2014). Sea shipping emissions 2012: Netherlands Continental Shelf, port areas and OSPAR Region II. MARIN, Wageningen.
- Molnár-in 't Veld, H. & A. Dohmen-Kampert (2010). Methodrapport verkeersprestaties autobussen. Statistics Netherlands, Heerlen (in Dutch).
- Morris, K.M. (2007). Emissions from aircraft, airframe sources: tyre and brake wear, British Airways, 12 April 2007, <http://www.cate.mmu.ac.uk/saaq/presentations/Morris.pdf>
- Netcen (2004). Revision to the Method of Estimating Emissions from Aircraft in the UK Greenhouse Gas Inventory. Abingdon.
- Nollet, J. (1993). Taxitijden t.b.v. PMMS-werkgroep 4 (herziene versie), NV Luchthaven Schiphol, Amsterdam (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.
- 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). Fortaitaire waarden voor gasvormige stikstofverliezen uit stallen en mestopslagen, Alterra rapport 107, gewijzigde druk, ISSN 1566-7197, Wageningen (in Dutch).
- PBL (2012). Environmental balance 2012, Netherlands Environmental Assessment Agency. Bilthoven (in Dutch).
- Pulles, T., & J. van Aardenne (2001). Good Practice Guidance for CLRTAP Emission Inventories. Available: <http://www.eea.europa.eu/publications/EMEPCORINAIR4/BGPG.pdf>
- Riemersma, I.J. & R. Smokers (2004) Ontwikkeling van het Versit+ HD emissiemodel. TNO, Delft (in Dutch).
- Rindlisbacher, T. (2007). Aircraft piston engine emissions, Report 0/3/33/33-05-003, FOCA, Bern. <http://www.hjelmco.com/upl/files/2425.pdf>
- Rindlisbacher, T. (2009). Guidance on the Determination of Helicopter Emissions, Report 0 / 3/33/33-05-020, Edition 1, FOCA, Bern.
- RIVM (2001). Environmental Balance 2000. RIVM report 251701051, Bilthoven (in Dutch).
- RIVM (2016). Werkplan Emissieregistratie 2016. National Institute for Public Health and the Environment, Bilthoven (in Dutch).
- RIVM (2017). Pollutant Release and Transfer Register, NEC pollutants and PM10 emissions, <http://www.emissieregistratie.nl/erpubliek/erpub/international/nec.aspx>, Bilthoven.
- Ruijter, F.J. de, J.F.M. Huijsmans, M.C. van Zanten, W.A.H. Asman & W.A.J. van Pul (2013). Ammonia emission from standing crops and crop residues: contribution to total ammonia emission in the Netherlands, Plant Research International Report 535, Wageningen.
- RWS (2008). Remslijtage. Waterdienst, Centre for Water Management, Lelystad (in Dutch).

- Schoots, K. & P. Hammingh (2015), Nationale Energieverkenning 2015. ECN-O--15-033. ECN, Petten (in Dutch).
- Schoots, K., M. Hekkenberg & P. Hammingh (2016), Nationale Energieverkenning 2016. ECN-O--16-035. ECN, Petten (in Dutch).
- Sluijs, J.P. van der, P. Kloprogge, J. Risbey & J. Ravetz (2003). Towards a synthesis of qualitative and quantitative uncertainty assessment: applications of the numeral, unit, spread, assessment, pedigree (NUSAP) system. Paper for the International Workshop on Uncertainty, Sensitivity, and Parameter Estimation for Multimedia Environmental Modeling. August 19-21, 2003, Rockville, Maryland, USA. Available: <http://www.nusap.net>.
- Sluijs, J.P. van der, M. Craye, S. Funtowicz, P. Kloprogge, J. Ravetz & J. Risbey (2005). Combining Quantitative and Qualitative Measures of Uncertainty in Model based Environmental Assessment: the NUSAP System, *Risk Analysis*, 25 (2). p. 481–492.
- Soest-Vercammen, E.L.J. van, J.H.J. Hulskotte & D.C. Heslinga (2002). Monitoringsprotocol Bijschatting Stationaire NO_x-bronnen kleiner dan 20 MWth. TNO report R2002/042, TNO Milieu, Energie en Procesinnovatie, Apeldoorn (in Dutch).
- Stelwagen, U., & N.E. Ligterink (2015). HD Euro-V Truck PM₁₀ and EC emission factors. TNO, Delft.
- Stelwagen, U., N.E. Ligterink & S. van Zyl (2015). NH₃ emission factors for road transport. 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
- Sutton, M.A., U. Dragosits, C. Geels, S. Gyldenkærne, T.H. Misselbrook & W. Bussink (2015). Review on the scientific underpinning of calculation of ammonia emission and deposition in the Netherlands. 31 pp.
- Tak, C. van der (2000). Actualisatie T₀-emissies. Report number 16196.620/2, MARIN, Wageningen (in Dutch).
- UNECE (2009). Guidelines for Estimating and Reporting Emission Data under the Convention on Long-range Transboundary Air Pollution. http://www.ceip.at/fileadmin/inhalte/emep/reporting_2009/R_ep_Guidelines_ECE_EB_AIR_97_e.pdf.
- UNECE (2014). Guidelines for Estimating and Reporting Emission Data under the Convention on Long-range Transboundary Air Pollution. http://www.ceip.at/fileadmin/inhalte/emep/2014_Guidelines/ece.eb.air.125_ADVANCE_VERSION_reporting_guidelines_2013.pdf
- Visschedijk, A., W. Appelman, J.H.J. Hulskotte & P. Coenen (2007). Onderhoud van methodieken Emissieregistratie 2006-2007. TNO report nr. A-R0865/B, Apeldoorn (in Dutch).
- Visschedijk (2014) Onderbouwing van aan RIVM geleverde EC_{2.5} gewichtsfracties in PM₁₀ voor toepassing in de Nederlandse Emissieregistratie en constructie van de GCN kaarten. TNO, Utrecht (in Dutch).
- Vonk, J., A. Bannink, C. van Bruggen, C.M. Groenestein, J.F.M. Huijsmans, J.W.H. van der Kolk, H.H. Luesink, S.V. Oude

