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

Emissions of transboundary air pollutants *in the Netherlands* *1990-2013*

Informative Inventory Report 2015

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

Emissions of transboundary air pollutants in the Netherlands 1990-2013

Informative Inventory report 2015

RIVM Report 2014-0166

Colophon

B.A. Jimmink, RIVM
P.W.H.G. Coenen, TNO
R. Dröge, TNO
G.P. Geilenkirchen, PBL
A.J. Leekstra, RIVM
C.W.M. van der Maas, RIVM
R.A.B. te Molder, RIVM
C.J. Peek, RIVM
J. Vonk, RIVM
D. Wever, RIVM

Contact:
Benno Jimmink
MIL-L&E
benno.jimmink@rivm.nl

This investigation has been performed by order and for the account of the Ministry of Infrastructure and the Environment, 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

Acknowledgements

Many colleagues from a number of organizations (CBS, LEI, Alterra, RVO.nl, PBL, RIVM and TNO) have been involved in the annual update of the Netherlands Pollutant Release & Transfer Register (PRTR), also called the Emission Registration (ER) system, which contains emission data from over 1000 facilities on about 350 pollutants. The emissions are calculated by members of the ER 'Task Forces'. This is a major task, since the Netherlands' inventory contains many detailed emission sources. Subsequently, the emissions and activity data of the Netherlands' inventory are converted into the NFR source categories and contained in the Excel files. The description of the various sources, the analysis of trends and uncertainty estimates (see Chapters 2 to 9) were made in co-operation with the following emission experts: Mr. Gerben Geilenkirchen (transport), Mr. Peter Coenen and Mrs. Rianne Dröge, (energy), Mr. Kees Peek (industrial processes, solvents and product use) Mr. Jan Vonk (agriculture) and. Mr. Dirk Wever (QA/QC and waste). We are particularly grateful to Mr. Bert Leekstra, Mr. R. te Molder and Mr. Dirk Wever, for their contribution to data processing, chart production and quality control. For their continued support, we acknowledge Mr. M. Taal and Mr. W. Prins in particular, from The Directorate for Climate Change, Air Quality and Noise of the Dutch Ministry of Infrastructure and Environment. For the design and layout of this report, we thank the RIVM's graphic department, in particular Mr. Gert Boer. We greatly appreciate the contributions of each of these groups and individuals to this Informative Inventory Report as well as the contributions of the external reviewers that provided comments on the draft report.

Publiekssamenvatting

Emissions of transboundary air pollutants in the Netherlands 1990-2013

Betere informatie over ammoniakemissies
De berekende ammoniakemissies in Nederland blijven dalen. Wel blijkt voor de periode 1990-2013 dat de totale emissie van ammoniak hoger is dan eerder gerapporteerd. De ammoniak-emissies kunnen dankzij betere waarnemingen nauwkeuriger worden berekend en een aantal nieuwe bronnen zijn toegevoegd. De emissies van stikstofoxiden, zwaveldioxiden en niet methaan vluchtige organische stoffen blijven licht dalen.

RIVM verzamelt en rapporteert de emissiecijfers samen met partnerinstituten in het project Emissieregistratie.

Nieuwe onderzoeksresultaten
Op basis van nieuw onderzoek konden bepaalde emissiefactoren voor ammoniak nauwkeuriger worden berekend. Zo is geconstateerd dat er per varken meer ammoniak wordt uitgestoten dan eerder verondersteld. Daarnaast blijkt de mest die over het land wordt verspreid meer stikstof te bevatten, waardoor er meer ammoniak vrijkomt. Verder is berekend dat de bijdrage van wegverkeer aan de ammoniakuitstoot in Nederland hoger is dan eerder gerapporteerd.

Eén van de bronnen die volgens internationale voorschriften (EMEP Guidebook 2013) nu is meegenomen in de berekeningen, is de uitstoot van ammoniak door gewassen terwijl ze rijpen (‘gewasafrijping’) en na de oogst (‘gewasresten’). Hetzelfde geldt voor de ammoniak die vrijkomt bij het gebruik van compost (zoals van gft-afval) en het slib van rioolwaterzuiveringsinstallaties.

Het RIVM verzamelt en analyseert de cijfers. Behalve bovengenoemde stoffen gaat het om de uitstoot van koolmonoxide, fijn stof, zware metalen en persistente organische stoffen. De uitstoot van al deze stoffen is tussen 1990 en 2013 gedaald. Dit komt vooral door schonere auto’s en brandstoffen en door emissiebeperkende maatregelen in de industrie.

Trefwoorden: emissies, grootschalige luchtverontreiniging, emissieregistratie

Synopsis

Emissions of transboundary air pollutants in the Netherlands 1990-2013

Better information on ammonia emissions

Calculated ammonia emissions in the Netherlands are still declining over time. However as a result of new research ammonia emissions can be calculated more accurate. This shows that over the whole period 1990-2013 these emissions are higher than previously assumed. Emissions of nitrogen oxides, sulphur dioxides and non-methane volatile organic compounds continue to decrease slightly.

RIVM collects together with partner institutes these data within the Dutch Pollutant Release and Transfer Register (PRTR).

New research results

Based on new research specific emission factors for ammonia could be calculated more precisely. For example, it is determined that the ammonia emission per pig is higher than previously known. Manure that is applied contains more nitrogen, resulting in higher ammonia emissions. Furthermore, road traffic emissions are considered to be higher than previously assumed.

In addition, following international guidelines (EMEP Guidebook 2013) emissions from new sources have been included, such as from ripening of crops and from crop residues left on the field. The same holds for ammonia, that is emitted from the application of compost and sewage sludge to soils.

RIVM collects and reports these data. Besides above-mentioned substances, emissions of carbon monoxide, particulate matter (PM10), heavy metals and persistent organic pollutants (POPs) have been reported. The emissions of all substances have decreased during the 1990 – 2013 period. The downward trend may in particular be attributed to cleaner fuels, cleaner car engines and to emission reductions in industry.

Keywords: emissions, transboundary air pollution, emission inventory

Glossary

AER	Annual Environmental Report
CLRTAP	Convention on Long-Range Transboundary Air Pollution
CBS	Statistics Netherlands
CNG	Compressed Natural Gas
DCS	Dutch Continental Shelf
DPF	Diesel particulate filter
EEA	European Environment Agency
EMEP	European Monitoring and Evaluation Programme
ER-I	Emission Inventory data of individual point-source emissions and activities
ERT	Emission Review Team
EU	European Union
HCB	Hexachlorobenzene
IEF	Implied Emission Factor
IenM	Dutch Ministry of Infrastructure and the Environment IIR Informative Inventory Report
LEI	Agricultural Economics Research Institute
LPG	Liquefied petroleum gas
NACE	Nomenclature statistique des activités économiques dans la Communauté européenne
NAP	national car Passport Corporation
NEC	National Emission Ceiling
NEH	Netherlands Energy Statistics
NEMA	National Emission Model for Agriculture
NFR	Nomenclature for Reporting
NIR	National Inventory Report
NMVOC	Non-methane volatile organic compounds
NRMM	Non-Road Mobile Machinery
NS	Dutch Railways
NUSAP	Numeral Unit Spread Assessment Pedigree
PAH	Polycyclic aromatic hydrocarbon
PBL	Netherlands Environmental Assessment Agency
PM	Particulate matter
POP	Persistent organic pollutant
PRTR	Pollutant Release and Transfer Register
Rav	Dutch Ammonia and Livestock Farming Regulation
RDW	national motor vehicle and driving licence registration authority
RLD	Dutch national air traffic service
SPIN	Co-operation project on Industrial Emissions
TAN	Total ammonia nitrogen
TWC	Three-way catalyst
QA/QC	Quality Assurance/Quality Control
RIVM	National Institute for Public Health and the Environment
RVO.nl	Netherlands Enterprise Agency
RWS	Rijkswaterstaat
TNO	Netherlands Organisation for Applied Scientific Research
UNECE	United Nations Economic Commission for Europe
UNFCCC	United Nations Framework Convention on Climate Change
WWTP	Waste Water Treatment Plant

Contents

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 SO_2, NO_X, NMVOC, CO, NH_3 and various heavy metals and POP is prepared using the Guidelines for Estimating and Reporting Emission Data under the CLRTAP (UNECE, 2009).
The Netherlands’ IIR 2015 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 2013, 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. Moreover, this year, the spatial distributions of emission data have been reported, this has to be done every five years. A chapter on the followed methodology has therefore been included.

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 (EEA, 2009), 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 produce an annual set of unequivocal emission data that is up to date, complete, transparent, comparable, consistent and accurate. Emission data are produced in annual (project) cycles (RIVM, 2014; 2015). Various external agencies contribute to the PRTR by performing calculations or submitting activity data (see next section). In addition to the RIVM, the following institutes contribute to the PRTR:

- Netherlands Environmental Assessment Agency (PBL);
- Statistics Netherlands (CBS);
- Netherlands Organisation for Applied Scientific Research (TNO);
- RWS Centre for Water Management (RWS-WD);
- RWS Centre for Transport and Navigation (RWS-DVS);
- Deltares;
- Alterra WUR;
- Wageningen UR Livestock Research;
- RWS Centre for Environment(RWS-Afval);
- 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

1.3.1 Data collection

For the collection and processing of data (according to pre-determined methods), the PRTR is organised according to task forces. The 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).

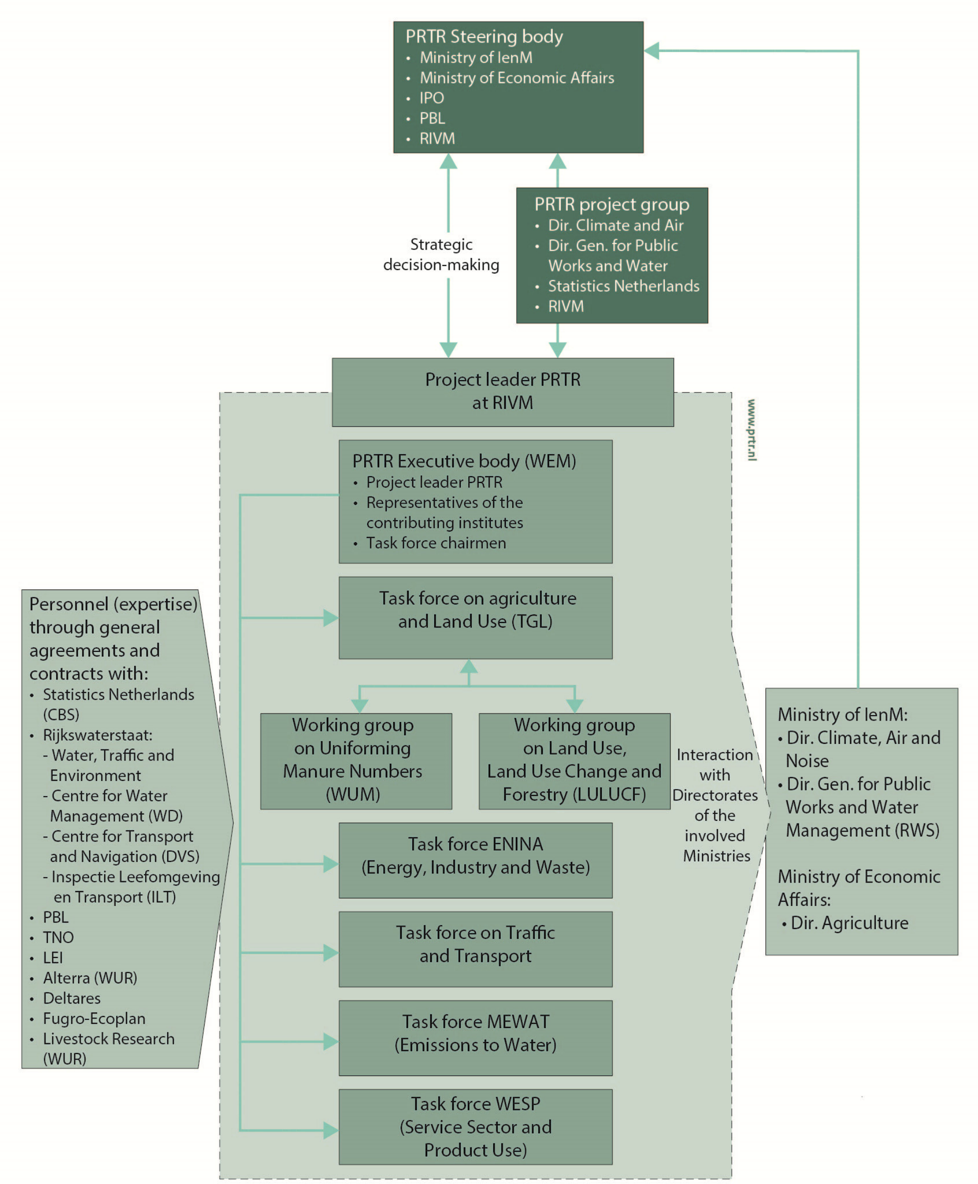


Figure 1.1 The organisational arrangement of the Netherlands Pollutant Release and Transfer Register (PRTR)

1.3.2 *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, 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.

1.3.3 *Data storage*

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

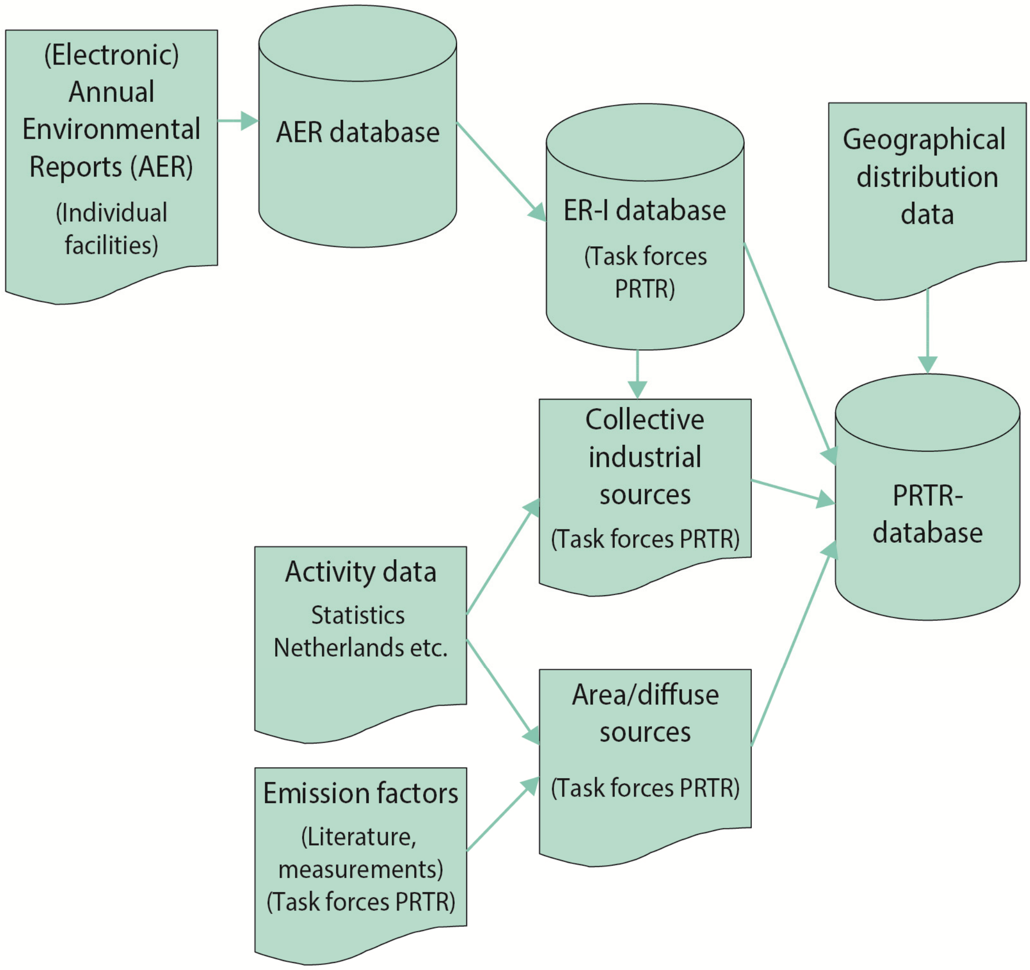


Figure 1.2 The data flow in the Netherlands Pollutant Release and Transfer Register

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 (www.greenhousegases.nl), 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').

1.5 Key source analysis

Following recommendations 9 and 10 from the Stage 3 in-depth review report for the Netherlands (UNECE, 2010), 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, 2009). The level assessments were performed for both the latest inventory year 2013, 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 annual project plans (RIVM, 2014; 2015). The general QA/QC activities meet the international inventory QA/QC requirements described in part A, chapter 6 of the EMEP inventory guidebook (EEA, 2009)
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 2014 inventory the PRTR task forces filled in a standard-format database with emission data from 1990 to 2013. 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 taskforces to resolve the identified clarification issues, are documented at RIVM. Required changes to the database are then made by the taskforces.

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, NH_3, PM_{10} 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.

Table 1.1 Key items of the verification actions data processing 2013 and NFR/IIR 2014.

OC 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.	27-11-2014	RIVM-PRTR	List of remaining issues/actions from last inventory	Actiepunten definitieve cijfers 1990-2013 v 21 nov 2014.xls
Input for checking allocations from de PRTR-database to the NFR tables.	29-10-2014	RIVM-NIC	List of allocations	NFR-ER-Koppellijst-NFR14-2014-10-03.xlsx
Input for error checks	26-11-2014	RIVM-PRTR	Comparison sheets 2012-2013 data	VerschiltabelNieuw_LuchtActueel_25-11-2014.xlsx
Input for trend analysis	01-12-2014	RIVM-PRTR	Updated list of required actions	Actiepunten definitieve cijfers 1990-2013 v 1 dec 2014.xls
Trend analysis workshops	04-12-2013	Sector specialists, RIVM-PRTR	Explanations for observed trends and actions to resolve before finalising the PRTR dataset	– Emissies uit de landbouw 1990-2013.ppt – Presentatie ENINA TrendAnalyse dag 4 dec 2014.ppt – Trendanalyse verkeer 2014.ppt – Trendanalyse WESP 2014.ppt – Presentatie HCB_EC_ENINA TrendAnalyse dag 4 dec 2014.ppt
Input for resolving the final actions before finalising the PRTR dataset	17-12-2014	RIVM-PRTR	Updated Action list	Actiepunten definitieve cijfers 1990-2013 v 17 dec 2014.xls
Request to the contributing institutes to endorse the PRTR database	17-12-2014 till 26-01-2015	PRTR project secretary, Representatives of the contributing institutes	Reactions of the contributing institutes to the PRTR-project leader.	– Email with the request – Actiepunten definitieve cijfers 1990-2013 v 16 jan 2015.xls – Emails with consent from PBL and CBS.
Input for compiling the NEC report (in NFR-format)	18-12-2014	RIVM-NIC	List of allocations for compiling from the PRTR-database to the NFR-tables	NFR-ER-Koppellijst-NFR14-2014-12-10-DTT48-BJ-BL.xlsx
Final PRTR dataset	19-12-2014	PRTR project leader	Updated Action list	Email with approval on the data for reporting.
List of allocations for compiling from the PRTR-database to the NFR-tables	5-03-2015	RIVM	Input for compiling the EMEP/LRTAP report (NFR format)	NFR-ER-Koppellijst-2015-02-02-DTT48_bj.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 2011 from the new time series were compared with the time series of last years' inventory and 2) the data for 2012 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.

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 gives only 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, SO_2 and NH_3 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. Therefore, it is necessary to update the uncertainty assessment. This is foreseen within the next years and results will be presented in the IIR in question. Then also a more detailed uncertainty analyses as suggested by the ERT in their Stage 3 in-depth review will be provided (UNECE, 2010)

1.7.1 *Quantitative uncertainty*

Uncertainty estimates on national total emissions have been reported in the Dutch Environmental Balances since 2000 (PBL, 2009). 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 NH_3, 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 SO_2 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 (SO_2) 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 and 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).

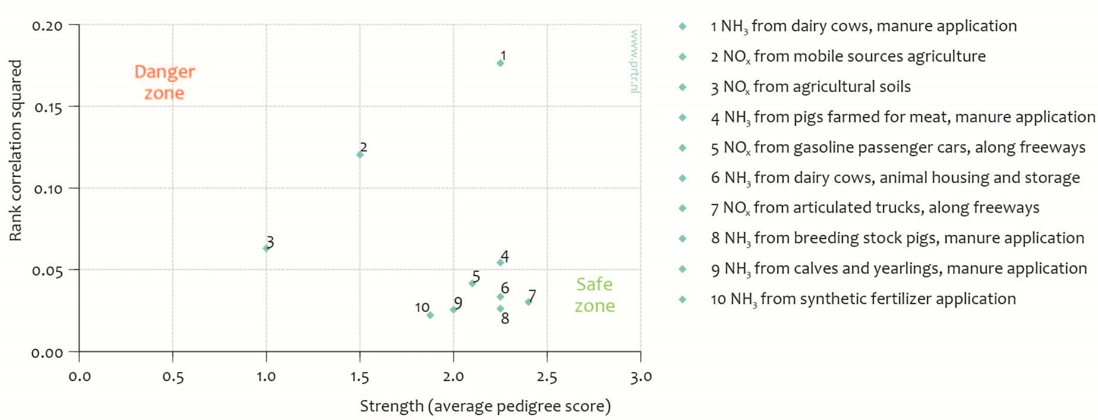


Figure 1.3. NUSAP diagnostic diagram indicating strong and weak elements in the available knowledge on acidifying substances.