- Voshaar, S.M. van der Sluis & G.L. Velthof (2016). Methodology for estimating emissions from agriculture in the Netherlands. Calculations of CH₄, NH₃, N₂O, NO_x, PM₁₀, PM_{2.5} and CO₂ with the National Emission Model for Agriculture (NEMA). WOt-technical report 53, WOT Natuur & Milieu, Wageningen.
- VROM (2002). MilieuEffectRapport Landelijk afvalbeheerplan (Environmental Impact Report National Waste Management Plan) 2002-2012. Ministry of Housing, Spatial Planning and the Environment (VROM), VROM 02.0115/04-03 21770/206, Den Haag.
- VROM (2008). Milieuverslaglegging en PRTR: veranderingen vanaf het verslagjaar 2009. Ministerie van Infrastructuur en Milieu, Den Haag. Available:
<https://www.rijksoverheid.nl/documenten/brochures/2009/10/01/milieuverslaglegging-en-prtr-veranderingen-vanaf-het-verslagjaar-2009> (in Dutch).

Appendix 1 Key category analysis results

Results from the key (source) category analysis have been calculated and sorted for every component. In addition to a 2015 and 1990 level assessment, a trend assessment was also performed. In both approaches, key source categories are identified using a cumulative threshold of 80%.

Table 1.1.a SO_x key source categories identified by 2015 level assessment (emissions in Gg)

NFR14 Code	Longname	2015	Contribution	Cumulative contribution
1A1b	Petroleum refining	11.1	37%	37%
1A1a	Public electricity and heat production	8.6	28%	65%
1A2a	Stationary combustion in manufacturing industries and construction: Iron and steel	3.0	10%	75%
1A2gviii	Stationary combustion in manufacturing industries and construction: Other	2.6	8.7%	84%

Table 1.1.b SO_x key source categories identified by 1990 level assessment (emissions in Gg)

NFR14 Code	Longname	1990	Contribution	Cumulative contribution
1A1b	Petroleum refining	67	35%	35%
1A1a	Public electricity and heat production	48	25%	60%
1A2c	Stationary combustion in manufacturing industries and construction: Chemicals	20	10%	71%
1A2a	Stationary combustion in manufacturing industries and construction: Iron and steel	9.1	4.7%	75%
1A3biii	Road transport: Heavy duty vehicles and buses	7.8	4.0%	79%
2A6	Other mineral products	5.5	2.9%	82%

Table 1.1.c SO_x key source categories identified by 1990-2015 trend assessment (emissions in Gg)

NFR14 Code	Longname	Trend	Trend contribution	Cumulative trend contribution
1A2gviii	Stationary combustion in manufacturing industries and construction: Other	1.0%	17%	17%
1A2a	Stationary combustion in manufacturing industries and construction: Iron and steel	0.8%	14%	30%

NFR14 Code	Longname	Trend	Trend contribution	Cumulative trend contribution
1A2c	Stationary combustion in manufacturing industries and construction: Chemicals	0.8%	13%	44%
1A3biii	Road transport: Heavy duty vehicles and buses	0.6%	10%	54%
1A1a	Public electricity and heat production	0.5%	9.1%	63%
1A3bi	Road transport: Passenger cars	0.4%	6.4%	70%
1A1b	Petroleum refining	0.3%	5.4%	75%
1A3bii	Road transport: Light duty vehicles	0.2%	2.9%	78%
2A3	Glass production	0.2%	2.6%	81%

Table 1.2.a NO_x key source categories identified by 2015 level assessment (emissions in Gg)

NFR14 Code	Longname	2015	Contribution	Cumulative contribution
1A3biii	Road transport: Heavy duty vehicles and buses	37	16%	16%
1A3bi	Road transport: Passenger cars	27	12%	28%
1A1a	Public electricity and heat production	20	8.8%	37%
1A3bii	Road transport: Light duty vehicles	17	8.4%	46%
1A3di(ii)	International inland waterways	17	7.3%	53%
1A4ci	Agriculture/Forestry/Fishing: Stationary	11	4.8%	58%
1A3dii	National navigation (shipping)	9.5	4.0%	62%
1A2c	Stationary combustion in manufacturing industries and construction: Chemicals	9.1	4.0%	66%
1A4cii	Agriculture/Forestry/Fishing: Off-road vehicles and other machinery	8.7	3.8%	70%
1A4bi	Residential: Stationary	8.2	3.6%	73%
1A2gvii	Mobile Combustion in manufacturing industries and construction	8.1	3.5%	77%
1A4ai	Commercial/institutional: Stationary	6.7	2.9%	79.7%
1A2a	Stationary combustion in manufacturing industries and construction: Iron and steel	5.9	2.6%	82.3%

Table 1.2.b NO_x key source categories identified by 1990 level assessment
(emissions in Gg)

NFR14 Code	Longname	1990	Contribution	Cumulative contribution
1A3bi	Road transport: Passenger cars	145	24%	24%
1A3biii	Road transport: Heavy duty vehicles and buses	113	19%	43%
1A1a	Public electricity and heat production	83	14%	56%
1A2c	Stationary combustion in manufacturing industries and construction: Chemicals	36	6.0%	62%
1A3bii	Road transport: Light duty vehicles	24	3.9%	66%
1A3di(i)	International inland waterways	22	3.7%	70%
1A2gvi i	Mobile combustion in manufacturing industries and construction	21	3.4%	73%
1A4bi	Residential: Stationary	20	3.4%	77%
1A2gvi ii	Stationary combustion in manufacturing industries and construction: Other	20	3.3%	80.1%

Table 1.2.c NO_x key source categories identified by 1990-2015 trend assessment
(emissions in Gg)

NFR14 Code	Longname	Trend	Trend contribution	Cumulative trend contribution
1A3bi	Road transport: Passenger cars	4.6%	25%	25%
1A1a	Public electricity and heat production	1.8%	10%	35%
1A3bii	Road transport: Light duty vehicles	1.7%	9.3%	45%
1A3di(ii)	International inland waterways	1.4%	7.6%	52%
1A4ci	Agriculture/Forestry/Fishing: Stationary	1.3%	6.9%	59%
1A3dii	National navigation (shipping)	1.2%	6.5%	65%
1A3biii	Road transport: Heavy duty vehicles and buses	0.9%	4.9%	70%
1A2c	Stationary combustion in manufacturing industries and construction: Chemicals	0.75%	4.1%	74%
1A2a	Stationary combustion in manufacturing industries and construction: Iron and steel	0.54%	3.0%	77%
1A4cii	Agriculture/Forestry/Fishing: Off-road vehicles and other machinery	0.53%	2.9%	80.4%

Table 1.3.a NH_x key source categories identified by 2015 level assessment
(emissions in Gg)

NFR14 Code	Longname	2015	Contribution	Cumulative contribution
3Da2a	Animal manure applied to soils	38	30%	30%
3B1a	Manure management - Dairy cattle	19	15%	45%
3B3	Manure management - Swine	14	11%	56%
3Da1	Inorganic N-fertilizers (includes also urea application)	12	9%	65%
3B1b	Manure management - Non-dairy cattle	10.4	8.2%	73%
6A	Other (included in national total for entire territory)	9.5	7.5%	80.3%

Table 1.3.a NH_x key source categories identified by 1990 level assessment
(emissions in Gg)