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.

Table 1.3 The Not Estimated (NE) notation key explained

NFR code	Substance(s)	Reason for not estimated
1A2fii	Cd, Cr, Cu, Ni	Not in PRTR
1A3bv	Cr, Cu, Zn	Not in PRTR
1A3bvii	Cd, Cr, Cu, Ni, Zn	Not in PRTR
1A3c	Cd	Not in PRTR
1A3di(ii)	Cd	Not in PRTR
1A3dii	Cd	Not in PRTR
1A4aii	Cd-Ni, Zn	Not in PRTR
1A4bii	Pb-Cu, Se, Zn	Not in PRTR
1A4cii	Cd-Ni, Zn	Not in PRTR
1A4ciii	Cd	Not in PRTR
1A5b	Cd	Not in PRTR
2B2	NO_x	Not in PRTR
4B	NMVOC	Not in PRTR
4B2	NO_x, NH_3, TSP, PM_{10}, $PM_{2.5}$	Not in PRTR
4B3	TSP, PM_{10}, $PM_{2.5}$	Not in PRTR
4B7	NO_x, NH_3, TSP, PM_{10}, $PM_{2.5}$	Not in PRTR
6A	NH_3	Not in PRTR
6B	NH_3	Not in PRTR
6Cd	NH_3, Pb, Cd, As-Zn, PAHs, HCB	Not in PRTR
1A3aii(ii)	All	Not in PRTR
1A3ai(ii)	All	Not in PRTR

Table 1.4 The Included Elsewhere (IE) notation key explained

NFR code	Substance(s)	Included in NFR code
1A3aii(i)	All	1A3ai(i)
1A3e	All	1A2fi, 1A4cii, 1B2b
1B1a	TSP, PM_{10}, $PM_{2.5}$	2G
1B2c	NMVOC, TSP, PM_{10}, $PM_{2.5}$, CO	1B2b, 1B2aiv
2A2	NO_x, NMVOC, SO_2	2A7d
2A5	NMVOC	2A7d
2A6	NO_x, NMVOC, SO_2	2A7d
2B1	NMVOC, NH_3	2B5a
2B2	NH_3	2B5a
2B4	NMVOC	2B5a
2C2	All	1A2a
2C5f	All	1A2b
3C	NMVOC	2B5a
4B3	NO_x	4B4
4B9c	NO_x, NH_3, TSP, PM_{10}, $PM_{2.5}$	4B9b
4B9d	NO_x, NH_3, TSP, PM_{10}, $PM_{2.5}$	4B9b
4D1a	NO_x	11C
4D2c	NO_x	11C
4D2c	NH_3	4B
6A	NO_x, NH_3, TSP, PM_{10}, $PM_{2.5}$, CO, PAHs	1A5a
6B	NO_x, NMVOC, NH_3, TSP, PM_{10}, $PM_{2.5}$, CO, PAHs	1A4ai
6Cc	All	1A1a
6Cd	NO_x, SO_2, NH_3, CO	1A4ai

Table 1.5 Sub-sources accounted for in reporting 'other' codes, with NO/NA meaning not occurring or not applicable

NFR code	Substance(s) reported	Sub-source description
1A2f		Combustion (not reported elsewhere) in industries, machineries, services, product-making activities.
1A5a		Combustion gas from landfills
1A5b		Recreational navigation
1B1c		NO/NA
1B3		NO/NA
2A7d		Processes, excl. combustion, in building activities, production of building materials
2B5a		Production of chemicals, paint, pharmaceutics, soap, detergents, glues and other chemical products.
2B5b		NO/NA
2C5e		Production of non-ferrous metals
2C5f		NO/NA
2G		Making products of wood, plastics, rubber, metal, textiles, paper. Storage and handling.
3A3		NO/NA
4B13	NO_x, NH_3, TSP, PM_{10}, $PM_{2.5}$	Pets, rabbits and furbearing animals
4G	NMVOC, Zn	Volatilization of crops and from use of pesticides
6D		Handling waste
7A	NO_x, NH_3, TSP, PM_{10}, $PM_{2.5}$	Smoking tobacco products and burning candles; transpiration, breathing, manure application to private domains and nature, horses and ponies from private owners
7B		NO/NA
11C	NO_x	Volatilization of NO from agricultural and non-agricultural land

1.9 Missing sources

The Netherlands emission inventory covers all sources relevant to the NFR-categories.

2 Trends in emissions

2.1 Trends in national emissions

Following the implementation of new insights in the emission calculation, the Dutch NH_3 emission series are now superseding the national emission ceiling set for the year 2010 (NEC2010). For NO_x, SO_2 and NMVOC the Netherlands is in compliance with the respective ceilings in 2013. The emissions of all substances showed a downward trend in the 1990-2013 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, 66% for PM, 64% for NO_x and 98% for SO_2, despite a growth in road transport of 23%. 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, 1990-2013

	Main Pollutants				Particulate Matter				Other
	NO_x	NMVOC	SO_x	NH_3	$PM_{2.5}$	PM_{10}	TSP	BC	CO
Year	Gg	Gg	Gg	Gg	Gg	Gg	Gg	Gg	Gg
1990	574	483	192	373	46	70	93	14	1141
1995	475	340	129	230	34	52	70	11	890
2000	395	239	73	182	25	40	49	9	755
2005	341	178	65	160	20	34	42	7	727
2010	274	158	34	144	15	29	36	5	679
2013	240	150	30	134	13	27	35	4	621
1990-2013 period [1]	-334	-333	-162	-239	-34	-43	-58	-10	-520
1990-2013 period [2]	-58%	-69%	-84%	-64%	-72%	-62%	-63%	-74%	-46%

[1] Absolute difference in Gg

[2] Relative difference to 1990 in %

	Priority Heavy Metals			POPs		Other Heavy Metals					
	Pb	Cd	Hg	DIOX	PAH	As	Cr	Cu	Ni	Se	Zn
Year	Mg	Mg	Mg	g I-Teq	Mg	Mg	Mg	Mg	Mg	Mg	Mg
1990	337	2.1	3.5	742	20	1.5	12	37	75	0.4	224
1995	155	1.1	1.4	66	10	1.0	8.5	39	87	0.3	146
2000	28	0.9	1.0	31	5.1	1.1	5.0	40	19	0.5	95
2005	30	1.7	0.9	29	5.1	1.5	4.3	42	11	2.6	88
2010	38	2.5	0.5	31	4.9	0.8	3.7	46	2	1.5	110
2013	14	0.6	0.5	25	4.7	0.9	3.6	43	2	0.5	99
1990-2013 period [1]	-323	-1.5	-3.0	-717	-16	-0.5	-8.2	5.4	-73	0.1	-125
1990-2013 period [2]	-96%	-70%	-85%	-97%	-77%	-36%	-70%	15%	-97%	28%	-56%

[1] Absolute difference in Gg

[2] Relative difference to 1990 in %

2.2 Trends in sulphur dioxide (SO_2)

The Dutch SO_x emissions (reported as SO_2) decreased by 162 Gg in the 1990-2013 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 96% of the national SO_2 emissions.

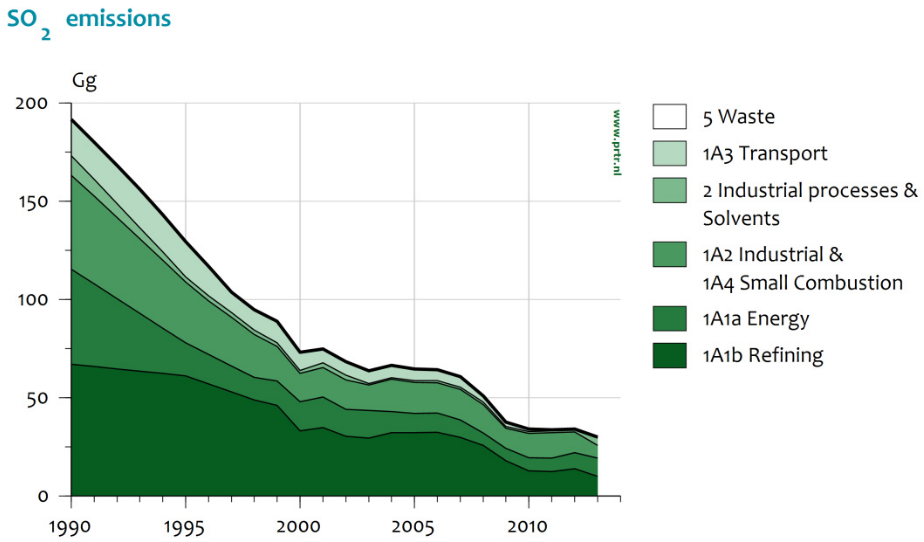


Figure 2.1 SO_2, emission trend 1990-2013

2.3 Trends in nitrogen oxides (NO_x)

The Dutch NO_x emissions (NO and NO_2, expressed as NO_2) decreased by 334 Gg in the 1990-2013 period, corresponding to 58% of the national total in 1990 (Figure 2.2). Main contributors to this decrease are the road-transport and energy sectors. 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.

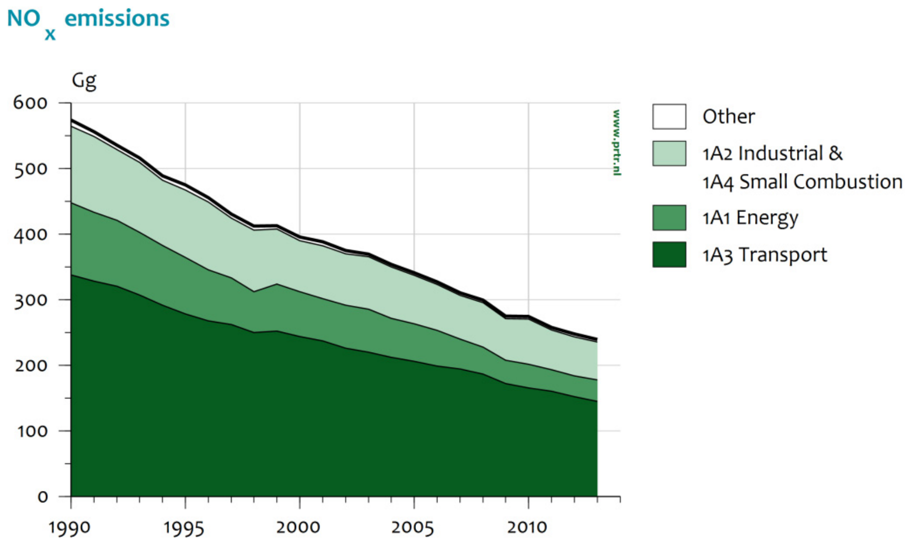


Figure 2.2 NO_x, emission trend 1990-2013

2.4 Trends in ammonia (NH_3)

The Dutch NH_3 emissions decreased by 239 Gg in the 1990-2013 period, corresponding to 64% of the national total in 1990 (Figure 2.3). This decrease was due to emission reductions from agricultural sources. The direct emissions from animal husbandry decreased slightly because of decreasing animal population and measures to reduce emissions from animal houses. Application emissions decreased because of measures taken to reduce the emissions from applying manure to soil and to reduce the total amount of N applied to soil. At present, 90% of Dutch NH_3 emissions come from agricultural sources.

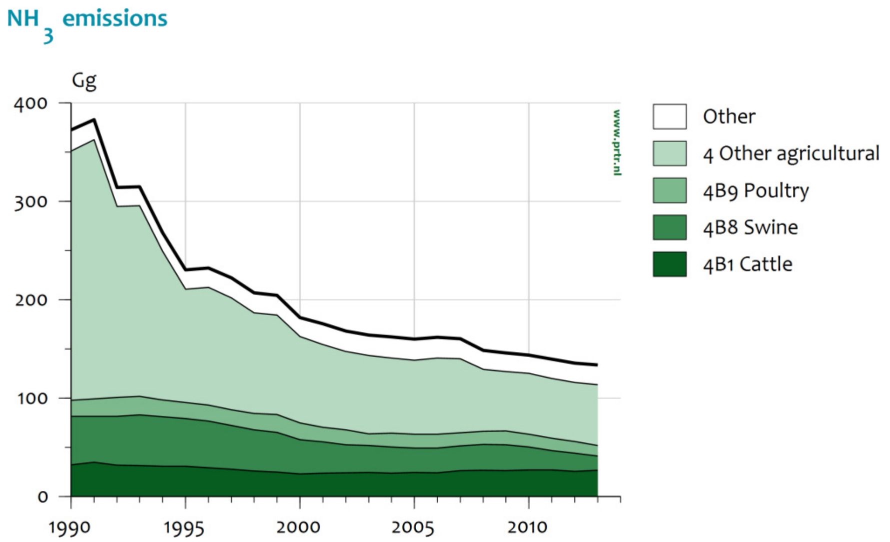


Figure 2.3 NH_3, emission trend 1990-2013

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

The Dutch NMVOC emissions decreased by 333 Gg in the 1990-2013 period, corresponding with 69% 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).

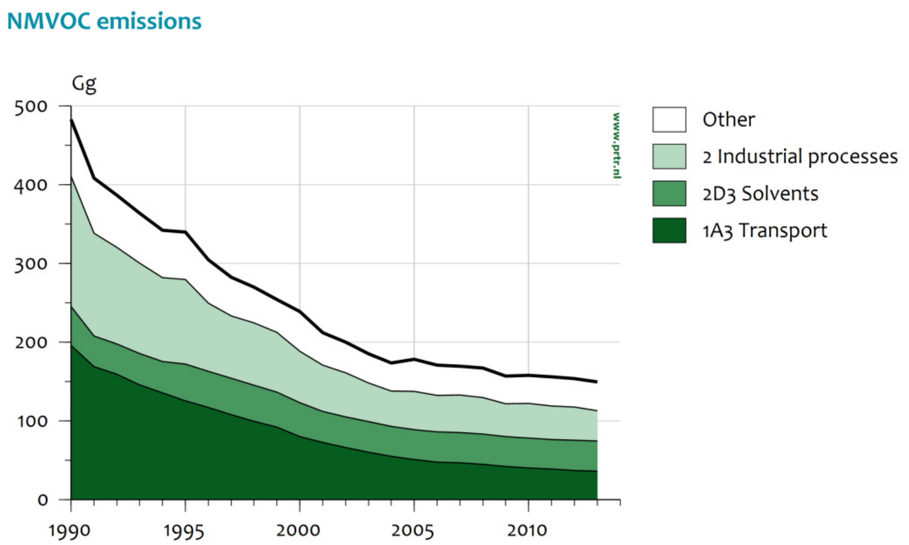


Figure 2.4 NMVOC, emission trend 1990-2013

2.6 Trends in $PM_{2.5}$

$PM_{2.5}$ emissions are calculated as a specific fraction of PM_{10} by sector (based on Visschedijk et al., 1998) and decreased by 34 Gg in the 1990-2013 period, corresponding with 72% of the national total in 1990 (Figure 2.6). 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 SO_2 and NO_x and the transport sector.

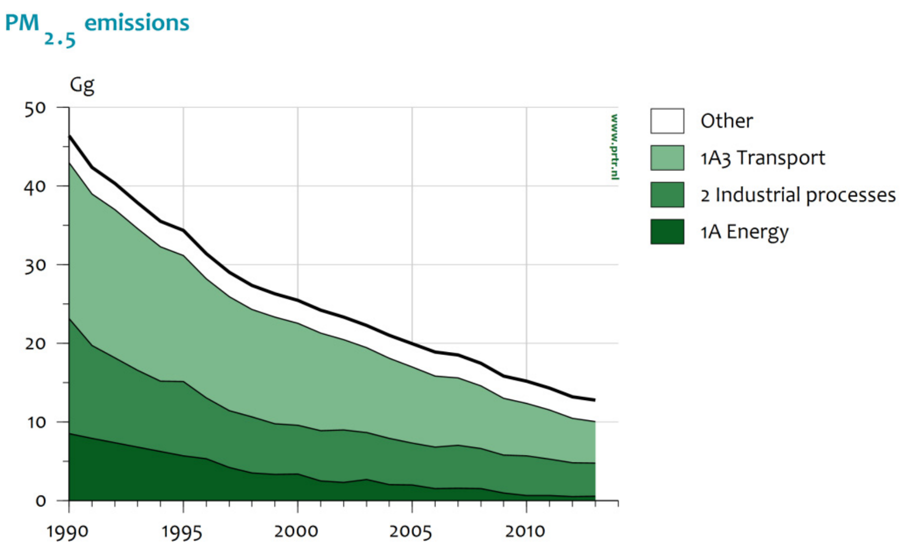


Figure 2.5 $PM_{2.5}$, emission trend 1990-2013

2.7 Trends in PM_{10}

Dutch PM_{10} emissions decreased by 43 Gg in the 1990-2013 period, corresponding with 62% of the national total in 1990 (Figure 2.5). 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 SO_2
- and NO_x ;
- traffic and transport.

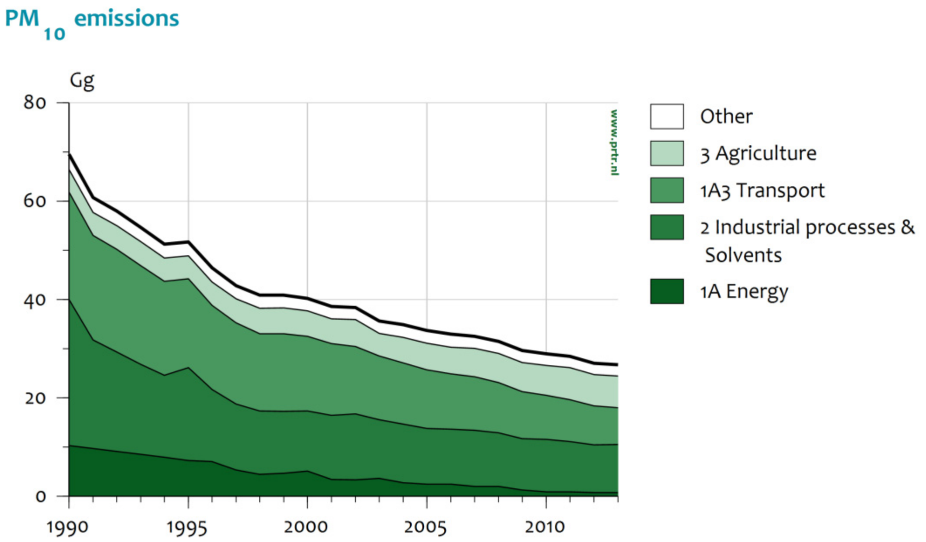


Figure 2.6 PM_{10}, emission trend 1990-2013

PM_{10} 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 1990-2013 period, corresponding with 96% 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.