NFR14 Code	Longname	1990	Contribution	Cumulative contribution
3Da2a	Animal manure applied to soils	210	57%	57%
3B3	Manure management - Swine	49	13%	70%
3B1a	Manure management - Dairy cattle	22	5.9%	76%
3Da3	Urine and dung deposited by grazing animals	18	4.8%	81.0%

Table 1.3.c NH_x key source categories identified by 1990-2015 trend assessment
(emissions in Gg)

NFR14 Code	Longname	Trend	Trend contribution	Cumulative trend contribution
3Da2a	Animal manure applied to soils	9%	40%	40%
3B1a	Manure management - Dairy cattle	3.1%	13%	53%
3Da1	Inorganic N-fertilizers (includes also urea application)	1.9%	7.9%	61%
3B1b	Manure management - Non-dairy cattle	1.8%	7.7%	68%
6A	Other (included in national total for entire territory)	1.4%	6.1%	74%
3B4gi	Manure management - Laying hens	1.3%	5.4%	79.8%
3Da3	Urine and dung deposited by grazing animals	1.2%	5.0%	84.8%

Table 1.4.a NMVOC key source categories identified by 2015 level assessment
(emissions in Gg)

NFR14 Code	Longname	2015	Contribution	Cumulative contribution
2D3a	Domestic solvent use including fungicides	21	15%	15%
2D3d	Coating applications	19	14%	29%
1A3bi	Road transport: Passenger cars	12	9.0%	38%
1A4bi	Residential: Stationary	11	8.1%	46%
2H3	Other industrial processes	10	7.3%	53%
2D3i	Other solvent use	9.9	7.1%	60%
1A3biv	Road transport: Mopeds & motorcycles	8.1	5.9%	66%
1B2aiv	Fugitive emissions oil: Refining / storage	7.9	5.7%	72%
2B10a	Chemical industry: Other	5.2	3.8%	75%
1B2ai	Fugitive emissions oil: Exploration, production, transport	4.7	3.3%	79%
2D3h	Printing	4.1	2.9%	81%

Table 1.4.b NMVOC key source categories identified by 1990 level assessment
(emissions in Gg)

NFR14 Code	Longname	1990	Contribution	Cumulative contribution
1A3bi	Road transport: Passenger cars	101	21%	21%
2D3d	Coating applications	93	19%	40%
1A3bv	Road transport: Gasoline evaporation	36	7.3%	47%
2B10a	Chemical industry: Other	33	6.8%	54%
1B2aiv	Fugitive emissions oil: Refining / storage	32	6.5%	60%
2H3	Other industrial processes	25	5.2%	65%
1A3biv	Road transport: Mopeds & motorcycles	25	5.1%	70%
1A3biii	Road transport: Heavy duty vehicles and buses	16	3.3%	74%
2D3i	Other solvent use	15	3.1%	77%
1B2ai	Fugitive emissions oil: Exploration, production, transport	14	2.9%	79.7%
2D3h	Printing	14	2.9%	83%

Table 1.4.c NMVOC key source categories identified by 1990-2015 trend assessment (emissions in Gg)

NFR14 Code	Longname	Trend	Trend contribution	Cumulative trend contribution
2D3a	Domestic solvent use including fungicides	3.5%	19%	19%

NFR14 Code	Longname	Trend	Trend contribution	Cumulative trend contribution
1A3bi	Road transport: Passenger cars	3.3%	17%	36%
1A3bv	Road transport: Gasoline evaporation	1.7%	9.2%	45%
1A4bi	Residential: Stationary	1.5%	8.1%	53%
2D3d	Coating applications	1.5%	8.0%	61%
2D3i	Other solvent use	1.1%	6.1%	67%
2B10a	Chemical industry: Other	0.98%	5.2%	73%
1A3biii	Road transport: Light duty vehicles	0.71%	3.8%	76%
2H3	Road transport: Heavy duty vehicles and buses	0.59%	3.1%	79%
1A3bii	Other industrial processes	0.52%	2.7%	82%

Table 1.5.a CO key source categories identified by 2015 level assessment (emissions in Gg)

NFR14 Code	Longname	2015	Contribution	Cumulative contribution
1A3bi	Road transport: Passenger cars	228	40%	40%
1A4bi	Residential: Stationary	78	14%	54%
1A2a	Stationary combustion in manufacturing industries and construction: Iron and steel	66	12%	65%
1A3biv	Road transport: Mopeds & motorcycles	59	10%	75%
1A4bii	Residential: Household and gardening (mobile)	28	5.2%	80.5%

Table 1.5.b CO key source categories identified by 1990 level assessment (emissions in Gg)

NFR14 Code	Longname	1990	Contribution	Cumulative contribution
1A3bi	Road transport: Passenger cars	589	52%	52%
1A2a	Stationary combustion in manufacturing industries and construction: Iron and steel	187	16%	68%
1A4bi	Residential: Stationary	76	6.6%	75%
1A3bii	Road transport: Light duty vehicles	48	4.2%	79%
1A3biv	Road transport: Mopeds & motorcycles	45	3.9%	83%

Table 1.5.c CO key source categories identified by 1990-2015 trend assessment (emissions in Gg)

NFR14 Code	Longname	Trend	Trend contribution	Cumulative trend contribution
1A3bi	Road transport: Passenger cars	5.8%	25%	25%
1A4bi	Residential: Stationary	3.5%	15%	40%
1A3biv	Road transport: Mopeds & motorcycles	3.2%	14%	54%
1A2a	Stationary combustion in manufacturing industries and construction: Iron and steel	2.4%	11%	65%
1A4bii	Residential: Household and gardening (mobile)	1.9%	8.1%	73%
1A3bii	Road transport: Light duty vehicles	1.8%	7.8%	80.8%

Table 1.6.a PM₁₀ key source categories identified by 2015 level assessment (emissions in Gg)

NFR Code	Longname	2015	Contribution	Cumulative contribution
3B4gi	Manure management - Laying hens	2.9	11%	11%
2H3	Other industrial processes	2.6	9.9%	21%
1A4bi	Residential: Stationary	2.1	7.9%	29%
2H2	Food and beverages industry	1.8	6.8%	35%
1A3bvi	Road transport: Automobile tyre and brake wear	1.4	5.2%	41%
3B4gii	Manure management - Broilers	1.3	4.9%	46%
2C1	Iron and steel production	1.3	4.8%	50%
2D3i	Other solvent use	1.2	4.5%	55%
1A3bvii	Road transport: Automobile road abrasion	1.1	4.2%	59%
2B10a	Chemical industry: Other	1.1	4.2%	63%
2A6	Other mineral products	1.1	4.1%	67%
3B3	Manure management - Swine	1.0	4.1%	71%
1A3bii	Road transport: Light duty vehicles	1.0	3.6 %	75%
1A3bi	Road transport: Passenger cars	0.9	3.5%	78%
3Dc	Farm-level agricultural operations including storage, handling and transport of agricultural products	0.6	2.3%	80.4%

Table 1.6.b PM_{10} key source categories identified by 1990 level assessment (emissions in Gg)

NFR14 Code	Longname	1990	Contribution	Cumulative contribution
2C1	Iron and steel production	9.1	12%	12%
1A3biii	Road transport: Heavy duty vehicles and buses	7.0	9.5%	22%
1A3bi	Road transport: Passenger cars	6.6	8.9%	31%
1A1b	Petroleum refining	6.4	8.6%	39%
2H3	Other industrial processes	5.4	7.4%	47%
1A3bii	Road transport: Light duty vehicles	4.6	6.2%	53%
2H2	Food and beverages industry	4.3	5.9%	59%
2B10a	Chemical industry: Other	4.1	5.6%	64%
1A4bi	Residential: Stationary	2.5	3.4%	68%
1A2gvii	Mobile Combustion in manufacturing industries and construction	2.2	3.0%	71%
1A1a	Public electricity and heat production	2.2	2.9%	74%
2A6	Other mineral products	2.0	2.7%	76%
2D3i	Other solvent use	1.9	2.5%	79%
3B3	Manure management - Swine	1.6	2.1%	81%

Table 1.6.c PM_{10} key source categories identified by 1990-2015 trend assessment (emissions in Gg)

NFR14 Code	Longname	Trend	Trend contribution	Cumulative trend contribution
3B4gi	Manure management - Laying hens	3.5%	13%	13%
1A1b	Petroleum refining	2.8%	10%	23%
1A3biii	Road transport: Heavy duty vehicles and buses	2.8%	10%	33%
2C1	Iron and steel production	2.7%	10%	43%
1A3bi	Road transport: Passenger cars	1.9%	7.0%	50%
1A4bi	Residential: Stationary	1.6%	5.8%	55%
1A3bvi	Road transport: Automobile tyre and brake wear	1.3%	4.7%	60%
3B4gii	Manure management - Broilers	1.2%	4.3%	64%
1A3bvii	Road transport: Automobile road abrasion	1.1%	3.9%	68%
1A3bii	Road transport: Light duty vehicles	0.9%	3.4%	72%
2H3	Other industrial processes	0.9%	3.2%	75%
2D3i	Other solvent use	0.7%	2.5%	78%
1A1a	Public electricity and heat production	0.6%	2.0%	79.5%
3B3	Manure management - Swine	0.6%	2.0%	82%