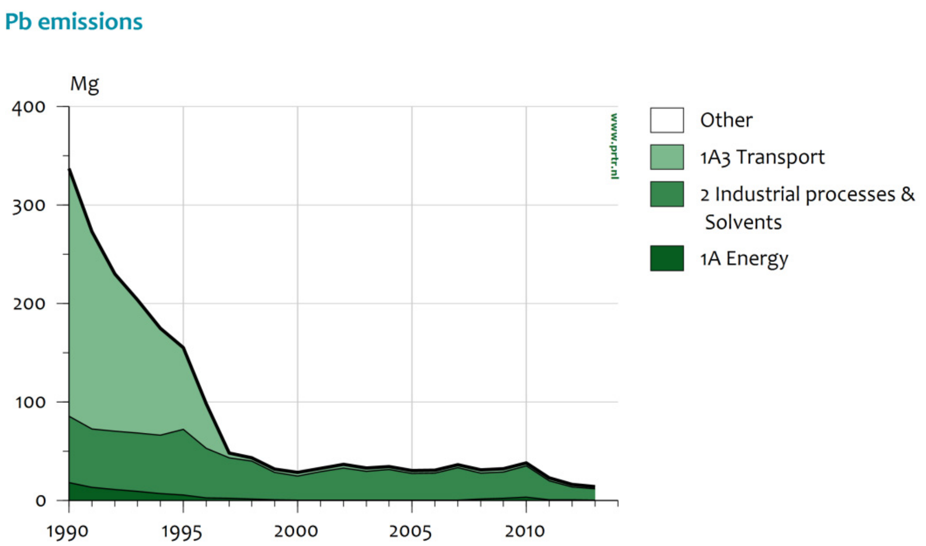


Figure 2.7 Pb emission trend 1990-2013

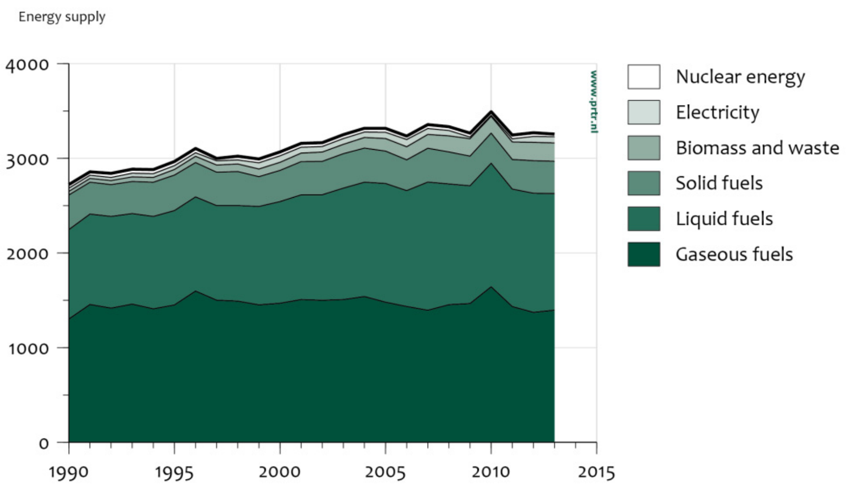
3 Energy

3.1 Overview of sector

Emissions from this sector include all energy-related emissions from industrial activities and transport. Furthermore, they include fugitive emissions from the energy sector.

About 84% to 98% of the NO_x, SO_2, PM, NMVOC and NH_3 emissions from stationary combustion for electricity production and industry (categories 1A1 and 1A2) are reported based on environmental reports by large industrial companies. 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 2013, natural gas supplied about 43% of the total primary fuels used in the Netherlands, followed by liquid fuels (38%) and solid fossil fuels (11%). The contribution of non-fossil fuels, including renewables and waste streams, is rather limited (6%). Figure 3.1 shows the energy supply and energy demand in the Netherlands.



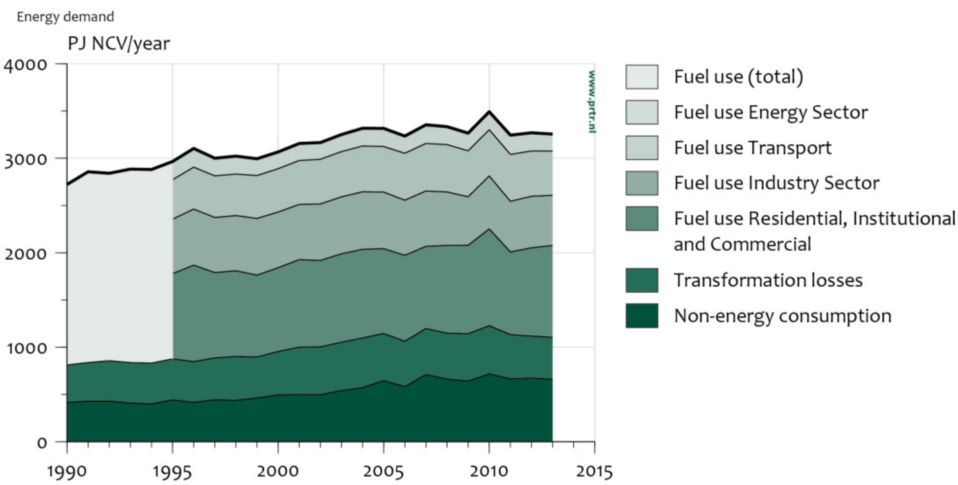


Figure 3.1 Energy supply and demand in the Netherlands. For the years 1990 – 1994, only the total fuel use is shown.

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 (NFR 1A1a) sector is a key source

Category / Sub-category	Pollutant	Contribution to national total 2013 (%)
1A1a Public electricity and heat production	SO_x	31.4
	NO_x	9.2
	Hg	33.0

3.2.3 *Overview of shares and trends in emissions*

An overview of the trends in emissions is shown in Table 3.2. For almost all pollutants emissions decreased between 1990 and 2013, while fuel consumption increased over the same period.
The NO_x and SO_x emissions decreased by 73% and 81%. 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, NH_3 and Se due to an increase in activity rate.

Table 3.2 Overview of trends in emissions

	Main Pollutants				Particulate Matter				Other	Priority Heavy Metals		
	NO_x	NMVOC	SOx	NH_3	$Pm_{2.5}$	PM_{10}	TSP	BC	CO	Pb	Cd	Hg
Year	kt	kt	kt	kt	kt	kt	kt	kt	kt	Mg	Mg	Mg
1990	83	0.7	48	0	1.9	2.2	2.5	0.00	8.2	16	0.95	1.92
1995	62	1.1	17	0.04	0.39	0.62	0.98	0.00	7.4	1.6	0.16	0.38
2000	52	2.2	15	0.04	0.27	0.32	0.32	0.00	15.8	0.18	0.08	0.40
2005	43	0.6	9.9	0.25	0.44	0.54	0.82	0.00	8.2	0.24	0.09	0.38
2010	26	0.3	6.7	0.07	0.27	0.34	0.68	0.00	5.0	0.34	0.18	0.22
2013	22	2.3	9.4	0.08	0.20	0.29	0.74	0.00	5.8	0.44	0.04	0.17
1990-2013 period 1)	-61	1.7	-39	0.08	-1.7	-1.9	-1.7	0	-2.4	-16	-0.91	-1.75
1990-2013 period 2)	-73%	241%	-81%		-89%	-87%	-70%		-29%	-97%	-96%	-91%

	POPs			Other Heavy Metals					
	DIOX	PAH	HCB	As	Cr	Cu	Ni	Se	Zn
Year	g I-Teq	t	t	t	t	t	t	t	t
1990	568	0.17	45	0.50	0.62	2.05	2.49	0.02	41
1995	6.0	0.05	0.58	0.20	0.37	0.44	1.41	0.05	3.34
2000	0.1	0.00	0.98	0.08	0.19	0.17	0.08	0.45	0.26
2005	0.7	0.01	1.05	0.16	0.33	0.28	1.91	1.68	0.44
2010	1.2	0.01	1.39	0.11	0.14	0.15	0.16	1.33	11
2013	0.9	0.02	1.66	0.10	0.20	0.23	0.15	0.43	15
1990-2013 period 1)	-567.1	-0.15	-43	-0.40	-0.42	-1.82	-2.34	0.41	-26
1990-2013 period 2)	-99.8%	-86%	-96%	-80%	-68%	-89%	-94%	2104%	-63%

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, 80% 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.

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

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 3.3).

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

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 3.3 Emission factors for electricity production (g/GJ)

	Natural gas	Biogas	Cokes	Domestic fuel oil	LPG	Petroleum	Coal	Oil fuel
VOC	12	8	91	15	2	10	3	7
SO_2		2	370	87		46	300	450
NO_x	1)	1)	1)	1)	1)	1)	1)	1)
CO	15	20	12437	30	10	10	50	10
PM_{10}	0.15	2	6	4.5	2	1.8	60	22.5
PM coarse			4	0.5		0.2	40	2.5

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

3.2.6 *Uncertainties and time-series 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 1.3 on QA/QC), the information is used.

3.2.8 *Source-specific recalculations*
Emissions of the following sources have been recalculated:

- $PM_{2.5}$ emissions of some sources have been recalculated, as a result of error corrections

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 2013 (%)
1A1b Petroleum refining	SO_x	33.2
1A2c Stationary combustion in manufacturing industries and construction: Chemicals	NO_x	4.1
1A2gviiiStationary combustion in manufacturing industries and construction: Other	SO_x Hg	8.8 11.2

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 NH_3 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 SO_2 and PM_{10} is mainly caused by a shift in fuel use by refineries from oil to natural gas.

Table 3.5 Overview of trends in emissions

	Main Pollutants				Particulate Matter				Other	Priority Heavy Metals		
	NO_x	NMVOC	SOx	NH_3	$PM_{2.5}$	PM_{10}	TSP	BC	CO	Pb	Cd	Hg
Year	kt	kt	kt	kt	kt	kt	kt	kt	kt	Mg	Mg	Mg
1990	101	6.5	110	0.58	6.6	8.1	8.9	0.37	267	1.89	0.14	0.18
1995	78	7.0	90	0.33	5.3	6.7	7.0	0.36	215	3.88	0.17	0.08
2000	49	2.2	46	0.05	3.1	4.8	4.8	0.29	161	0.04	0.01	0.11
2005	49	2.6	46	0.06	1.5	1.9	2.1	0.11	154	0.01	0.00	0.00
2010	40	3.9	24	0.45	0.40	0.53	0.77	0.02	124	3.08	1.28	0.02
2013	36	3.5	18	0.39	0.34	0.48	0.62	0.01	91	0.11	0.00	0.07
1990-2013 period 1)	-65	-3.0	-92	-0.19	-6.3	-7.6	-8.3	-0.36	-234	-1.77	-0.14	-0.12
1990-2013 period 2)	-64%	-46%	-83%	-33%	-95%	-94%	-93%	-98%	-88%	-94%	-99%	-64%

	POPs			Other Heavy Metals					
	DIOX	PAH	HCB	As	Cr	Cu	Ni	Se	Zn
Year	g I-Teq	t	t	t	t	T	t	t	t
1990	0.01	1.02	45	0.17	2.5	1.4	65	0.04	2.9
1995	1.02	0.38	0.58	0.15	3.1	2.3	80	0.05	3.5
2000	0.35	0.00	0.98	0.00	0.51	0.15	17	0.00	0.8
2005	0.94	0.10	1.05	0.78	0.08	0.09	6.5	0.08	0.5
2010	5.79	0.13	1.39	0.01	0.14	1.13	0.02	0.12	9.8
2013	0.22	0.09	1.66	0.01	0.01	0.01	0.16	0.00	1.1
1990-2013 period 1)	0.21	-0.92	-43	-0.17	-2.5	-1.4	-64	-0.04	-1.9
1990-2013 period 2)		-91%	-96%	-96%	-100%	-100%	-100%	-100%	-64%

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, 90% of the CO emissions and 20% of the SO_x emissions are collectively estimated (in 2013).

Non-ferrous metals (1A2b)
Emission data have been based on AERs and collectively estimated industrial sources. For this source category, 16% of the NMVOS emission, 8% of the NO_x emissions and 25% of the SO_x emissions are collectively estimated (in 2013).

Chemicals (1A2c)
Emission data have been based on AERs and collectively estimated industrial sources. For this source category, 4% of the NO_x and SO_x emissions and 2% of the PM and NMVOC emissions are collectively estimated (in 2013).

Pulp, paper and print (1A2d)
Emission data have been based on AERs and collectively estimated industrial sources. For this source category, 50% NMVOC emissions, 12% of NO_x emissions and 7% of the CO emissions are collectively estimated (in 2013).

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.

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

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).

$$\textbf{ER-C\_emission}_{(NACE,\ fuel)} = \textbf{EF ER-I}_{(NACE,\ fuel)} * \textbf{Energy Statistics}_{(NACE,\ fuel)}$$

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)

	Natural gas	**Biogas**	**Cokes**	**Domestic fuel oil**	**LPG**	**Petroleum**	**Coal**	**Oil fuel**
VOC	12	8	91	15	2	10	3	7
SO_2		2	370	87		46	300	450
NO_x	1)	1)	1)	1)	1)	1)	1)	1)
CO	15	20	12437	30	10	10	50	10
PM_{10}	0.15	2	6	4.5	2	1.8	60	22.5
PM coarse			4	0.5		0.2	40	2.5

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

3.3.6 *Uncertainties and time-series 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 1.3 on QA/QC), the information was used.

3.3.8 Source-specific recalculations

Emissions of the following sources have been recalculated:

- Emissions of HCB have been calculated for the combustion coal and wood.
- Emissions of Black Carbon have been calculated for the iron and steel sector and for the refineries.
- PM2,5 emissions of some sources have been recalculated, as a result of error corrections

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 2013 (%)
1A4ai Commercial/institutional, stationary	NO_x	4.8
1A4bi Residential, stationary	NO_x	4.2
	NMVOC	7.7
	CO	12.6
	PM_{10}	8.0
	$PM_{2.5}$	15.9
	Cd	9.2
	Hg	6.5
1A4ci Agriculture/forestry/fishing, stationary	NO_x	4.4

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

	Main Pollutants				Particulate Matter				Other	Priority Heavy Metals		
	NO_x	NMVOC	SOx	NH_3	$PM_{2.5}$	PM_{10}	TSP	BC	CO	Pb	Cd	Hg
Year	kt	kt	kt	kt	kt	kt	kt	kt	kt	Mg	Mg	Mg
1990	74	21	6.5	0.006	4.5	4.8	7.5	1.7	110	0.84	0.07	0.12
1995	82	22	4.6	0.007	4.2	4.5	7.0	1.7	132	0.15	0.05	0.04
2000	75	20	3.4	0.006	3.7	3.9	6.3	1.5	131	0.10	0.05	0.03
2005	63	19	3.2	0.005	3.4	3.6	5.9	1.3	131	0.13	0.05	0.03
2010	57	18	1.0	0.005	2.9	3.0	5.3	1.0	131	0.11	0.05	0.03
2013	47	17	0.8	0.004	2.7	2.8	5.1	0.9	130	0.11	0.06	0.03
1990-2013 period 1)	-27	-4	-5.7	-0.002	-1.8	-2.0	-2.5	-0.8	20	-0.72	-0.01	-0.08
1990-2013 period 2)	-36%	-18%	-87%	-29%	-41%	-42%	-33%	-46%	18%	-87%	-19%	-71%

	POPs			Other Heavy Metals					
	DIOX	PAH	HCB	As	Cr	Cu	Ni	Se	Zn
Year	g I-Teq	t	t	t	t	t	t	t	t
1990	108.7	1.38	0.07	0.06	3.60	0.77	4.35	0.005	2.14
1995	8.4	1.38	0.07	0.02	0.11	0.38	2.26	0.003	0.85
2000	7.6	1.34	0.07	0.01	0.01	0.34	0.19	0.00	0.75
2005	7.2	1.40	0.08	0.02	0.04	0.39	1.07	0.001	0.87
2010	7.0	1.39	0.09	0.01	0.01	0.39	0.04	0.00	0.88
2013	7.0	1.40	0.10	0.01	0.01	0.41	0.08	0.00	0.90
1990-2013 period 1)	-101.7	0.02	0.03	-0.05	-3.59	-0.37	-4.27	-0.005	-1.24
1990-2013 period 2)	-94%	1%	45%	-81%	-100%	-48%	-98%	-98%	-58%

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 and agriculture (g/GJ)

	Natural gas	Domestic fuel oil	LPG	Paraffin oil	Coal	Oil fuel
VOC	30	10	2	10	35	10
SO2	0.22	87	0.22	4.6	460	450
NOx	1)	50	40	50	300	125
CO	10	10	10	10	100	10
Carbon black		5	10	2		50
Fly ash					100	
PM10	0.15	4.5	2	1.8	2	45
PM coarse		0.5		0.2	80	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)

	Natural gas	Domestic fuel oil	LPG	Paraffin oil	Coal
VOC	6.3	15	2	10	60
SO_2	0.22	87	0.22	4.6	420
NO_x	1)	50	40	50	75
CO	15.8	60	10	10	1500
Carbon black	0.3	5	10	2	
Fly ash					200
PM_{10}	0.3	4.5	2	1.8	120
PM coarse		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 3.9).

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 time-series 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:
- Emissions of HCB have been calculated for the combustion coal and wood.
- Emissions of Black Carbon have been calculated for residential wood combustion for the whole time series.
- Emissions of NO_x from combustion of natural gas in households and in the agricultural sector have been recalculated with new emission factors (Kok, 2014)
- Emissions from residential combustion of natural gas, wood and other fuels have been recalculated due to updated activity data for the whole time series.
- Emissions from meat consumption has been recalculated due to updated activity data for the last years.
- Activity data of natural gas combustion in the institutional sector (1A4ai) and the agricultural sector (1A4ci) have been updated for the year 2012, and the emissions have been recalculated based on the new activity data.

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 3.11.

Table 3.11 Pollutants for which the Fugitive emissions category (NFR 1B) is a key source sector

Category / Sub-category		Pollutant	Contribution to total of 2013 (%)
1B2ai	Oil and gas production	NMVOC	5.4
1B2aiv	Refining	NMVOC	8.8

3.5.3 *Overview of shares and trends in emissions*

An overview of the trends in emissions is shown in Table 3.12. The emissions from NMVOC decreased between 1990 and 2013.

Table 3.12 Overview of trends in emissions

	NMVOC	PAH
Year	kt	kt
1990	47	0.015
1995	34	0.063
2000	29	0
2005	21	0.039
2010	15	0
2013	16	0
1990-2013 period 1)	-32	-0.015
1990-2013 period 2)	-67%	-100%

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 NMVOC 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 NMVOC emissions from category 1B2aiv comprise dissipation losses from gasoline service stations, leakage losses during vehicle and airplane refueling and refinery processes. Emissions were calculated based on annual fuel consumption (Tier-2 methodology).

The fugitive NMVOC emissions from category 1B2b comprise emissions from gas transport (compressor stations) and gas distribution networks (pipelines for local transport). The NMVOC emissions from gas transport were completely derived from the companies' environmental reports (Tier-3 methodology). The NMVOC emissions from gas distribution were calculated on the basis of a NMVOC profile with the CH_4 emission from annual reports of the sector as input (Tier-2 methodology).

3.5.6 *Uncertainties and time-series consistency*

Uncertainties are explained in Section 1.7.

3.5.7 Source-specific QA/QC and verification
General QA/QC is explained in Section 1.3.

3.5.8 Source-specific recalculations
Emissions of the following sources have been recalculated:

- NMVOC emissions from oil production (1B2ai) in 2010 and gas transport (1B2b) in 2012 have been updated, due to improved data from the companies' environmental reports.

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 national emissions of NO_x, NMVOC, CO, TSP, PM_{10} and $PM_{2.5}$. Emissions of most compounds have decreased throughout the time series, mainly due to the introduction of increasingly stringent European emission standards for new road vehicles. The source category 1A3 'Transport' 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, road transport and water-borne navigation were calculated based on fuel used, whereas emissions from railways were calculated using fuel sales data.

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

NFR code	Source category description	Method	AD	EF	Basis
1A3a	Civil Aviation	Tier 3	NS	CS	Fuel used
1A3b	Road Transport	Tier 3	NS	CS	Fuel used
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

This chapter also covers emissions from 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, 1A4aii, 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 were reported under 1A5b 'Other, mobile' and were calculated using a Tier-3 methodology. 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 of the different source categories within the transport sector are described. 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).

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 2013 level and the 1990-2013 trend (in italics) assessment. Some source categories are key sources for both the trend and the 2013 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 italic 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)								11.6%
1A3aii(i)	Domestic aviation LTO (civil)								
1A3bi	Passenger cars	*4.5%*	*27.0%*	*16.6%*	42.7%	*5.2%*	9.0%	19.6%	*45.0%*
1A3bii	Light duty vehicles		5.6%	*2.6%*	*7.9%*	3.9%	8.1%	23.5%	
1A3biii	Heavy duty vehicles and buses	*8.2%*	18.2%			*7.2%*	*9.8%*	*29.9%*	
1A3biv	Mopeds and motorcycles			6.8%	*14.5%*				
1A3bv	Gasoline evaporation			*9.4%*					
1A3bvi	Automobile tyre and brake wear					5.2%	*2.3%*		
1A3bvii	Automobile road abrasion					4.2%			
1A3c	Railways								
1A3di(ii)	International inland waterways		7.0%				3.8%	*6.4%*	

1A3dii	National navigation (shipping)	*6.1%*		*3.1%*	*6.8%*
1A2gvii	Mobile Combustion in manufacturing industries and construction	4.0%		3.1%	5.5%
1A4aii	Commercial/institutional: mobile				
1A4bii	Residential: household and gardening (mobile)		*7.7%*		
1A4cii	Agriculture/forestry/fishin g: off-road vehicles and other machinery	3.7%		3.0%	
1A4ciii	Agriculture/forestry/fishin g: 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 1A3a 'Civil Aviation' comprises emissions from all landing and take-off cycles (LTO) from domestic (1A3aii) and international (1A3ai) aviation in the Netherlands, excluding military aviation. It also includes emissions from auxiliary power units (APU) used at Amsterdam Airport Schiphol, and emissions from the storage and transfer of kerosene. It does not include emissions from vehicles operating at airports (platform traffic), since these vehicles are classified as mobile machinery. Cruise emissions of domestic and international aviation (i.e. all emissions occurring above 3.000 ft.) are not part of the national totals and were not estimated.