Table 1.7.a $PM_{2.5}$ key source categories identified by 2015 level assessment
(emissions in Gg)

NFR14 Code	Longname	2015	Contribution	Cumulative contribution
1A4bi	Residential: Stationary	2.0	15%	15%
2D3i	Other solvent use	1.2	9.2%	25%
1A3bii	Road transport: Light duty vehicles	1.0	7.5%	32%
1A3bi	Road transport: Passenger cars	0.9	7.2%	39%
2B10a	Chemical industry: Other	0.8	6.2%	46%
2C1	Iron and steel production	0.8	6.1%	52%
2H3	Other industrial processes	0.7	5.3%	57%
1A2gvii	Mobile Combustion in manufacturing industries and construction	0.5	3.9%	61%
1A3di(ii)	International inland waterways	0.5	3.7%	65%
1A4cii	Agriculture/Forestry/Fishing: Off-road vehicles and other machinery	0.5	3.6%	68%
1A3biii	Road transport: Heavy duty vehicles and buses	0.4	3.5%	72%
2A6	Other mineral products	0.4	2.8%	74%
1A3dii	National navigation (shipping)	0.3	2.7%	77%
2H2	Food and beverages industry	0.3	2.6%	79.7%
1A3dii	National navigation (shipping)	0.3	2.2%	82%

Table 1.7.b $PM_{2.5}$ key source categories identified by 1990 level assessment
(emissions in Gg)

NFR Code	Longname	1990	Contribution	Cumulative contribution
1A3biii	Road transport: Heavy duty vehicles and buses	7.0	14%	14%
1A3bi	Road transport: Passenger cars	6.6	13%	27%
2C1	Iron and steel production	5.8	11%	38%
1A1b	Petroleum refining	5.0	10%	48%
1A3bii	Road transport: Light duty vehicles	4.6	9.1%	57%
2B10a	Chemical industry: Other	2.7	5.2%	62%
1A4bi	Residential: Stationary	2.4	4.7%	67%
1A2gvii	Mobile Combustion in manufacturing industries and construction	2.1	4.1%	71%
2D3i	Other solvent use	1.9	3.7%	75%
1A1a	Public electricity and heat production	1.9	3.7%	79%
2H3	Other industrial processes	1.6	3.2%	82%

Table 1.7.c $PM_{2.5}$ key source categories identified by 1990-2015 trend assessment (emissions in Gg)

NFR14 Code	Longname	Trend	Trend contribution	Cumulative trend contribution
1A4bi	Residential: Stationary	2.7%	15%	15%
1A3biii	Road transport: Heavy duty vehicles and buses	2.6%	14%	29%
1A1b	Petroleum refining	2.2%	12%	41%
1A3bi	Road transport: Passenger cars	1.4%	7.9%	49%
2D3i	Other solvent use	1.4%	7.6%	56%
2C1	Iron and steel production	1.4%	7.4%	64%
2H3	Other industrial processes	0.5%	3.0%	67%
1A3dii	National navigation (shipping)	0.5%	2.8%	70%
1A3di(ii)	International inland waterways	0.5%	2.6%	72%
1A3bii	Road transport: Light duty vehicles	0.4%	2.2%	74%
1A3bvi	Road transport: Automobile tyre and brake wear	0.4%	2.1%	76%
1A1a	Public electricity and heat production	0.4%	2.0%	78%
3B4gi	Manure management – Laying hens	0.3%	1.7%	80.2%

Table 1.8.a Pb key source categories identified by 2015 level assessment (emissions in Mg)

NFR14 Code	Longname	2015	Contribution	Cumulative contribution
2C1	Iron and steel production	3.5	40%	40%
2C6	Zinc production	1.1	13%	53%
2A3	Glass production	1.0	11%	64%
1A3ai(i)	International aviation LTO (civil)	0.8	9.5%	74%
2H3	Other industrial processes	0.5	5.3%	79.3%
1A3bi	Road transport: Passenger cars	0.4	5.1%	84%

Table 1.8.b Pb key source categories identified by 1990 level assessment (emissions in Mg)

NFR14 Code	Longname	1990	Contribution	Cumulative contribution
1A3bi	Road transport: Passenger cars	230	69%	69%
2C1	Iron and steel production	56	17%	86%

Table 1.8.c Pb key source categories identified by 1990-2015 trend assessment
(emissions in Mg)