4.2.2 Key sources

International civil aviation is a key source for lead (2013 level and trend) in the emission inventory.

4.2.3 Overview of shares and trends in emissions

Fuel consumption in civil aviation (including APU) has more than doubled between 1990 and 2013, increasing from 4.9 to 10.4 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 an 8% decrease in 2009 due to the economic crisis, fuel consumption increased again between in 2010 and 2011 and was approximately at pre-crisis levels in 2011. In 2013, total fuel consumption by civil aviation at Schiphol Airport increased slightly (+0.2%). These trends are in line with the trend in the number of flights at Schiphol (+0.5% in 2013 compared to 2012).

Fuel consumption in civil aviation at regional airports in the Netherlands was fairly constant at 0.4-0.5 PJ between 1990 and 2003. After 2003 fuel consumption increased steadily to 0.8 PJ in 2013. 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 156% since 2003 to 1.6 million in 2013, whereas the number of passengers at Eindhoven Airport increased from 0.4 million to 3.4 million in this time span.

Table 4.3: Trends in emissions from 1A3a Civil Aviation

	Main Pollutants				Particulate Matter				Other	Priority Heavy Metals
	NO_x	NMVOC	SO_x	NH_3	$PM_{2.5}$	PM_{10}	TSP	BC	CO	Pb
Year	Gg	Gg	Gg	Gg	Gg	Gg	Gg	Gg	Gg	Mg
1990	1.4	0.4	0.1	0.001	0.03	0.03	0.03	0.02	3.48	2.55
1995	1.8	0.4	0.1	0.001	0.04	0.04	0.04	0.03	3.93	2.81
2000	2.4	0.3	0.2	0.002	0.04	0.05	0.05	0.03	4.33	2.97
2005	2.8	0.2	0.2	0.002	0.04	0.05	0.05	0.03	3.85	2.12
2010	2.8	0.2	0.2	0.002	0.04	0.05	0.05	0.03	4.20	2.45
2013	3.0	0.3	0.2	0.002	0.04	0.06	0.06	0.03	3.58	1.64
1990-2013 period 1)	1.7	-0.1	0.1	0.001	0.02	0.02	0.02	0.01	0.10	-0.91
1990-2013 period 2)	123%	-33%	77%	111%	55%	74%	74%	53%	3%	-36%

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 associated fuel consumption in the past 23 years has led to an increase in emissions of NO_x, SO_x, NH_3, TSP, PM_{10}, $PM_{2.5}$, BC and CO. 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 2013, following the trend in fuel consumption. Fleet average PM_{10} emission factors (per unit of fuel) have decreased significantly (+/-30%) since 1990, but since total fuel consumption more than doubled between 1990 and 2013 total PM exhaust emissions also increased throughout the time series. PM_{10} emissions due to tyre and brake wear increased by 197% between 1990 and 2013, in line with the increase in the maximum permissible take-off weight (MTOW) of the airplanes. The share of tyre and break wear in PM_{10} emissions from civil aviation increased from 2.5% to 4.8% between 1990 and 2013.

Civil aviation is a small emission source in the Netherlands and is only a key source for Pb. Aviation gasoline still contains lead, whereas gasoline for other transport purposes has been unleaded for quite some time. With Pb emissions from other source categories decreasing substantially, the share of civil aviation in Pb emissions in the Netherlands increased to 12% in 2013, thereby becoming a key source in the 2013 level assessment. The share of civil aviation in total emissions of NO_x (1.3%) and other substances (<1%) in the Netherlands is very small.

4.2.4 *Activity data and (implied) emission factors*

The exhaust emissions of CO, NMVOC, NO_x, PM, SO_2 and heavy metals from civil aviation in the Netherlands were calculated using a 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 EMASA model from TNO to calculate fuel consumption and resulting emissions (see also Klein *et al.*, 2015). The EMASA 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 EMASA were taken from the ICAO Engine Emissions DataBank (http://www.caa.co.uk/default.aspx?catid=702). The EMASA database also contains a number of emission factors for smaller engines determined by the EPA and published in the AP42 (EPA, 1985).

Per group of aircraft engines the PM emission factors were calculated from 'Smoke Numbers' according to the method described in a Eurocontrol report (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 are multiplied by a factor of two. The $PM_{2.5}/PM_{10}$ ratio for combustion emissions is assumed to be 1.0. The 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). Emissions of different VOC and PAH species were calculated using species profiles as reported in Klein *et al*. (2015).

The duration of the different flight modes (except the Idle mode) was derived from the 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 of Auxiliary Power Units (APUs) were calculated based on the estimated quantity of fuel that is consumed during power generation. The quantity of fuel that is used per arriving and departing passenger is estimated at 500 g. NMVOC emissions from storage and transfer of kerosene were derived from the total volume of kerosene that was delivered annually. Because the kerosene at Schiphol airport is transferred multiple times, the volume of vapour is multiplied with a specific factor (the turnover factor). At Schiphol airport, the average turnover factor is approximately 3. One cubic metre of kerosene vapour contains approximately 12 grams of hydrocarbons. This amount has been experimentally measured by TNO.

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 1A3i 'International aviation'.

The methodology for calculating fuel consumption and resulting emissions from Auxiliary Power Units (APUs) needs to be updated. 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*

There was no accurate information available for assessing the uncertainties of the emissions from civil aviation. 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 Subsection 4.2.3. Agreement between both is good.

4.2.8 *Source-specific recalculations*

In this year's submission, the emissions of SO_x by civil aviation have been recalculated using adjusted sulphur contents for both kerosene and avgas. Based on a study by Eurocontrol (2001), the sulphur content for kerosene has been adjusted to 0.84 g SO_2/kg fuel. Previously, the sulphur content of kerosene was assumed to be 0.4 g/kg. The sulphur content of aviation gasoline has been brought in line with the sulphur content of gasoline for road transport. As a result, total SO_x emissions of civil aviation have increased from 0.1 Gg in last year's submission to 0.2 Gg in this year's submission for recent years of the time series.

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 1A3b 'Road Transport' comprises all 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.

4.3.2 *Key sources*

The different source categories within Road Transport are key sources for many substances in both the trend assessment and the 1990 and 2013 level assessment, as is shown in Table 4.4.

Table 4.4: Key source analysis for road transport subcategories

Source category		**1990 level**	**2013 level**	**1990-2013 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	SO_x, NO_x, NMVOC, CO, PM_{10}, $PM_{2.5}$, BC, Pb
1A3b ii	Light duty vehicles	NO_x, CO, PM_{10}, $PM_{2.5}$, BC	NO_x, PM_{10}, $PM_{2.5}$, BC	NO_x, NMVOC, CO, BC
1A3b iii	Heavy duty vehicles and buses	SO_x, NO_x, PM_{10}, $PM_{2.5}$, BC	NO_x, $PM_{2.5}$, BC	SO_x, NO_x, PM_{10}, $PM_{2.5}$, BC
1A3b iv	Mopeds and motorcycles	NMVOC, CO	NMVOC, CO	NMVOC, 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 36% of total NO_x emissions (national totals), 20% of PM_{10}, 26% of $PM_{2.5}$, 54% of BC, 19% of NMVOC and 56% of CO in The Netherlands in 2013. The trends in emissions from road transport are shown in Table 4.5.

Table 4.5: Trends in emissions from 1A3b Road transport

	Main Pollutants				Particulate Matter				Other
	NO_x	NMVOC	SO_x	NH_3	$PM_{2.5}$	PM_{10}	TSP	BC	CO
Year	Gg	Gg	Gg	Gg	Gg	Gg	Gg	Gg	Gg
1990	254	182	13	0.9	15	17	17	10	709
1995	193	111	12	2.2	12	13	13	7	489
2000	155	66	3	4.4	9	11	11	6	398
2005	130	39	0	5.4	7	9	9	4	388
2010	105	32	0	4.8	4	7	7	3	373
2013	87	29	0	4.5	3	5	5	2	349
1990-2013 period [1)]	-167	-153	-13	3.6	-12	-11	-11	-8	-361
1990-2013 period [2)]	-66%	-84%	-98%	390%	-78%	-68%	-68%	-81%	-51%

	Priority Heavy Metals			POPs		Other Heavy Metals					
	Pb	Cd	Hg	DIOX	PAH	As	Cr	Cu	Ni	Se	Zn
Year	Mg	Mg	Mg	g I-Teq	Mg	Mg	Mg	Mg	Mg	Mg	Mg
1990	248	0.03	0	2.29	1.53	0.17	2.08	20	0.66	0.01	33
1995	80	0.03	0	1.32	1.05	0.18	2.05	20	0.67	0.01	34
2000	0.3	0.04	0	0.68	0.67	0.20	2.06	20	0.69	0.01	37
2005	0.3	0.04	0	0.49	0.42	0.22	2.19	21	0.74	0.01	40
2010	0.3	0.04	0	0.34	0.31	0.22	2.26	22	0.76	0.01	41
2013	0.3	0.04	0	0.28	0.25	0.22	2.24	22	0.75	0.01	41
1990-2013 period [1)]	-247	0.0	0	-2.01	-1.28	0.06	0.2	1	0.1	0.0	8
1990-2013 period [2)]	-100%	29%		-88%	-83%	33%	8%	7%	14%	27%	25%

1) Absolute difference in Gg 2) Relative difference to 1990 in %

Emissions from the main pollutants and particulate matter have all decreased significantly throughout the time series with the exception of NH_3. This decrease in emissions can mainly be attributed to the introduction of increasingly stringent European emission standards for new road vehicles. Even though emission totals decreased throughout the time series, the share of road transport in the national totals for NO_x, PM_{10} and $PM_{2.5}$ decreased only slightly between 1990 and 2013 as emissions in other sectors decreased also. Road transport therefore is still a major source of pollutant emissions in the Netherlands.

Emissions of SO_x decreased by 98% between 1990 and 2013 due to increasingly stringent EU fuel quality standards regulating the maximum allowable sulphur content for 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 decreased subsequently from 7% in 1990 to less than 1% in 2013.

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 2013.

Emissions from heavy metals have increased, with the exception of Pb. Road transport, however, is not a key source for emissions of heavy metals. Pb emissions from passenger cars are the only exception, being a key source in the 1990 level assessment and the 1990-2013 trend assessment.

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 2013 (Figure 4.1). The kilometres driven by diesel cars have 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 2013. In comparison: gasoline mileages have increased by 17% in the same time span. The share of LPG cars in the passenger car fleet has decreased significantly, leading to a decrease in LPG mileages by 77% between 1990 and 2013. Figure 4.1 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 cars has increased from 20% in 1990 to 31% in 2013, mostly at the cost of the market share of LPG which decreased from 16% to 3% in the same time span.

Passenger cars were responsible for 12% of total NO_x emissions in the Netherlands in 2013. NO_x emissions of passenger cars have decreased significantly though throughout the time series: from 143 Gg in 1990 (24% of total NO_x) to 29 Gg in 2013. This decrease can mainly be attributed to the introduction of the (closed loop) three way catalyst (TWC), which has led to a major decrease in NO_x emissions from gasoline passenger cars. Total NO_x emissions from gasoline passenger cars decreased by 93% between 1990 and 2013 even though traffic volumes increased by 30%. NO_x emissions from diesel-powered passenger cars increased from 12 Gg in 1995 to 19 Gg in 2008. 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 2008, NO_x emissions from diesel cars have remained fairly constant at 18 Gg. 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 78% in 1990 to 34% in 2013, whereas the share of diesel has increased from 9% to 61% between 1990 and 2013.

The introduction of the TWC for gasoline passenger cars also led to a significant reduction of NMVOC and CO emissions. NMVOC exhaust emissions from gasoline passenger cars decreased from 84 Gg in 1990 to 13 Gg in 2013, whereas CO emissions decreased from 549 to 265 Gg. NMVOC and CO emissions from diesel and LPG-powered passenger cars also decreased significantly, but both are minor sources of NMVOC and CO. Gasoline passenger cars were responsible for 85-90% of total NMVOC exhaust emissions and over 90% of total CO emissions from passenger cars throughout the time series. In 2013, passenger cars (not including evaporative NMVOC emissions) were responsible for 10% of total NMVOC emissions (down from 21% in 1990) and 43% of total CO emissions (down from 52% in 1990) in the Netherlands.

Passenger cars (source category 1A3bi, only including exhaust emissions) were responsible for 9% of total $PM_{2.5}$ emissions and 4% of total PM_{10} emissions in The Netherlands in 2013. PM_{10} exhaust emissions from passenger cars have decreased by 79% between 1990 and 2013. 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 2013 were 1.2 Gg, down 0.1 Gg (7%) from 2012. The continuing decrease of PM_{10} 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 market 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 was already equipped with a DPF. Since 2008, the share of new diesel passenger cars with a DPF has been above 90%. Since the $PM_{2.5}/PM_{10}$ ratio for exhaust emissions is assumed to be 1.0, $PM_{2.5}$ exhaust emissions show the same trends as PM_{10}.

NH_3 emissions of passenger cars increased since 1990 resulting from the introduction of the TWC. Between 2004 and 2007, NH_3 emissions were more or less stable at 4.8 Gg. Since 2007, emissions have decreased to 4.3 Gg in 2013. The increase in vehicle kilometres driven has been compensated by the introduction of newer generations of TWCs with lower NH_3 emissions, resulting in a decrease of the fleet average NH_3 emission factor. Pb emission from passenger cars decreased from 247 Mg in 1990 to 0.09 Mg in 2013 due to the phase-out of leaded gasoline.

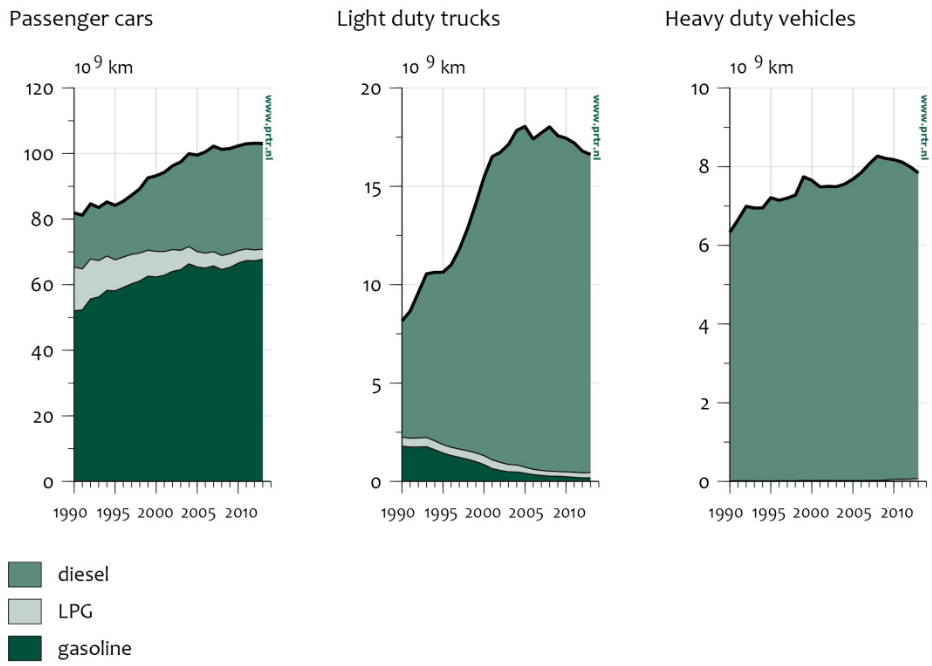


Figure 4.1 Kilometres driven per vehicle and fuel type in the Netherlands

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 kilometres driven (see Figure 4.1). In 2005, private ownership of light duty trucks became less attractive due to changes in the tax scheme for light duty trucks. As a result, the size of the vehicle fleet has more or less stabilized since. The number of vehicle kilometres varied between 17 and 18 billion between 2005 and 2011, and actually decreased in 2012 (-2%) and 2013 (-1%). This decrease 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 slowly decreased since 2001. NO_x emissions in 2013 were 34% lower than in 1990 (20.5 Gg vs. 13.4 Gg), even though the number of vehicle kilometres driven has more than doubled in this time span. Diesel NO_x emissions increased between 1990 and 2001 and remained constant between 2001 and 2005. The tightening of the EU emission standards for light duty vehicles and the subsequent market penetration of light duty diesel engines with lower NO_x emissions caused a minor decrease since 2005. Because of the poor NO_x-emission performance of recent Euro-5 trucks, the fleet average NO_x emission factor for diesel light duty trucks only decreased by 2% in 2013 compared to 2012. The share of light duty trucks in total NO_x emissions in The Netherlands was approximately 6% in 2013.

The exhaust emissions of NMVOC and CO from light duty trucks have shown a major decrease throughout the time series. NMVOC emissions decreased from 10 Gg in 1990 to 0.7 Gg in 2013, whereas CO emissions decreased from 47 to 3.4 Gg over the same time period. The increasingly stringent EU emissions standards for both substances have led to a decrease in the fleet average emission factors for both gasoline and diesel trucks of 70-80% between 1990 and 2013. 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 an NMVOC emissions, accounting for less than 1% of the national totals for both substances in 2013.

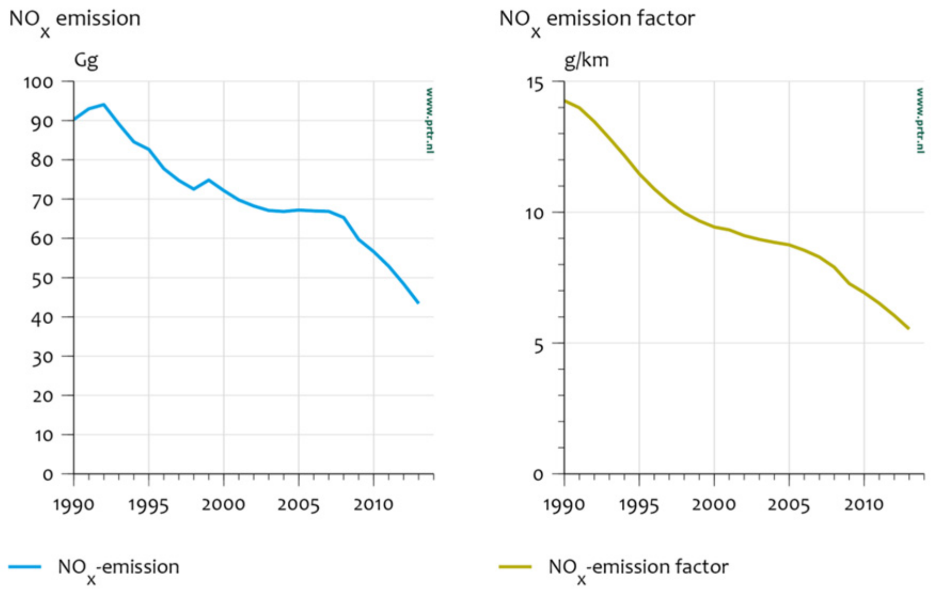


Figure 4.2 NO_x emissions and NO_x emission factors of heavy duty vehicles in the Netherlands

Exhaust emissions of PM_{10} (and subsequently also of $PM_{2.5}$) from light duty trucks mostly decreased throughout the time series. The fleet average PM_{10} emission factor has decreased consistently throughout the time series, but in earlier years this decrease was offset by the increase in kilometres driven. Diesel-powered trucks are dominant in the total PM_{10} exhaust emissions, with a share of over 99%. The average PM_{10} exhaust emission factor for diesel-powered light duty trucks decreased by approximately 3% annually between 2005 and 2013, although market penetration of DPFs in the new diesel-powered light duty truck fleet has been lacking behind compared to passenger cars. In recent years market penetration of DPFs increased significantly though, helped by voluntary agreements between the government and the automotive sector in The Netherlands. The share of DPFs in new light duty truck sales increased from 30% in 2008 to 90% in 2010. Combined with the stabilisation of the amount of vehicle kilometres driven since 2005, PM_{10} exhaust emissions decreased by 48% between 2005 and 2013. In 2013, light duty trucks were responsible for 4% of total PM_{10} and 8% of total $PM_{2.5}$ emissions in The Netherlands.

Heavy duty vehicles and buses (1A3biii)
The number of vehicle kilometres driven by heavy duty vehicles (trucks and buses) in the Netherlands increased by approximately 31% between 1990 and 2008 (see Figure 4.1). The economic crisis has since led to a slight decrease in traffic volumes: total vehicle kilometres driven in 2013 was 5% lower than in 2008. Diesel dominates the vehicle fleet with a share of over 99%.