NFR14 Code	Longname	Trend	Trend contribution	Cumulative trend contribution
1A3bi	Road transport: Passenger cars	1.67%	45%	45%
2C1	Iron and steel production	0.61%	16%	62%
2C6	Zinc production	0.34%	9%	71%
2A3	Glass production	0.24%	6%	78%
1A3c	Railways	0.23%	6%	84%

Table 1.9.a Hg key source categories identified by 2015 level assessment
(emissions in Mg)

NFR14 Code	Longname	2015	Contribution	Cumulative contribution
1A1a	Public electricity and heat production	0.23	41%	41%
2C1	Iron and steel production	0.07	13%	54%
1A3bi	Road transport: Passenger cars	0.06	11%	65%
2C5	Lead production	0.05	9.7%	75%
1A2gviii	Stationary combustion in manufacturing industries and construction: Other	0.04	7.7%	83%

Table 1.9.b Hg key source categories identified by 1990 level assessment
(emissions in Mg)

NFR14 Code	Longname	1990	Contribution	Cumulative contribution
1A1a	Public electricity and heat production	1.9	54%	54%
2B10a	Chemical industry: Other	0.7	20%	73%
2C1	Iron and steel production	0.4	11%	84%

Table 1.9.c Hg key source categories identified by 1990-2015 trend assessment
(emissions in Mg)

NFR14 Code	Longname	Trend	Trend contribution	Cumulative trend contribution
2B10a	Chemical industry: Other	3.1%	28%	28%
1A1a	Public electricity and heat production	2.0%	19%	47%
1A3bi	Road transport: Passenger cars	1.5%	14%	61%
1A2gviii	Stationary combustion in manufacturing industries and construction: Other	1.2%	11%	72%
1A4bi	Residential: Stationary	0.9%	8.2%	81%

Table 1.10.a Cd key source categories identified by 2015 level assessment
(emissions in Mg)

NFR14 Code	Longname	2015	Contribution	Cumulative contribution
2C1	Iron and steel production	0.17	27%	27%
2C6	Zinc production	0.15	23%	51%
1A3bi	Road transport: Passenger cars	0.09	14%	65%
2B10a	Chemical industry: Other	0.08	13%	79%
1A4bi	Residential: Stationary	0.06	9.4%	88%

Table 1.10.b Cd key source categories identified by 1990 level assessment
(emissions in Mg)

NFR14 Code	Longname	1990	Contribution	Cumulative contribution
1A1a	Public electricity and heat production	0.9	44%	44%
2C1	Iron and steel production	0.7	32%	76%
1A1b	Petroleum refining	0.11	5.1%	81%

Table 1.10.c Cd key source categories identified by 1990-2015 trend assessment
(emissions in Mg)

NFR14 Code	Longname	Trend	Trend contribution	Cumulative trend contribution
1A1a	Public electricity and heat production	12%	39%	39%
2C6	Zinc production	5.5%	18%	57%
2B10a	Chemical industry: Other	3.9%	13%	70%
1A3bi	Road transport: Passenger Cars	3.3%	11%	81%

Table 1.11.a Dioxine key source categories identified by 2015 level assessment
(emissions in g I-Teq)

NFR14 Code	Longname	2015	Contribution	Cumulative contribution
2D3i	Other solvent use	13	58%	58%
1A4bi	Residential: Stationary	6.9	32%	90%

Table 1.11.b Dioxine key source categories identified by 1990 level assessment
(emissions in g I-Teq)

NFR14 Code	Longname	1990	Contribution	Cumulative contribution
1A1a	Public electricity and heat production	568	77%	77%
1A4ai	Commercial/institutional: Stationary	100	13%	90%

Table 1.11.c Dioxine key source categories identified by 1990-2015 trend assessment (emissions in g I-Teq)

NFR14 Code	Longname	Trend	Trend contribution	Cumulative trend contribution
1A1a	Public electricity and heat production	2.1%	41%	41%
2D3i	Other solvent use	1.6%	31%	72%
1A4bi	Residential: Stationary	0.9%	17%	89%

Table 1.12.a PAH key source categories identified by 2015 level assessment (emissions in Mg)

NFR14 Code	Longname	2015	Contribution	Cumulative contribution
1A4bi	Residential: Stationary	4.12	87%	87%

Table 1.12.b PAH key source categories identified by 1990 level assessment (emissions in Mg)

NFR14 Code	Longname	1990	Contribution	Cumulative contribution
2C3	Aluminium production	6.9	35%	35%
1A4bi	Residential: Stationary	3.8	19%	54%
2D3d	Coating applications	2.4	12%	66%
2C1	Iron and steel production	1.6	8.3%	74%
2H3	Other industrial processes	1.4	6.9%	81%