Heavy duty vehicles are a major source of NO_x emissions in The Netherlands with a share of 18% in 2013. NO_x emissions from heavy duty vehicles decreased from 90 Gg in 1990 to 44 Gg in 2013 (see Figure 4.2). Emission totals have decreased significantly in recent years due to the combination of a decrease in vehicle mileages and a decrease in the fleet average NO_x emission factor. The fleet average NO_x emission factor decreased by 61% between 1990 and 2013, from 14 g/km to 5.5 g/km. This decrease has mainly been caused by the increasingly stringent EU emission standards for heavy duty engines. With recent (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 (6% average annual decrease).

NMVOC exhaust emissions decreased by 88%, from 10 Gg in 1990 to 1.2 Gg in 2013, whereas PM_{10} and $PM_{2.5}$ exhaust emissions decreased by 89%, from 5 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 (0.8%) and PM_{10} emissions (2%) in 2013. Their share in $PM_{2.5}$ emissions was slightly higher at 4% 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 total emissions of most substances. They are a key source though for NMVOC and CO in both the 1990 and 2013 level assessment and in the trend assessment. Even though vehicle kilometres increased by 87% between 1990 and 2013, exhaust emissions of NMVOC decreased significantly due to the increasingly stringent EU emissions standards for two-wheelers. NMVOC exhaust emissions decreased from 25 to 10 Gg between 1990 and 2013. Motorcycles and mopeds were responsible for 7% of NMVOC emissions in The Netherlands in 2013. CO emissions from motorcycles and mopeds increased from 46 to 65 Gg between 1990 and 2013. In 2013, motorcycles and mopeds were responsible for 11% of CO emissions in The Netherlands.
NO_x emissions increased from 0.4 to 1.1 Gg between 1990 and 2013, but the share of motorcycles and mopeds in total NO_x emissions in the Netherlands was still small (0.5%) in 2013. The share in $PM_{2.5}$ emissions was approximately 1.1% in 2013, with emissions decreasing from 0.4 to 0.2 Gg in the 1990-2013 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 37 Gg in 1990 to 2 Gg in 2013 (see Figure 4.3). As a result, evaporative emissions are no longer a key source in the emission inventory, accounting for only 1% of total NMVOC emissions in the Netherlands in 2013 (down from 7% in 1990).

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 PM_{10} emissions in the Netherlands in 2013, being responsible for 5% and 4% respectively of total PM_{10} emissions in The Netherlands. Total PM_{10} emissions from brake wear, tyre wear and road abrasion have increased throughout the time series, resulting from the increase in vehicle kilometres driven by light and heavy duty vehicles. PM_{10} emission factors were kept constant throughout the time series.
$PM_{2.5}$ emissions were derived from PM_{10} emissions using $PM_{2.5}/PM_{10}$ ratios of 0.2 for tyre wear and 0.15 for both brake wear and road surface wear. Therefore the trend in $PM_{2.5}$ wear emissions is similar to the trend in PM_{10} emissions. The share of tyre and brake wear (2%) and road abrasion (1%) in total $PM_{2.5}$ emissions in The Netherlands is smaller though than for PM_{10}.

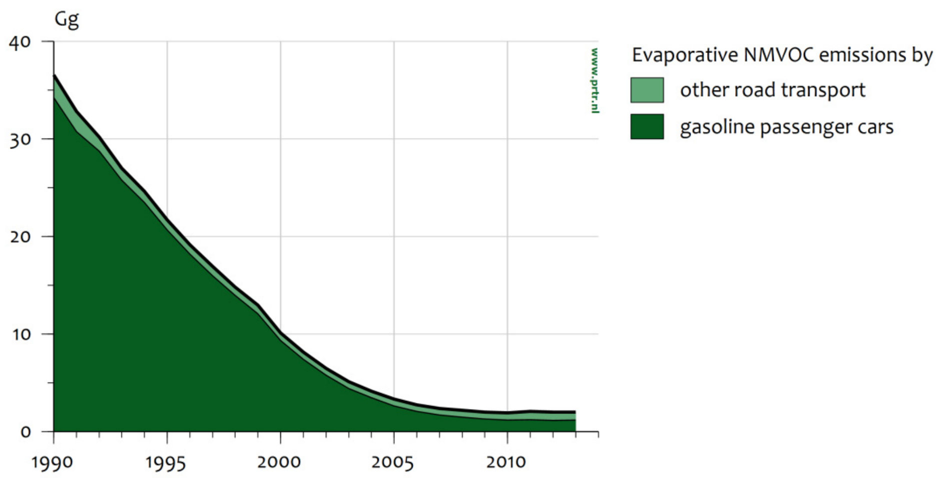


Figure 4.3. Emissions of NMVOC from evaporation by road transport in the Netherlands

4.3.4 *Activity data and (implied) emission factors*
The exhaust emissions of CO, NMVOC, NO_x, NH_3 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 Pb were calculated using fuel consumption estimates combined with the sulphur and lead 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.

Activity data
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 using data on:

1. The size and composition of the Dutch vehicle fleet;
2. Average annual mileages for different vehicle types, and
3. The 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 a sample of the NAP database and uses this data combined with RDW-data on vehicle characteristics to derive average annual mileages for different vehicles 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*. (2015).
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*. (2015). Vehicle kilometres travelled by foreign trucks were derived from statistics on road transportation in the Netherlands and in other EU countries, collected by Eurostat. The vehicle kilometres travelled 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 and 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 total vehicle kilometres travelled 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 motorways in total mileages. The road type distribution for different vehicle categories is reported in Klein *et al.* (2015).

Total fuel consumption per vehicle and fuel type, used for calculating SO_x and Pb emissions, 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.

Emission factors

The CO, NMVOC, NO_x and PM exhaust emission factors for road transport were calculated by TNO using the VERSIT+ model (Smit *et al.*, 2007). VERSIT+ derives average emission factors for different vehicle types under different driving circumstances, using an extensive emission measurements database. Separate VERSIT+ models were developed for light duty and heavy duty vehicles. VERSIT+ LD contains statistical models for 246 vehicle classes using multiple linear regression analysis. The statistical models are used for determining empirical relationships between average emission factors, including confidence intervals, and an optimized number of vehicle and driving behaviour characteristics. Since 2009, version 3 of VERSIT+ LD is used to derive real-world emission factors for light duty vehicles (Ligterink and De Lange, 2009).

VERSIT+ HD (Ligterink *et al.*, 2009) was used to derive emission factors for heavy duty vehicles (trucks and buses). For older vehicle types, VERSIT+ HD is based on European measurement data, mostly derived from engine tests in laboratory settings. For new vehicle types (Euro-III, -IV and -V) results from recent on-road measurements, using Portable Emission Measurement Systems (PEMS), are used in the model (e.g. Ligterink *et al.*, 2009). To derive real-world emission factors from the measurement data, VERSIT+ uses the PHEM model developed by the Graz University of Technology (Hausberger *et al.*, 2003). The input is composed of speed-time diagrams which make the model suitable for the prediction of emissions in varying traffic situations.
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.* (2015). 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.

Emissions of SO_2 and heavy metals (and CO_2) 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 SO_2 and heavy metals were based on the sulphur, carbon and heavy metal contents of the fuels. It is assumed that 75% of the lead is emitted as particles and 95% of the sulphur is transformed to sulphur dioxide. The NH_3 emission factors for passenger cars were derived from a recent study by TNO, as is described in more detail in paragraph 4.3.8.

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).

4.3.5 *Methodological issues*

Emission factors for recent generations of light duty trucks are mainly estimated based on the emission factors for diesel passenger cars, due to a lack of recent emission 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, they examined the variation in the different input variables used for estimating total NO_x emissions for Euro-4 diesel passenger cars, 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 also 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.

There was no recent and accurate information available for assessing the uncertainties of total emissions from road transport for different substances. Consistent methodologies were used throughout the time series.

4.3.7 *Source-specific QA/QC and verification*

There are no source-specific QA/QC or verification procedures for road transport.

4.3.8 *Source-specific recalculations*

In this year’s submission, several recalculations were done, compared to last year’s submission.

NH_3 emission factors for road transport

The NH_3 emission factors for different types of road vehicles have been updated in 2014. Emission factors for NH_3 had not been updated since 2003 and needed to be adjusted. Therefore, TNO performed a study using NH_3 emission data from various sources, including COPERT, the Dutch Emission Testing Program and recent scientific literature, to derive a new set of NH_3 emission factors for all 333 vehicle classes within road transport (Stelwagen et al., 2015). It was concluded that gasoline passenger cars with three-way catalysts (TWC) and SCR equipped heavy duty vehicles are the main sources of NH_3 within road transport. On the basis of the available data TNO decided to use the COPERT data as a basis and to extend this data with recent measurements for the two main NH_3 emitting vehicle classes: gasoline passenger cars and heavy duty vehicles.
The new NH_3 emission factors for earlier generations of gasoline passenger cars are higher than previously estimated. This can partially be attributed to deterioration of the three-way catalysts, resulting in

higher NH_3 emissions per vehicle kilometre. NH_3 emission factors for Euro-1 and Euro-2 gasoline passenger cars have therefore been adjusted upwards when applied in recent years of the time series. This is described in more detail in the accompanying report by TNO. NH_3 emission factors for recent generations of heavy duty trucks and buses have also been adjusted upwards, since previous estimates did not take into account the introduction of SCR catalysts and resulting increases in NH_3 emissions.

The new NH_3 emission factors have been applied in this year's submission, resulting in a major increase in total NH_3 emissions from road transport throughout most of the time series compared to last year's submission. This is shown in Figure 4.4. NH_3 emissions by road transport increased only marginally in earlier years of the time series, but since 1995 the difference between both time series increases substantially as more TWC-equipped passenger cars enter the car fleet. Emission totals for the 2003-2008 period more than doubled compared to last year's submission. Between 2005 and 2012 total NH_3 emissions decrease in the new time series (IIR2015), as NH_3 emission factors for newer generations of gasoline passenger cars are lower than for the Euro-1 and Euro-2 vehicles. Gasoline passenger cars are responsible for approximately 90% of total NH_3 emissions by road transport.

Adjustments in vehicle kilometres driven by passenger cars and light duty trucks in the Netherlands
Statistics Netherlands updated the time series for the vehicle kilometres driven on Dutch territory by passenger cars and light duty trucks in 2014. Since 2013, data on odometer readings for these vehicle types is derived from RDW for all registered vehicles in the Netherlands. Previously, these odometer readings were derived from the NAP register for only a sample of the car fleet. Using the new data resulted in lower mileages for older vehicle types (> 9 years old) in 2012 and 2013 compared to the historic time series. This led to a deviation from the historic trend, therefore it was decided that the time series for 1990-2011 would also be adjusted, resulting in a reduction of the mileages for these vehicle types by approximately 2%.

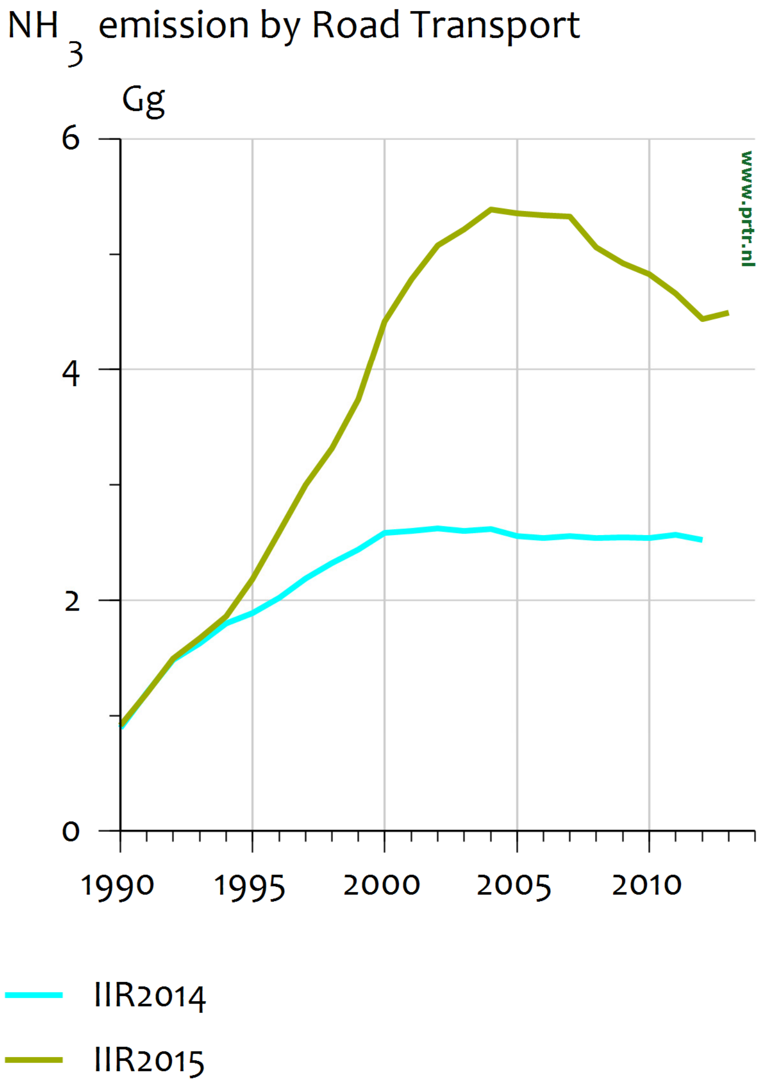


Figure 4.4. NH_3 emissions from Road transport in this year's and last year's submission

Statistics Netherlands also updated the estimates for the percentage of total mileages driven abroad for the Dutch car fleet. The odometer readings are used to derive total annual mileages. For emission calculations, these mileages need to be split in kilometres driven in the Netherlands and abroad. Using new data from the Dutch mobility survey (OViN), Statistics Netherlands updated the estimates for the share of total mileages driven abroad per vehicle type for the 2008-2013 period. The new data showed that a higher percentage of total mileages is driven abroad compared to previous assumptions, resulting in lower national mileages (and thus lower emissions on Dutch territory).
Finally, Statistics Netherlands also updated the estimated mileages from foreign passenger cars on Dutch territory, using new data on cross-border traffic for the German border in 2013. The new data showed a higher share of foreign passenger cars on Dutch motorways than previously estimated. The new data has also been used to adjust the historic time series for the 1990-2012 period, resulting in higher vehicle

kilometres driven on Dutch territory than previously estimated. These adjustment are all described in more detail in CBS (2014).

These adjustments combined led to an increase in total kilometres driven on Dutch territory by passenger cars of approximately 2-3% for the 1990-2007 period. For the 2008-2012 period, the difference between both time series varies between -1% and +1%.

Updated emission model for mopeds
In 2011, TNO developed an emission model for mopeds and motorcycles that is used for the annual emission inventory. At the time no differentiation could be made for different engines, speed limiters or configurations of the mopeds. Due to lack of data, the model only distinguished between Euro-classes 0, 1 and 2. In 2013, TNO performed new measurements on Euro-2 mopeds (Hensema *et al*., 2013). These measurements gave new insights in the impact of different parameters on vehicle emissions. It was concluded among other things that the tested mopeds did not comply with EU emission standards. PM emission of 2-stroke mopeds are substantially higher than PM emissions of 4-stroke mopeds. Tampering affects emissions and fuel consumption. Fuel consumption decreases when the speed limiters are removed, but increases with tuning. The impact on emissions varies per substance.

The new emission measurements have been used to determine a new set of emission factors for Euro-2 mopeds and to update emissions factors for Euro-0 and Euro-1 mopeds. Based on this update, the total emissions of mopeds in the Netherlands were recalculated for the historic time series. In general, all new emission factors are higher than previously calculated emission factors, with some exceptions for NO_x and PM_{10} for 4-stroke engines. NO_x emissions are lower than previously reported, mainly because Euro-2 NO_x emission factors are 50-80% lower than previously estimated.

Finally, emissions of ‘micro-cars’ (motorised quadricycles) were determined and these vehicles were added to the emission model (Van Zyl *et al*., 2015). By Dutch laws these micro-cars are classified as mopeds, and there maximum speed is limited at 45 km/h. These vehicles had not been part of the existing emission model for mopeds, which so far only included gasoline powered two-wheeled mopeds. All micro-cars are diesel-powered. Given the small number of vehicles in the fleet (approximately 20.000 in 2012), the emissions are low: NO_x emissions were estimated at 0.07 Gg in 2012.

PM emissions of Euro V trucks
PM exhaust emissions of heavy duty trucks have been recalculated in this year’s inventory using updated emission factors for Euro V trucks that resulted from new measurements by TNO. The previous emission factors were based on expert judgement and a few filter measurements in the laboratory and needed to be updated. Hence, engine test-bed measurements on a Euro-V truck engine were performed acquiring a comprehensive set of engine and engine emission data. This data was used for the design and calculation of models that predict instantaneous PM and EC emission rates based from the instantaneous CO_2 emission rate. The CO_2 emission rate is directly related to the engine load of the

vehicle. Hence linking PM and EC emissions to the instantaneous CO_2 rate allows for a direct link between PM and EC emissions and the load profile of the engine. By applying VERSIT+ to the TNO Standard Dutch HD Cycles for emission factor road types urban, rural and motorway, instantaneous CO_2 emission profiles were calculated for representative Euro-V truck types. Finally, the new PM and EC models were applied to calculate the associated instantaneous PM and EC emission profiles and from these the PM and EC emission factors were calculated. For all three road types, the new PM exhaust emission factors for the most part are lower than the previous ones, with some exceptions for heavy tractor-trailer combinations where new emission factors were higher than the previous ones. Since tractor-trailer combinations are dominant in total heavy duty vehicle kilometres in the Netherlands, using the new PM emission factors resulted in a minor increase (0-4%) in reported PM_{10} exhaust emissions.

New emission model for buses
The emissions of buses have been recalculated in the current inventory using a new emission model that was developed by CE Delft (Den Boer *et al*., 2015). In 2011, Statistics Netherlands derived new annual mileages for buses in the Netherlands using data from the NAP register. In this study, separate mileages were derived for public transport buses and for coaches. In 2014, CE Delft was commissioned to perform a study on the different technologies used within the Dutch bus fleet and on the road type distribution for public transport buses and coaches. Due to the specific demands for the types of buses used in public transport concessions, the public transport bus fleet is expected to include rather 'clean' buses, such as natural gas, hybrid and EEV buses. Using figures from different data sources, CE Delft re-estimated the distribution of public transport buses over different vehicle technologies. CE also updated the estimated road type distribution for both the public transport buses and for coaches, using data on public transport bus lines and expert judgement on the use of coaches. The resulting distributions are shown in Table 4.6. As expected, public transport buses mainly drive on urban roads, whereas coaches mainly drive on rural roads and highways. Since the share of coaches in total vehicle kilometres driven is rather small, the average road type distribution for all buses is dominated by public transport buses. Compared to the old distribution, the share of urban and rural in total vehicle kilometres driven increased whereas the share of highways decreased.

Table 4.6 Road type distribution for buses, in this year's and last year's submission

	IIR2014	**IIR2015**		
	All buses	**Public transport**	**Coaches**	***All buses[1)]***
Urban	38%	67%	15%	*56%*
Rural	25%	30%	40%	*32%*
Highways	37%	3%	45%	*12%*

1) Weighted average for 2013

The new emission model for buses resulted in an adjusted time series for bus emissions. Figure 4.5 shows the old and new time series for NO_x emissions. Emission totals increased slightly throughout the time series, mainly due to the higher number of urban roads in the road type distribution. NO_x emissions per vehicle kilometre in general are higher on urban roads than on rural roads and highways.

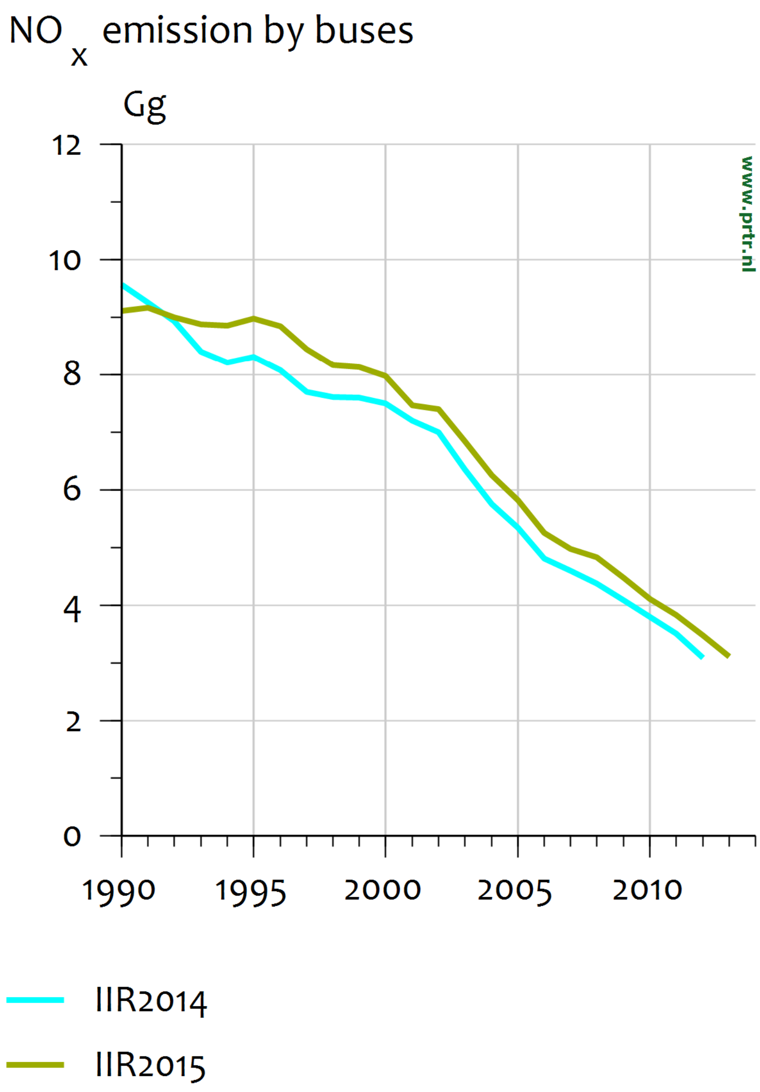


Figure 4.5. NO_x emissions from buses in this year's and last year's submission

4.3.9 *Source-specific planned improvements*

There are several improvements planned for the road transport emission inventory:

- TNO and Statistics Netherlands have initiated a study to derive improved specific fuel consumption figures for light duty trucks using fuel consumption figures from the EU type approval procedure and research by TNO on differences between type approval and real-world fuel consumption for different vehicles types. These figures should improve the bottom-up fuel consumption estimates used to calculate SO_2 emissions and heavy metals. The difference between bottom up fuel consumption and fuel sold in the Netherlands is also used to estimate fuel sold emissions. The new fuel consumption figures should therefore also help improve fuel sold estimates of road transport emissions. Similar studies have already been carried out for passenger cars and heavy duty trucks.

4.4 Railways

4.4.1 Source-category description

The source category 1A3c 'Railways' includes emissions from diesel-powered rail transport in the Netherlands. This includes both passenger transport and freight transport. It also includes PM_{10} emissions due to the wear of overhead contact lines and carbon brushes from railways.

4.4.2 Key sources

The source category 'Railways' is not a key source in the emission inventory.

4.4.3 Overview of emission shares and trends

Railways are a small source of emissions in The Netherlands, accounting for less than 1% of national totals for all substances in both 1990 and 2013. 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. For the most part, transport volumes have still increased since 2001, especially in freight transport, but this has been compensated by the increased electrification of rail transport. In 2013, diesel fuel consumption increased by 5% (0.06 PJ) to 1.2 PJ. The share of passenger transport in total 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 4.7. NO_x and PM_{10} emissions from railways show similar trends to the fuel consumption time series. NO_x emissions from Railways fluctuated around 1.9 Gg in recent years, but decreased to 1.6 Gg in 2013. PM_{10} emissions have fluctuated around 0.06 Gg. Pb emissions have increased by 35% between 1990 and 2012. Pb emissions from railways result from wear of carbon brushes. Wear emissions are estimated based on total electricity use by railways (in kWh). Trends in Pb emissions therefore follow trends in electricity use for railways. Emissions of other heavy metals are very low and are therefore not included in Table 4.7. SO_2 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 PM_{10} were derived by the Netherlands Environmental Assessment Agency (PBL) in consultation with the NS. Emission factors of NH_3 were derived from Ntziachristos and Samaras (2000). The emission factors for railways have not been updated recently and therefore are rather uncertain.

PM_{10} emissions due to the 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 and 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 4.7 Trends in emissions from 1A3c Railways

	Main Pollutants				Particulate Matter				Other	Priority Heavy Metals
	NO_x	NMVOC	SO_x	NH_3	$PM_{2.5}$	PM_{10}	TSP	BC	CO	Pb
Year	Gg	Gg	Gg	Gg	Gg	Gg	Gg	Gg	Gg	Mg
1990	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
2013	1.6	0.07	0.00	0.0003	0.05	0.06	0.06	0.02	0.26	0.29
1990-2013 period [1)]	-0.04	0.00	-0.10	0.0000	0.00	0.00	0.00	0.00	0.00	0.08
1990-2013 period [2)]	-3%	-1%	-99%	-2%	3%	3%	3%	-1%	-1%	35%

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*

There was no recent and accurate information available for assessing the uncertainties of the emissions from railways. 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 are no source-specific recalculations for railways in this 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, 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 1A3d 'Waterborne navigation' 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 1A5b 'Other mobile' 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 of NO_x, $PM_{2.5}$ and BC emissions. The source category 1A5b 'Other Mobile (including military, land based and recreational boats) is not a key source.

4.5.3 *Overview of emission shares and trends*

Inland waterway navigation in total was responsible for 11% of total NO_x emissions and 7% of $PM_{2.5}$ emissions in The Netherlands in 2013. With emissions from road transport decreasing rapidly, the share of inland waterway navigation in emission totals has increased throughout the time series. The share of inland waterway navigation in national emissions totals of PM_{10} (3.4%), NMVOC (1%), CO (1%) and SO_2 (0.04%) was small in 2013. International maritime navigation is not included in the national totals but 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 of international maritime shipping on Dutch territory (including the Dutch Continental Shelf) amounted to 102 Gg in 2013, down from 106 Gg in 2012 but still higher than the combined NO_x emissions of all road transport in The Netherlands. Total PM_{10} emissions amounted to 4.4 Gg in 2013. On the contrary, recreational craft are only a small emission source, being responsible for 2.3 Gg of NO_x, 2 Gg of NMVOC and 0.05 Gg of PM_{10} in 2013.

The trends in emissions from inland shipping in the Netherlands are shown in Table 4.8. 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 26 PJ in 2013 (see Figure 4.6). 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 of national and international inland navigation increased from 23 Gg in 2009 to 26 Gg in 2013. 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 2013.

SO_2 emissions from waterborne navigation have decreased by 95% between 2009 and 2013 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, therefore SO_2 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 PM_{10} emissions of waterborne navigation decreased by 0.01 Gg in 2013 compared to 2012.

Table 4.8 Trends in emissions from Inland shipping in the Netherlands (combined emissions of national and international inland shipping)

	Main Pollutants				Particulate Matter				Other
	NO_x	NMVOC	SO_x	NH_3	$PM_{2.5}$	PM_{10}	TSP	BC	CO
Year	Gg	Gg	Gg	Gg	Gg	Gg	Gg	Gg	Gg
1990	31	5.4	1.9	0.005	1.30	1.37	1.37	0.57	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	0.58	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
2013	29	3.2	0.0	0.006	0.91	0.96	0.96	0.40	27
1990-2013 period [1]	-2	-2.2	-1.9	0.001	-0.40	-0.41	-0.41	-0.17	4.4
1990-2013 period [2]	-6%	-41%	-99%	18%	-30%	-30%	-30%	-30%	20%

1) Absolute difference in Gg 2) Relative difference to 1990 in %

Since fuel consumption by recreational craft has remained stable in recent years, trends in total emissions follow trend in fleet average emission factors. Average emission factors of most substances decreased slightly from 2012 to 2013, resulting in small decreases in emissions. PM_{10}, $PM_{2.5}$ and CO emissions decreased by less than 1%. NMVOC emissions decreased by 10%, whereas NO_x emissions showed a minor increase (0.6%) from 2012 to 2013.

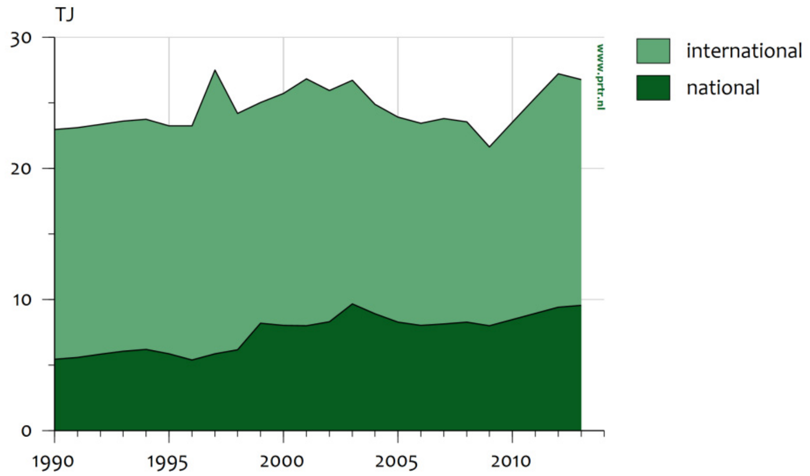


Figure 4.6 Fuel consumption in national and international inland shipping in the Netherlands

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 2013, total fuel consumption by maritime navigation on the Dutch part of the North Sea, the Dutch Continental Shelf (DCS), decreased by 3% compared to 2012, resulting in a similar reduction of SO_2 and PM_{10} emissions. NO_x emission decreased by 4% due to the IMO emission standards resulting in lower fleet average NO_x emission factors.

4.5.4 *Activity data and (implied) emission factors*

Fuel consumption and emission totals for 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, total (annual) power demand (kWh) is calculated for the 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:

*Emissions = Number of vessels * Power * Time * Emission factor*

Data on the total number of vessel kilometres per ship type are 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 model 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 factor 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 for different years of the time series are reported in Klein *et al*. (2015). 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.* (2015).

Since 2008, emissions of sea shipping on the Dutch Continental Shelf and in the Dutch port areas are calculated 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 of maritime shipping bottom-up, taking into account specific ship and voyage characteristics.
To estimate emissions of 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 are 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). Emission factors (in g/kWh) are derived from Hulskotte *et al*. (2003). Methodologies and resulting emissions for recent years are described in more detail in MARIN & TNO (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 boats and their average usage rates are rather uncertain.

4.5.6 Uncertainties and time series consistency
There was no recent and accurate information available for assessing the uncertainties of the emissions from inland waterborne navigation.

Consistent methodologies are 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 are 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

In 2015 TNO will perform a pilot study to determine whether AIS data can also be used to estimate emissions of inland navigation on Dutch territory. Currently, 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 also 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 industrial 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 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 are reported under 1A2gvii 'Mobile combustion in manufacturing industries and construction', 1A4aii 'Commercial/institutional mobile', 1A4bii 'Residential: household and gardening (mobile)', 1A4cii 'Agriculture/forestry/fishing: off-road vehicles and other machinery' and 1A5b 'Other mobile'. The latter source category is used for emissions from ground support equipment at airports.

4.6.2 Key sources

Emissions of NRMM are reported under different source categories. Mobile machinery in manufacturing industries and construction (1A2gvii) is a key source for NO_x, $PM_{2.5}$ and BC in the 2013 level assessment. The source category 1A4bii 'Residential: household and gardening (mobile)' is a key sources of emissions of CO in both the 2013 level and the trend assessment, whereas the source category 1A4cii 'Agriculture/forestry/fishing: off-road vehicles and other machinery' is a key source for NO_x and $PM_{2.5}$ in the 2013 level assessment and for NO_x in the trend assessment.

4.6.3 *Overview of shares and trends in emissions*

NRMM was responsible for 9% of CO emissions, 8% of NO_x, 7% of $PM_{2.5}$ and 3% of PM_{10} emissions in the Netherlands in 2013. CO emissions mainly resulted from the use of gasoline equipment by consumers (lawn mowers) and for public green maintenance. NO_x, PM_{10} and $PM_{2.5}$ emissions were for the most part related to diesel machinery used in agriculture (tractors) and construction. LPG fork lift were also a major source of NO_x emissions with a contribution of 17% in total NO_x of NRMM in 2013.

Total energy use in NRMM has fluctuated between 35 PJ and 40 PJ throughout the time series. Energy use in 2013 decreased by 1.6% (0.6 PJ) compared to 2012, mainly due to a reduction in the energy use by construction machinery. Since the start of the economic crisis, energy use by construction machinery decreased from 18.6 PJ in 2008 to 15.6 in 2013. Figure 4.7 shows total energy use within the different sectors where mobile machinery is applied. Construction and agricultural machinery were responsible for 83% of total energy use by NRMM in 2013. Diesel is the dominant fuel type, accounting for 88% of energy use in 2013. Gasoline and LPG have a share of 5% and 7% respectively in total energy use. LPG is used in the industrial sector (forklift trucks) and gasoline in the agricultural, construction and commercial/institutional sectors.

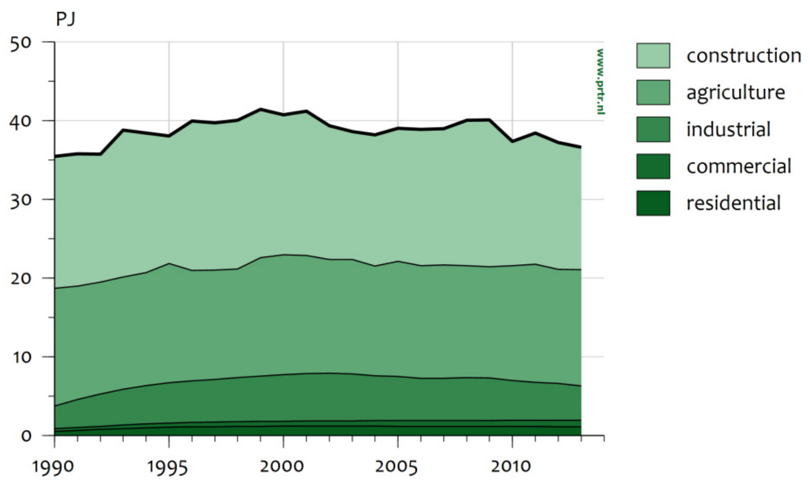


Figure 4.7 Fuel consumption in non-road mobile machinery in different sectors in the Netherlands

The trends in emissions from NRMM in the Netherlands are shown in Table 4.9. 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 of NRMM have steadily decreased, as is shown in

Figure 4.8. Since 1999, NO_x emissions have decreased by 52%, whereas fuel consumption has only decreased by 12%. Emissions from spark ignition engines above 19 kW are currently not regulated by EU NRMM emission legislation. NO_x emissions from gasoline-and LPG-powered machinery have steadily increased throughout the time series. In 2013, gasoline and LPG machinery had a combined share of 18% in total NO_x emissions, whereas in 1990 their combined share was only 5%. CO emissions have also increased throughout the time series.

Table 4.9 Trends in emissions from non-road mobile machinery in the Netherlands

	Main Pollutants				Particulate Matter				Other
	NO_x	NMVOC	SO_x	NH_3	$PM_{2.5}$	PM_{10}	TSP	BC	CO
Year	Gg	Gg	Gg	Gg	Gg	Gg	Gg	Gg	Gg
1990	34	7.5	2.8	0.008	3.1	3.3	3.3	1.6	38
1995	36	8.1	2.7	0.008	2.7	2.8	2.8	1.4	58
2000	38	7.8	2.9	0.008	2.3	2.5	2.5	1.2	60
2005	31	6.0	2.7	0.008	1.6	1.7	1.7	0.8	55
2010	22	4.1	0.2	0.008	1.0	1.1	1.1	0.5	56
2013	19	3.6	0.0	0.008	0.8	0.9	0.9	0.4	58
1990-2013 period [1]	-15	-3.9	-2.8	0.000	-2.3	-2.4	-2.4	-1.2	20
1990-2013 period [2]	-44%	-52%	-99%	-2%	-73%	-73%	-73%	-75%	53%

1) Absolute difference in Gg 2) Relative difference to 1990 in %

Emissions from most other substances have decreased significantly throughout the time series. For PM_{10} and NMVOC, this can mainly be attributed to the EU NRMM emission legislation. SO_2 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, SO_2 emissions have reduced significantly.

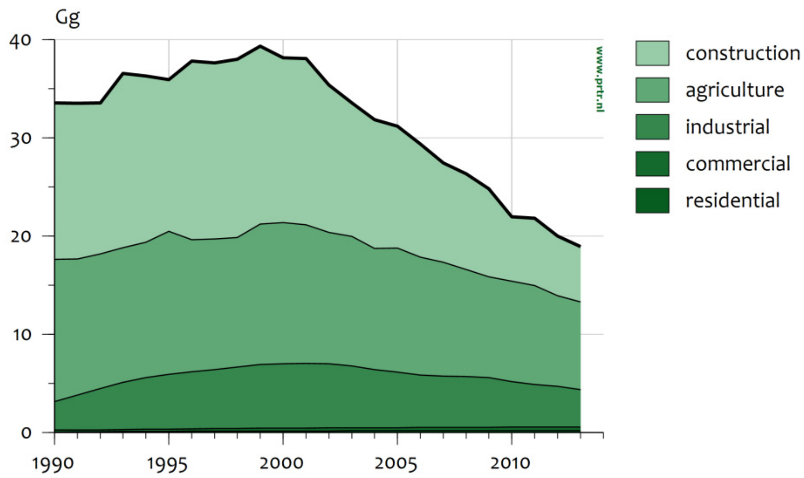


Figure 4.8 NO_x emissions by non-road mobile machinery in different sectors in the Netherlands

4.6.4 *Activity data and (implied) emission factors*

Fuel consumption and emissions from NRMM were calculated using a Tier-3 methodology. Energy use and emissions were derived from the EMMA-model (Hulskotte and Verbeek, 2009). This model is based on sales data for different types of mobile machinery and assumptions on the average use (hours per year) and fuel consumption (kilograms per hour) for different machine types. Emissions of CO, NO_x, PM_{10}, $PM_{2.5}$ and NMVOC 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 and 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. Emission factors were derived from different literature sources.

Emissions of SO_2 were calculated based on total fuel consumption and sulphur content per fuel type. The use of sulphur-free diesel (S content < 10 ppm) in recent years was calculated by the EMMA model, based on the assumption that certain machinery requires the use of sulphur-free diesel in order to function properly. Emission factors for NH_3 were derived from Ntziachristos and Samaras (2000).

The distribution of total energy use to different sectors was estimated using different data sources. Total energy use by machinery in the agricultural sector (excluding agricultural contractors) was derived from the LEI research institute of Wageningen University and Research Centre. Energy use by agricultural contractors was derived from CUMELA, the trade organisation for agricultural contractors in the Netherlands. Total energy use as reported by LEI and CUMULA is lower than the agricultural energy use calculated by EMMA. An explanation for this could be that some agricultural machinery (e.g. tractors) is frequently used in construction. In the EMMA model, which is based on machine types, this energy use is reported under agriculture. In the new approach this energy use is (properly) reported under construction industries. Total fuel consumption in the other sectors was derived from the EMMA model. Because the EMMA model 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 cannot only lead to fluctuations in the sales data, but also in the usage rates of the machinery (hours per year). The latter effect is not included in the model; therefore the EMMA results are adjusted based on economic indicators from Statistics Netherlands for the specific sectors where the machinery is used. The adjusted EMMA results are used to calculate emissions from non-road mobile machinery. The resulting energy use is also reported by Statistics Netherlands in the national energy statistics.

4.6.5 *Methodological issues*

Since there were no reliable data available on fuel sales to non-road mobile machinery, fuel consumption was estimated bottom-up with the EMMA model. This model has been based on sales data for different types of machinery since there were no data available on the total machinery fleet in the Netherlands. Emission estimates for NRMM are therefore rather uncertain.

4.6.6 *Uncertainties and time series consistency*

There was no recent and accurate information available for assessing the uncertainties of the emissions from non-road mobile machinery. 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 linear 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 ground support equipment and vehicles used for ground transport at airports have been added to the inventory. Ground support equipment is used to service aircrafts between flights, for example by providing power (ground power units) or for loading operations. Data on diesel use for ground operations at Amsterdam Airport Schiphol was 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 by TNO 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.

Total diesel fuel consumption at Amsterdam Airport Schiphol increased from 0.1 PJ in 1990 to 0.3 PJ in 2013. Diesel fuel consumption at regional airports in the Netherlands was estimated at 0.01 PJ in 1990, increasing to 0.05 PJ in 2013. Resulting NO_x emissions were estimated at 0.3 Gg (in total for all airports), whereas PM_{10} emissions were estimated at 0.01 Gg. Since all equipment is diesel fuelled, CO and NMVOC emissions are small.

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 2013, national fishing was responsible for 2% of NO_x emissions and 1% of $PM_{2.5}$ emissions in The Netherlands. 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 4.9. 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).