Table 1.12.c PAH key source categories identified by 1990-2015 trend assessment (emissions in Mg)

NFR14 Code	Longname	Trend	Trend contribution	Cumulative trend contribution
1A4bi	Residential: Stationary	16%	56%	56%
2C3	Aluminium production	8%	28%	85%

Appendix 2 Planned improvements; quick view

As result of the stage 3 review on the informative inventory report 2015 and 2015 NFR tables, a planning is made on the implementation of actions regarding the issues found. Table A2.1 gives a quick view on the planning of the implementation of actions from the stage 3 review.

Table A2.1 Quick view on the implementation of actions as result of the 2015 stage 3 review

Issue in review report	Planned for	Issue in review report	Planned for
1	See from issue 43 onwards	71	No action necessary
2	See from issue 43 onwards	72	No action necessary
3	See from issue 43 onwards	73	No action necessary
4	See from issue 43 onwards	74	No action necessary
5	See from issue 43 onwards	75	In IIR2016
6	See from issue 43 onwards	76	gradually in IIR's 2016 - 2018
7	See from issue 43 onwards	77	In IIR2016
8	See from issue 43 onwards	78	No action necessary
9	See from issue 43 onwards	79	In IIR2016
10	See from issue 43 onwards	80	In IIR2016
11	See from issue 43 onwards	81	gradually in IIR's 2016 - 2018
12	See from issue 43 onwards	82	gradually in IIR's 2016 - 2018
13	See from issue 43 onwards	83	No action necessary
14	See from issue 43 onwards	84	In IIR2016
15	See from issue 43 onwards	85	No action necessary
16	See from issue 43 onwards	86	No action necessary
17	See from issue 43 onwards	87	No action necessary
18	See from issue 43 onwards	88	No action necessary
19	See from issue 43 onwards	89	In IIR2016
20	See from issue 43 onwards	90	In IIR2016
21	See from issue 43 onwards	91	In IIR2016
22	See from issue 43 onwards	92	gradually in IIR's 2016 - 2018
23	See from issue 43 onwards	93	In IIR2016
24	See from issue 43 onwards	94	No action necessary
25	See from issue 43 onwards	95	In IIR2016
26	See from issue 43 onwards	96	In IIR2016
27	See from issue 43 onwards	97	In IIR2016
28	See from issue 43 onwards	98	In IIR2016
29	See from issue 43 onwards	99	In IIR2016
30	See from issue 43 onwards	100	IIR2017
31	See from issue 43 onwards	101	IIR2017

Issue in review report	Planned for	Issue in review report	Planned for
32	See from issue 43 onwards	102	In IIR2016
33	See from issue 43 onwards	103	IIR2017
34	See from issue 43 onwards	104	No action necessary
35	See from issue 43 onwards	105	No action necessary
36	See from issue 43 onwards	106	In IIR2017 / IIR2018
37	See from issue 43 onwards	107	No action necessary
38	See from issue 43 onwards	108	In IIR2017
39	See from issue 43 onwards	109	No action necessary
40	See from issue 43 onwards	110	No action necessary
41	See from issue 43 onwards	111	In IIR2016
42	See from issue 43 onwards	112	In IIR2016
43	Not settled yet	113	In IIR2016
44	Not settled yet	114	IIR2017
45	No action necessary	115	In IIR2016
46	Not settled yet	116	In IIR2016
47	Not settled yet	117	In IIR2016
48	In IIR2016	118	In IIR2017
49	In IIR2016	119	In IIR2016
50	In IIR2016	120	In IIR2016
51	In IIR2016	121	See Issue 127
52	In IIR2017	122	In IIR2017
53	Not settled yet	123	In IIR2017
54	Not settled yet	124	No action necessary
55	Not settled yet	125	No action necessary
56	In IIR2016	126	In IIR2017
57	Not settled yet	127	In IIR2017
58	Not settled yet	128	In IIR2017
59	In IIR2016	129	In IIR2017
60	No action necessary	130	In IIR2017
61	In IIR2016	131	In IIR2017
62	In IIR2017	132	No action necessary
63	In IIR2018	133	In IIR2016
64	No action necessary	134	In IIR2016
65	In IIR2016	135	In IIR2016
66	In IIR2016	136	In IIR2016
67	In IIR2017	137	In IIR2017
68	In IIR2016	138	In IIR2017
69	In IIR2016	139	In IIR2017
70	In IIR2017		

RIVM

Committed to *health and sustainability*