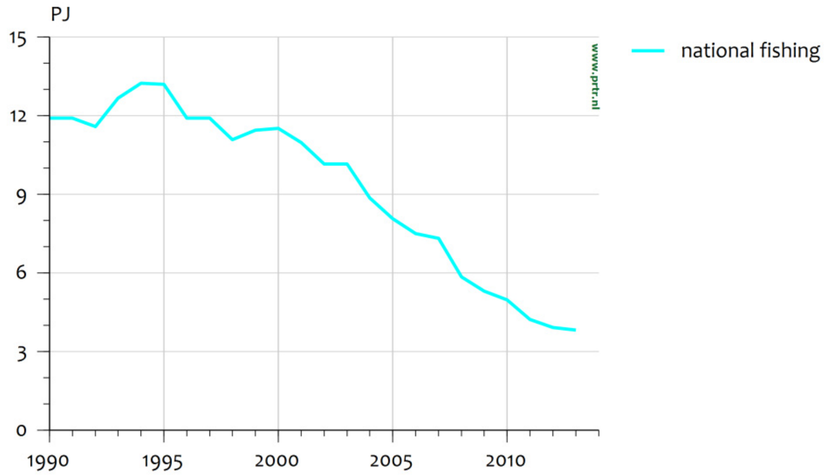


Figure 4.9 Fuel consumption by the fishing fleet in the Netherlands

The trends in emissions from national fishing are shown in Table 4.10. Since the same emission factors were used for the entire 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 2013, whereas PM_{10} emissions decreased from 0.39 to 0.13 Gg.

Table 4.10: Trends in emissions from National Fishing in the Netherlands

	Main Pollutants				Particulate Matter				Other
	NO_x	NMVOC	SO_x	NH_3	$PM_{2.5}$	PM_{10}	TSP	BC	CO
Year	Gg	Gg	Gg	Gg	Gg	Gg	Gg	Gg	Gg
1990	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
2013	5.3	0.2	0.0	0.001	0.12	0.13	0.13	0.05	0.71
1990-2013 period [1)]	-11.2	-0.5	-1.0	-0.002	-0.25	-0.27	-0.27	-0.11	-1.52
1990-2013 period [2)]	-68%	-68%	-100%	-68%	-68%	-68%	-68%	-68%	-68%

4.7.4 *Activity data and (implied) emission factors*

Because fuel sales to the fishing sector in the Netherlands cannot be distinguished from the sales of bunker fuels, 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 times 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, ports of arrival and total 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. In all other cases, it has been assumed that the vessels have taken on fuel elsewhere. Furthermore, vessels are assumed always to refuel after completion of a fishing trip.

The applied emission factors for NO_x, CO, NMVOC and PM_{10} were derived from Hulskotte and Koch (2000), whereas the SO_2 emission factors were derived from Van der Tak (2000). Emission factors for NH_3 were derived from Ntziachristos and 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*

There was no recent and accurate information available for assessing the uncertainties of the emissions from national fishing. 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, as reported in Section 4.7.3.

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.

4.8 Fuel used and fuel sold emissions for road transport

The emissions as reported in the current submission for the different source categories within road transport (1A3b) are estimated based on vehicle kilometres driven in the Netherlands, as described in section 4.3.4. Emissions of air pollutants are not directly proportional to fuel consumption as they also depend on driving conditions, motor and exhaust gas after-treatment technology etcetera (notable exceptions are SO_x and Pb, with emissions being directly dependant on sulphur and lead content of the fuel). Using the NAP register, the Netherlands has detailed information on the average annual mileages from different types of road vehicles. Since road transport is a key source for many substances, applying a Tier-3 methodology based on vehicle kilometres driven for different vehicle types under different driving conditions is considered the appropriate method to derive emission estimates for air pollutants by road transport. Resulting emission totals are considered the best estimates of total emissions of air pollutants 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 fuel used (FU) or kilometres driven on national territory (UNECE, 2009). To comply with the UNECE-guidelines, emission totals for road transport are also estimated and reported based on fuel sold. Compliance checking for the 2010 national emission ceilings under the CLRTAP and the NEC directive for the Netherlands is based on the FU emission totals, therefore the FS emissions from road transport are reported as a memo item and the methodology for estimating fuel sold emissions has so far been straightforward.

4.8.1 *Deriving fuel sold emission totals for road transport*

To derive FS emissions for road transport, the 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 in the Energy Balance. Fuel used by road transport on Dutch territory is estimated on the basis of the vehicle kilometres driven per vehicle type, combined with specific fuel consumption factors (gram fuel per vehicle kilometre), as described in more detail in section 4.3.4. The emission totals per fuel type are subsequently adjusted for differences in fuel used and fuel sold per fuel type.

Figure 4.10 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 1990-2013 time series. For gasoline, both time series show good agreement in both the absolute level and the trend in energy use. In recent years of the time series, differences between fuel used and fuel sold vary between 0 and 2%. In 2012 and 2013 the amount of gasoline sold within the Netherlands was actually lower than estimated fuel used. Gasoline fuel sales decreased by 6% in 2013 compared to 2012, whereas gasoline fuel consumption by road transport in the Netherlands decreased by only 0.3%. Part of this difference might be attributed to the use of preliminary data on vehicle kilometres travelled in the Netherlands. Since odometer readings from 2013 and 2014 are not yet available for all passenger cars in the car fleet, average annual mileages from different car types in 2013 are still preliminary.

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 has increased from 15% in earlier years of the time series to 29% in 2006 and has since varied around 25%. 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 extend 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. Another possible explanation is that fuel used is underestimated due to a lack of knowledge on specific fuel consumption of light duty trucks in the Netherlands. 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.

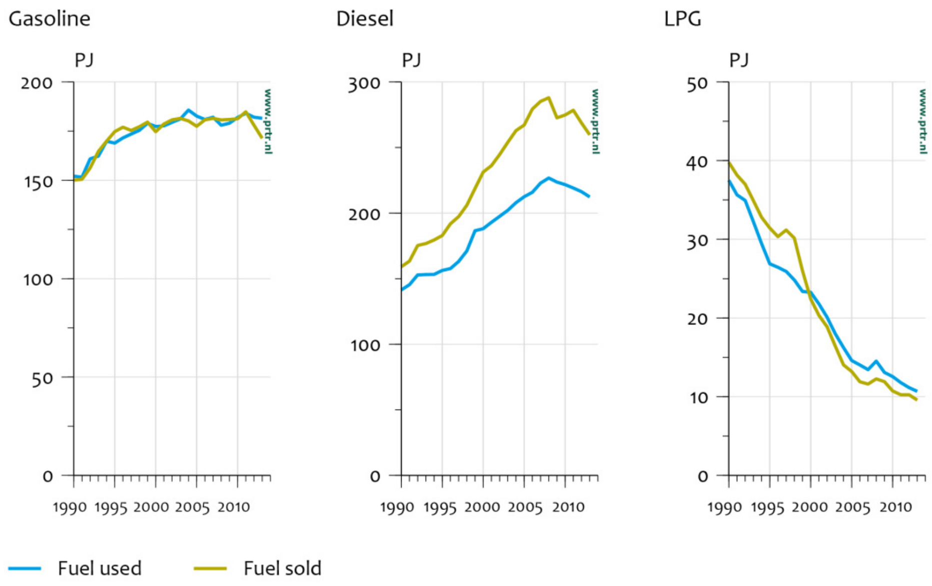


Figure 4.10: Fuel used vs. fuel sold trends, for gasoline, diesel and LPG fuelled road transport in the Netherlands

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. Again, the amount of fuel sold is larger than the estimated fuel used on Dutch territory and the causes for these differences are currently unknown.

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 are substantially adjusted upwards, as can be seen in Figure 4.11. 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.

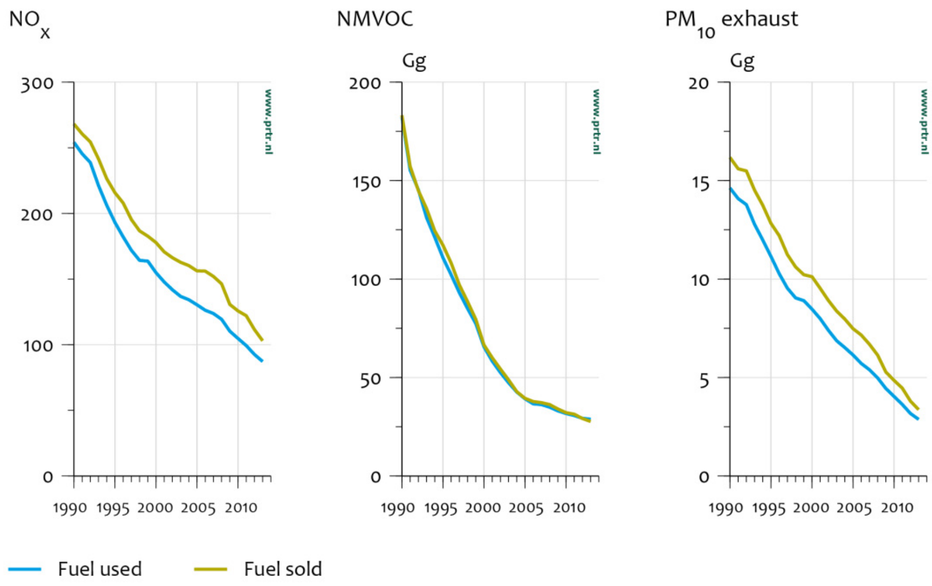


Figure 4.11: NO_x, NMVOC and PM_{10} exhaust emissions from road transport in the Netherlands based on fuel used and fuel sold

4.8.2 *Improvements of fuel sold methodology*

Because fuel sold emissions from road transport in the Netherlands were not used for compliance checking with the CLRTAP and the NEC directive for 2010, and have only been reported as a memo item, the differences between fuel used and fuel sold in the Netherlands have not been studied extensively in the recent years. A straightforward methodology to estimate fuel sold emissions, based on a generic correction of fuel used emissions per fuel type, was deemed sufficient. The Gothenburg protocol has been amended though in 2012 to include national emission reduction commitments for 2020 and beyond. Compliance checking for the new targets in the Netherlands will now be based on fuel sold emissions. Therefore, the difference between fuel used and fuel sold for road transport in the Netherlands is a subject of study in the coming years, in order to improve the fuel sold emissions totals.

In 2014, both the fuel used estimates and the fuel sold figures for road transport have been adjusted, resulting in adjusted time series for both in the current submission compared to last year’s submission. Fuel sales data for gasoline and LPG have been adjusted downwards to account for the use of gasoline and LPG in non-road applications. Gasoline fuel use for recreational craft and non-road mobile machinery and LPG use for non-road mobile machinery is not reported separately in the Energy Balance by Statistics Netherlands. After consultation with national experts at Statistics Netherlands, it was concluded that these applications were actually included in the fuel sales data for road transport. Therefore, the fuel sales data for road transport have been adjusted downwards in the current submission. The resulting reduction in reported gasoline fuel sold for road transport was approximately 1.0

to 1.5% in the time series. Use of gasoline in non-road applications (2 PJ) is only minor compared to the use in road transport (150-180 PJ). For LPG the adjustment in reported fuel sales for road transport starts at 1 PJ in 1990 (3% reduction of fuel sold for road transport), increasing to 3 PJ in 2013 (20% reduction).

The fuel used estimated for road transport have also been adjusted in the current submission. The adjustments of time series for vehicle kilometres driven by passenger cars and light duty trucks, as described in paragraph 4.3.8, also affected fuel used estimates for both categories. Since the total amount of vehicle kilometres driven on Dutch territory increased for most of the time series, the estimated amount of fuel used also increased. The adjustments to the time series for both fuel used and fuel sold led to better agreement between fuel used and fuel sold for LPG and gasoline in the current submission.

4.8.3 Planned improvements of fuel sold methodology

In order to further improve the fuel sold emission totals, the bottom-up estimate of fuel used in the Netherlands by light duty trucks will be updated, as is described in section 4.3.9. This project was initiated in 2014, as described in last year’s inventory report, but results were not available in time for the current submission. Combined with the improved estimates of fuel used by passenger cars and heavy duty trucks, this should result in the best estimate of fuel used by road transport in the Netherlands and therefore in a better understanding on the actual differences between fuel used and fuel sold.

The next step to improve the fuel sold emission estimates will be to study the potential vehicle categories responsible for the differences between fuel used and fuel sold. If for example the difference for diesel is mainly caused by international freight transport, than it might be an option to adjust only the emission totals for heavy duty trucks. If freight transport is mainly on highways, then the emission totals for heavy duty trucks on motorways should be adjusted accordingly. And if the tractor-trailer fleet that is used for international transport is relatively new compared to the average fleet in the Netherlands, then this should also be taken into account when adjusting emission totals. This improved fuel sold emissions methodology is currently planned for 2015.

5 Industrial Processes and Product Use (NFR 2)

5.1 Overview of the sector

This submission includes NFR09 sector 3, "Solvent and other product use" in NFR14 sector 2 as source category 2D. Therefore the former Chapter 6 on Solvents and other product use has been incorporated in this Chapter 5. 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 2013 Guidebook is not clear in which sources belong to 2G and 2L, 2G is included in 2D3i (Other solvent 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

	Main Pollutants				Particulate Matter		
	NO_x	NMVOC	SO_x	NH_3	TSP	PM_{10}	$PM_{2.5}$
Year	Gg	Gg	Gg	Gg	Gg	Gg	Gg
1990	5.2	215	10	5.4	49	30	15
1995	3.3	154	2.8	5.2	34	19	9.4
2000	1.9	108	1.5	4.0	18	12	6.2
2005	0.6	87	1.0	3.6	17	11	5.4
2010	0.5	82	0.9	2.5	15	11	5.0
2012	0.7	81	0.9	2.1	15	10	4.3
2013	0.7	77	0.8	2.2	15	10	4.2
1990–2013 period [1]	-4.4	-138	-9.2	-3.2	-35	-20	-10.4
1990–2013 period [2]	-86%	-64%	-92%	-59%	-70%	-67%	-71%

	Priority Heavy Metals			POPs	
	Pb	Cd	Hg	DIOX	PAHs
Year	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	25	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
2012	13	0.6	0.3	15	0.1
2013	11	0.5	0.2	16	0.1
1990–2013 period [1]	-56	-0.4	-1.00	-46	-13
1990–2013 period [2]	-83%	-46%	-81%	-74%	-99%

[1] Absolute difference in Gg [2] Relative difference to 1990 in %

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 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:

Em non_IF = IEF * (TP -/- 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:

IEF = Em IF / 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:

Em non_IF = $Em\_IF_{(n)}$ / $Em\_IF_{(n-1)}$ * Em $non\text{-}IF_{(n-1)}$

where n = year

Method 2-IP

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

Em non_IF = IEF * (TP -/- 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:

IEF = Em IF / 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:

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

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 time-series 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 Subsection 1.6.2.

5.1.6 *Source-specific recalculations*
There have been no source-specific recalculations in comparison to the previous submission.

5.1.7 *Source-specific planned improvements*
Industrial processes
Incomplete TSP and Cd time series will be repaired, where possible, in future submissions.
Furthermore the incorrect allocation of some sources of 2B10a for the year 2000, will be corrected in next submission.

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 2013 (%)
2A3	Glass production	Pb	6.2
2A6	Other Mineral Products	$PM_{10}/PM_{2.5}$	4.0/2.8

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 emissions from the key sources of Mineral products (2A).

	NFR Code:	2A3	2A6	
	NFR NAME:	Glass production	Other mineral products	
	Pollutant:	Pb	PM_{10}	$PM_{2.5}$
	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
2012		0.8	1.1	0.4
2013		0.9	1.1	0.4

From 1990 to 2013, Pb emissions from 2A3 decreased from 7.3 to 0.9 Mg. This reduction is mainly caused by the implementation of technical measures.
The most important source of PM_{10} and $PM_{2.5}$ emissions in 2A6 is the ceramic industry (Production of bricks, roof tiles, etc). As a result of the implementation of technical measures the PM_{10} emission from 2A6 decreased from 2.0 Gg in 1990 to 1.1 Gg in 2013.

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 CO_2 and N_2O 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 2013 (%)
2B10a	Chemical industry: Other	NMVOC	3.6

5.3.3 *Overview of emission shares and trends*

Table 5.5 gives an overview of the emissions from the key sources of Chemical Industry 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:	NMVOC	PM_{10}	$PM_{2.5}$
	Unit:	Gg	Gg	Gg
Year				
1990		33	4.1	2.1
1995		18	3.0	1.5
2000		13	0.5	0.4
2005		7.9	1.2	0.7
2010		5.7	1.3	0.7
2012		7.2	1.2	0.6
2013		5.4	1.3	0.7

From 1990 to 2013, NMVOC emissions decreased from 33 Gg to 5.4 Gg, and PM_{10} emissions from 4.1 Gg to 1.3 Gg. These reductions were mainly caused by the implementation of technical measures. Due to a major incidental emission there was a jump in 2012.
For the year 2000 some sources of 2B10a were allocated in the 1A2c (Stationary combustion in manufacturing industries and construction:

Chemicals) category. Therefore there is a dip in the 2000 PM_{10} emissions. This will be corrected in next submission.

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 2013 (%)
2C1	Iron and Steel Production	PM_{10}/$PM_{2.5}$	6.9/4.7/6.3
		Pb	67.2
		Hg	33.3

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).

In addition to PM_{10}, $PM_{2.5}$, Pb and Hg (the key source pollutants), iron and steel production is also responsible for 11% of the total in dioxins and for 1.3% 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, Pb and Cd emission decreased in both 2012 and 2013. Dioxin emission fluctuations were mainly caused by the varying process conditions.

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

	NFR Code:	**2C1**					
	NFR NAME:	**Iron and steel production**					
	Pollutant:	**PM_{10}**	**$PM_{2.5}$**	**Pb**	**Hg**	**Dioxin**	**PAH's**
	Unit:	**Gg**	**Gg**	**Mg**	**Mg**	**g I-Teq**	**Mg**
Year							
1990		9.1	5.9	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	1.4	0.08
2005		1.7	1.1	23	0.2	1.4	0.06
2010		1.5	1.0	30	0.2	1.7	0.08
2012		1.4	0.8	11	0.2	1.2	0.08
2013		1.2	0.8	9.5	0.2	2.8	0.06

Aluminium production (2C3)
Aluminium production (category 2C3) is responsible for 0.12% 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 and primary aluminium was produced at two primary aluminium smelters in the Netherlands. One anode producer and one primary aluminium smelter were closed in 2011.
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
2012		0.001
2013		0.006

Between 1990 and 2000, PAH emissions decreased from 7 Mg in 1990 to less than 1 Mg in 2000. These reductions were mainly caused by the implementation of technical measures.

PAH emissions decreased to 0.006 Mg in 2013, because of the closure of one of the anode production plants and, at the other production plant, it being the first full year in which all three modern fume treatment plants were in operation. 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.

5.4.4 *Methodological issues*

Method 1-IP was used for estimating the emissions from iron and steel production (2C1) and aluminium production (2C3).
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 (2D3)*

As mentioned in paragraph 5.1 the former NFR sector 3 “Solvents and Other Product Use” has been incorporated in this sector as source category 2D3.

Table 5.9 gives an overview of the NMVOC and dioxin emissions from source category 2D3.

Table 5.9 Overview of emissions of NMVOC and dioxin from source category 2D3

	Pollutant:	NMVOC	Dioxin
	Unit:	Gg	g I-Teq
Year			
1990		141	25
1995		113	23
2000		81	20
2005		62	18
2010		58	15
2012		57	14
2013		56	14

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).

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 (2D3).

	Category / Subcategory	Pollutant	Contribution to total of 2013 (%)
2D3a	Domestic solvent use including fungicides	NMVOC	13.9
2D3d	Coating applications	NMVOC	11.7
2D3h	Printing	NMVOC	2.7
2D3i	Other solvent use	NMVOC $PM_{10}/PM_{2.5}$ DIOX	7.1 4.4/9.3 54.3

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	2D3h	2D3i			
	NFR NAME:	Domestic solvent use including fungicides	Coating applications	Printing	Other solvent use			
	Pollutant:	NMVOC	NMVOC	NMVOC	NMVOC	PM_{10}	$PM_{2.5}$	Dioxin
	Unit:	Gg	Gg	Gg	Gg	Gg	Gg	g I-Teq
Year								
1990		12	92	14	15	1.9	1.9	25
1995		15	66	14	13	1.8	1.8	23
2000		17	38	12	11	1.8	1.8	20
2005		18	24	5.6	11	1.5	1.5	18
2010		20	20	3.7	11	1.5	1.5	15
2012		21	18	3.6	11	1.3	1.3	14
2013		21	17	4.0	11	1.2	1.2	14

Domestic solvent use including fungicides (2D3a)

The emission sources in this key source are:

- Cosmetics (and toiletries);
- Car products;

- Cleaning agents;
- Others.

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

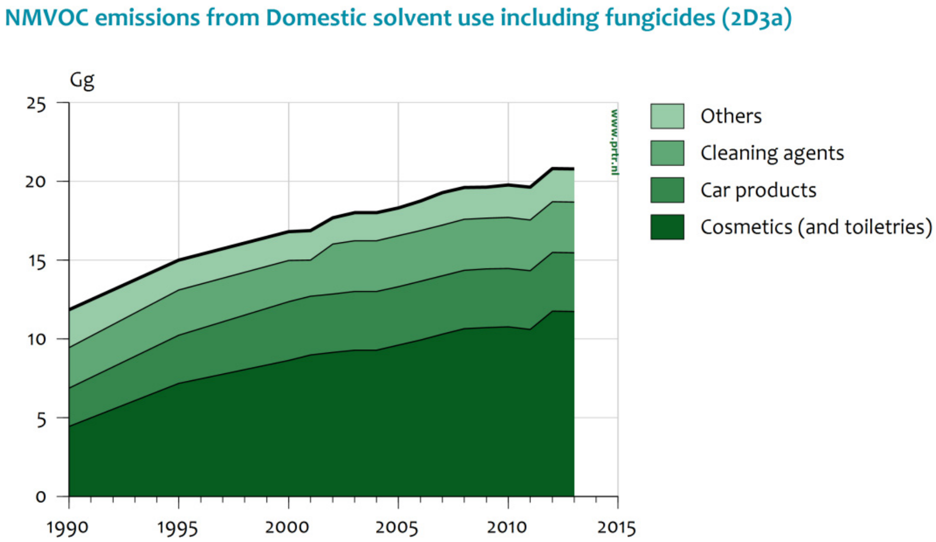


Figure 5.1 NMVOC emissions from sources of Domestic solvent use including fungicides (2D3a)

During the period 1990-2013, NMVOC emissions increased from 12 Gg in 1990 to 21 Gg in 2013. 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
- Boat building
- Construction and buildings
- Domestic use
- Car repairing

Mainly due to the lower average NMVOC content of the paints used (see also Table 6.3), NMVOC emissions from Coating applications (2D3d***)*** decreased from 92 Gg in 1990 to 23 Gg in 2008. As a result of the credit crunch, paint consumption decreased over the 2009–2013 period; therefore, NMVOC emissions also decreased to 17 Gg in 2013.

Figure 5.2 shows the trend in NMVOC emissions from the sources of Coating applications (category 2D3d) over the 1990–2013 period.

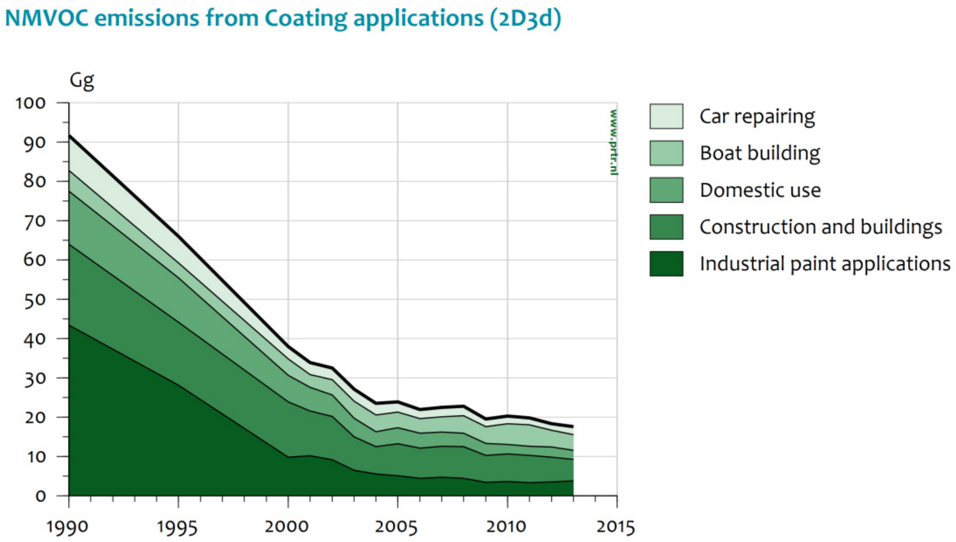


Figure 5.2 NMVOC emissions from sources of Coating applications (2D3d)

Printing (2D3h)
NMVOC emissions decreased from 14 Gg in 1990 to 4.2 Gg in 2008. These reductions were mainly the result of the implementation of technical measures (e.g. afterburners).
Due to the poor economic conditions, but also to the structural decline in demand for printed matter, caused by the ongoing digitization of information flows, the sales of printing ink declined during the period 2008-2012. Consequently, emissions from printing decreased to 3.4 Gg in 2012.
In 2013, both sales and emissions show an increase. However, this is not due to a revival of the market, but rather because the statistics of the sales has been changed. The reality is that the market is continuing to stagnate.

Other solvent use (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 2012. 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 14 g I-TEQ in 2012.
PM_{10} and $PM_{2.5}$ originate from sources which belong to Other product use (2G).
As already mentioned in 5.1 the 2013 Guidebook is not clear in which sources belong to 2G. Therefore 2G is included in 2D3i.
The most important source of PM_{10} 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 decreased from 1.8 Gg in 1990 to 0.9 Gg in 2012.

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).
Table 5.12 provides an overview of total paint consumption in the Netherlands and its NMVOC content.

Table 5.12 Overview of total paint consumption in the Netherlands and its NMVOC content

Year	Total Paint Consumption (kt)	VOC content in %
1990	197	30.0
1995	207	20.0
2000	272	14.8
2001	262	13.9
2002	251	13.6
2003	240	12.1
2004	224	11.1
2005	239	10.7
2006	236	9.8
2007	243	9.9
2008	233	10.2
2009	203	10.0
2010	206	10.3
2011	202	10.2
2012	180	10.6
2013	168	9.9

Table 5.12 shows a decrease in NMVOC content, from 30% in 1990 to almost 10% in 2006. After 2006, the NMVOC contents remained rather stable.

Printing (2D3h)
Up to 2008 (including emissions of 2007), the Dutch Government had an agreement with the printing industry through which data became available for the emission inventory. For the 2008–2013 period, emissions were calculated using the annual sales figures of printing ink, which have been available since 2007.

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, 2014: in preparation).

Printing (2D3h)
Since 2009 (including emissions of 2008), the emissions have been calculated as follows:

$$EM_n = EM_{(n-1)} * AS_{(n)} / AS_{(n-1)}$$

where n = year, and AS = Annual Sales

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.

5.6 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 2013 (%)
2H2	Food and beverages industry	NMVOC	2.5
		$PM_{10}/PM_{2.5}$	6.3/2.1
2H3	Other industrial processes	NMVOC	6,8
		$PM_{10}/PM_{2.5}$	9.8/5.2

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 emissions from the key sources of Other Production Industry (2H)

	NFR Code:	2H2					
	NFR NAME:	Food and beverages industry			Other industrial processes		
	Pollutant:	NMVOC	PM_{10}	$PM_{2.5}$	NMVOC	PM_{10}	$PM_{2.5}$
	Unit:	Gg	Gg	Gg	Gg	Gg	Gg
Year							
1990		7.1	4.3	0.7	27	5.4	1.6
1995		6.5	2.3	0.4	13	3.2	0.9
2000		6.0	1.8	0.3	11	3.3	1.0
2005		5.1	2.0	0.3	10	2.7	0.8
2010		5.1	1.8	0.3	11	2.7	0.7
2012		4.6	1.6	0.3	10	2.6	0.7
2013		3.8	1.7	0.3	10	2.6	0.7

Food and beverages industry (2H2)
From 1990 to 2013, NMVOC emissions decreased from 7 to 4 Gg, and for PM_{10} the decrease was from 4 to 2 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 2013, NMVOC emissions decreased from 27 Gg to 10 Gg. The contribution of storage and handling was 15 Gg in 1990 and 8 Gg in 2013. PM_{10} emissions decreased from 5.4 Gg to 2.6 Gg during the 1990–2013 period. The contribution of storage and handling was 1.4 Gg in 1990 and 1.0 Gg in 2013.

Figure 5.3 shows the trend in PM_{10} emissions from storage and handling of the 2H3 category over the 1990–2013 period.

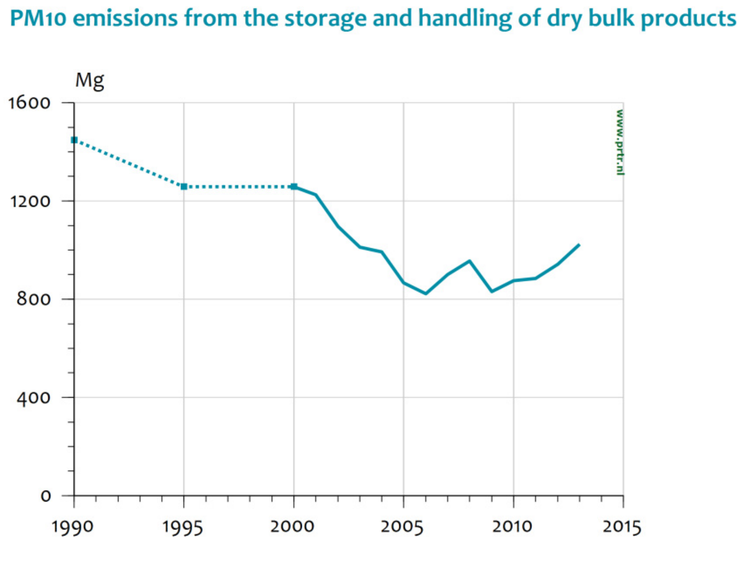


Figure 5.3 Storage and handling of dry bulk products: trend and emissions of PM_{10}

Reductions in NMVOC and PM_{10} emissions were mainly caused by the implementation of technical measures. After 2005, PM_{10} emission fluctuations were caused by the varying amounts of handling products.

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.

6 Agriculture

6.1 Overview of the sector

The data on this sector include all anthropogenic emissions from agricultural activities. However, emissions from fuel combustion (mainly those 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 categories:
3B Manure management
3D Crop production and agricultural soils
3F Field burning of agricultural residues
3I Agriculture other

In the Netherlands, no emissions have been allocated to category 3I and as field burning of agricultural residues is prohibited by law, emissions from activities belonging to category 3F do not occur. Emissions of the greenhouse gases methane (CH_4), nitrous oxide (N_2O) and carbon dioxide (CO_2) are reported in annual National Inventory Reports (NIR). Therefore, the Informative Inventory Report (IIR) focuses on emissions of ammonia (NH_3), nitric oxide (NO), non-methane volatile organic compounds (NMVOC), particulate matter (PM_{10}, $PM_{2.5}$) and zinc (Zn) from the source categories Manure management (3B) and Crop production and agricultural soils (3D).

The agricultural sector is responsible for almost 85% of NH_3 emissions in the Netherlands. Emissions of NO from agriculture are also considerable and could amount to about 10% of the national total, but only those from animal housing and manure storage are being counted towards the ceilings. NO emissions following the application of animal manure or inorganic N-fertilizers and from grazing, are not accounted for in the current ceilings and therefore reported as memo-items under category 11C Natural emissions. NMVOC emissions occur during the handling of manure and in crop production, but only the latter is being estimated and plays a minor role in the national total.

Agriculture is also a large source of PM_{10}, but much less so for $PM_{2.5}$ since the composition of particulate matter from animal houses tends to lean towards the coarser fraction. Zinc is not a priority heavy metal; however emissions stemming from drift following pesticide use are being reported for completeness.

6.1.1 Key sources

For NH_3 the four largest key sources originate in the agricultural sector: Animal manure applied to soils (3Da2a), Dairy cattle (category 3B1a), Swine (category 3B3) and Inorganic N-fertilizers (category 3Da1). Category 6A Other is also a key source and consists amongst others of privately owned horses and manure placed outside agriculture, calculated along the methods described in this chapter. In order to explain 80% of the NH_3 emissions, Non-dairy cattle (3B1b) and Laying hens (3B4gi) need to be included in the key source analysis too.

In the key source analysis for PM_{10}, Laying hens (category 3B4gi) are the largest contributor to emissions. Broilers (category 3B4gii), Swine (category 3B3) and Farm-level agricultural operations including storage, handling and transport of agricultural products (3Dc) are also key sources of PM_{10} within the agricultural sector.

6.1.2 Trends

NH_3 emissions have decreased sharply between 1990 and 2013, as a result of policy changes, with a significant reduction in the first few years of the time-series. A ban on manure surface spreading came into force in 1991, making it mandatory to incorporate the manure into the soil either directly or shortly after application. To a large extent, this prevented the emission of NH_3 following the application of animal manure. It also became mandatory to cover manure storages, and more recently the introduction of emission low housing helped in decreasing ammonia emissions further.

Maximum application standards for manure and inorganic N-fertilizer, together with systems of production rights, also promoted efficiency. For example milk quota led to feeding more maize in dairy cattle in order to increase production per cow, eventually decreasing animal numbers and thus emissions. Ongoing improvement in nutritional management with a profound reduction of dietary crude protein has resulted in lower N excretions per animal, which also contributed significantly to lower NH_3 emissions. This leads to high trend contributions from these source categories and, since the national total is dominated by emissions from agriculture, to an overall decreasing trend in NH_3 emissions.

Although PM emissions for most animal categories decreased slightly over the 1990–2013 period with falling animal numbers, these emissions nearly doubled for laying hens. The reason for this is the almost complete transition from battery cage systems with liquid manure, to ground housing or the aviary system with solid manure and higher associated emission factors for PM_{10} and $PM_{2.5}$.

6.2 Manure management

6.2.1 Source category description

This source comprises emissions from the handling and storage of animal manure. The category of Manure management (3B) has the following 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 categories 3B4a (Buffalo) and 3B4giv (Other poultry) do not occur in the Netherlands. Mules and asses (3B4f) have recently been added to the inventory, and are included in the NFR/IIR for the first time. Under category 3B4h (Other animals) rabbits and furbearing animals are being reported.

6.2.2 *Key sources*

Within the Manure management source category, Dairy cattle (category 3B1a) are the largest contributors to NH_3 emissions with 13.0% of the national total. Swine (category 3B3, 10.9%), Non-dairy cattle (category 3B1b, 6.8%) and Laying hens (category 3B4gi, 5.9%) also form key sources comprised within this sector.

Laying hens (category 3B4gi) form the largest source of PM_{10} emissions, with 10.7% of the national total. Broilers (category 3B4gii, 4.9%) and Swine (category 3B3, 4.5%) also are key categories for PM_{10}.

6.2.3 *Overview of emission shares and trends*

Table 6.1 presents an overview of emissions of the main pollutants NO and NH_3, together with the emissions of the particulate matter species PM_{10} and $PM_{2.5}$ that originate from the Manure management sector.

Table 6.1 Emissions of main pollutants and particulate matter from the category of Manure management (3B)

	Main Pollutants		Particulate Matter	
	NO_x	NH_3	$PM_{2.5}$	PM_{10}
Year	Gg	Gg	Gg	Gg
1990	3.7	100	0.4	3.9
1995	3.7	98	0.4	3.9
2000	3.0	78	0.4	4.4
2005	2.8	66	0.4	4.7
2010	3.0	66	0.5	5.3
2012	2.9	59	0.5	5.6
2013	2.9	55	0.5	5.7
1990-2013 period 1)	-0.8	-46	0.1	1.9
1990-2013 period 2)	-21%	-46%	13%	48%

1) Absolute difference in Gg

2) Relative difference to 1990 in %

Between 1990 and 2013, NH_3 emissions from Manure management reduced by 46%. The combination of higher production rates per animal and quotas, resulted in a decreasing trend in animal numbers (although in recent years they have rather stabilised). An ongoing decrease in N excretions per animal due to lower dietary crude protein and an increase in low emission housing, has added to the effect.

Since NO emissions from agriculture form a new emission source not accounted for under the National Emission Ceiling (NEC), most of these emissions are reported as memo items under the category of Other natural emissions (11C). Emissions from animal housing and storage however have been included in the national total, as they are deemed non-natural.

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

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.* (2014) for a full overview of subcategories and years). For horses, an estimated 300 000 additional animals are included in the inventory, to account for privately owned animals. The emissions of NH_3 and PM resulting from the Manure management of these animals were calculated using NEMA, but are reported under the source category Other (6A).

Table 7.2 Animal numbers over the 1990–2013 period (in 1000 heads)

Animal type	**1990**	**1995**	**2000**	**2005**	**2010**	**2011**	**2012**	**2013**
Cattle	4 926	4 654	4 069	3 797	3 975	3 885	3 879	3 999
- dairy cattle	1 878	1 708	1 504	1 433	1 479	1 470	1 484	1 553
- non-dairy cattle	3 048	2 946	2 565	2 364	2 497	2 416	2 395	2 446
Sheep	1 702	1 674	1 305	1 361	1 130	1 088	1 043	1 034
Swine (*1 000)	13.9	14.4	13.1	11.3	12.3	12.4	12.2	12.2
Goats	61	76	179	292	353	380	397	413
Horses[1]	70	100	117	133	141	136	131	129
Mules and asses	NO	NO	NO	NO	1	1	1	1
Poultry (*1 000)	94.9	91.6	106.5	95.2	103.4	98.9	97.0	99.4
- laying hens (*1 000)	51.6	45.7	53.1	48.4	56.5	53.0	51.4	53.5
- broilers (*1 000)[2]	43.3	45.9	53.4	46.8	46.9	45.9	45.6	45.9
Other animals[3]	1 340	951	981	1 058	1 261	1 278	1 358	1 342

[1] excluding privately owned horses
[2] including turkeys
[3] rabbits and furbearing animals
Source: CBS, 2014

A distribution is made of animals over the various housing types, using information from the agricultural census and where needed environmental permit data (Van Bruggen *et al.*, 2011). For instance the agricultural census only gives implementation grades of abatement techniques in a very general manner (e.g. floor/cellar adaptation or air scrubber). Further subdivision is possible by looking at environmental permits issued in a number of provinces.

Furthermore, the N excretions per animal calculated annually by the working group on uniformity of calculations of manure and mineral data (WUM) are being used. The data was recalculated in 2009 based on the latest insights (CBS, 2012a), and is supplemented on a yearly basis by means of the publication series 'Dierlijke mest en mineralen' (Animal manure and minerals, in Dutch).

Using the method described in Velthof *et al.* (2009), from this basic data the excretion of TAN and NH_3 emission factors expressed as % of TAN, are being derived for several (sub-)categories of animals. Distinction is made between animal housing, storage, grazing and application of animal manure in a balancing method. In such also corresponding emission factors for N_2O, NO and N_2 are used, based on the gross N excretion in each housing type. The Tier 1 default N_2O emission factors from the IPCC 2006 Guidelines are applied, which were also used for NO following research that set the ratio to 1:1 (Oenema *et al.*, 2000). From the same study losses in the form of N_2 were set to a factor five (solid manure) or ten (liquid manure) of these factors, all expressed as percentages of the total N available.

After subtracting the amounts of N emitted in animal houses and taking implementation grades in consideration, NH_3 emissions from manure storage outside the animal housing are being calculated in a similar manner. However no separate emissions of N_2O, NO and N_2 from outside storages are being estimated, since emission factors used for animal housing already include losses during storage.

The emission factors for PM coming from animal housing, are based on a measurement programme conducted by Wageningen UR Livestock Research between 2007 and 2009. For a range of livestock categories and animal housing types, PM_{10} and $PM_{2.5}$ emissions were determined, see the publication series 'Fijnstofemissie uit stallen' (Dust emission from animal houses, in Dutch with English summary and available through www.asg.wur.nl). The animal housing types not included were given emission factors proportional to those used before. Where emission factors had to be derived within animal categories (e.g. laying hens under and over 18 weeks of age), this was done on the basis of the excreted amount of phosphorus (P). An overview of the resulting emission factors is presented in Van Bruggen *et al.*, 2014.

6.2.5 *Methodological issues*

Emissions of NH_3 and NO from animal manure in animal houses and storage are calculated using the National Emission Model for Agriculture (NEMA) at a Tier 3 level. The total ammonia nitrogen (TAN) in manure was estimated, on the basis of faecal digestibility of the nitrogen in various feed components within the rations, taking into account organic N mineralisation/immobilisation and excretion on pasture land during grazing. From this, NH_3 emissions were calculated according to the method described in Velthof *et al.* (2009).

Other N losses from animal houses were also calculated and subtracted from the N excretion, before multiplying with the fraction outside storage. During storage again emissions of NH_3 take place, sum of both are reported under their respective subcategories in sector 3B Manure management (losses in the form of N_2O, NO and N_2 from outside storages are accounted for in the emission from animal houses). Net export, processing or incineration of manure are then also deducted, to calculate the amount of N available for application. Emissions following manure application and from grazing are allocated to sector 3D Crop production and agricultural soils, to be described in Section 6.3.

Figure 6.1 presents a schematic overview of NH_3 and NO emissions in relationship to N flows, including their allocation to source categories. Table 6.3 provides a summary of associated N flows (in Gg N), over the 1990–2013 period for the sector of Manure management.

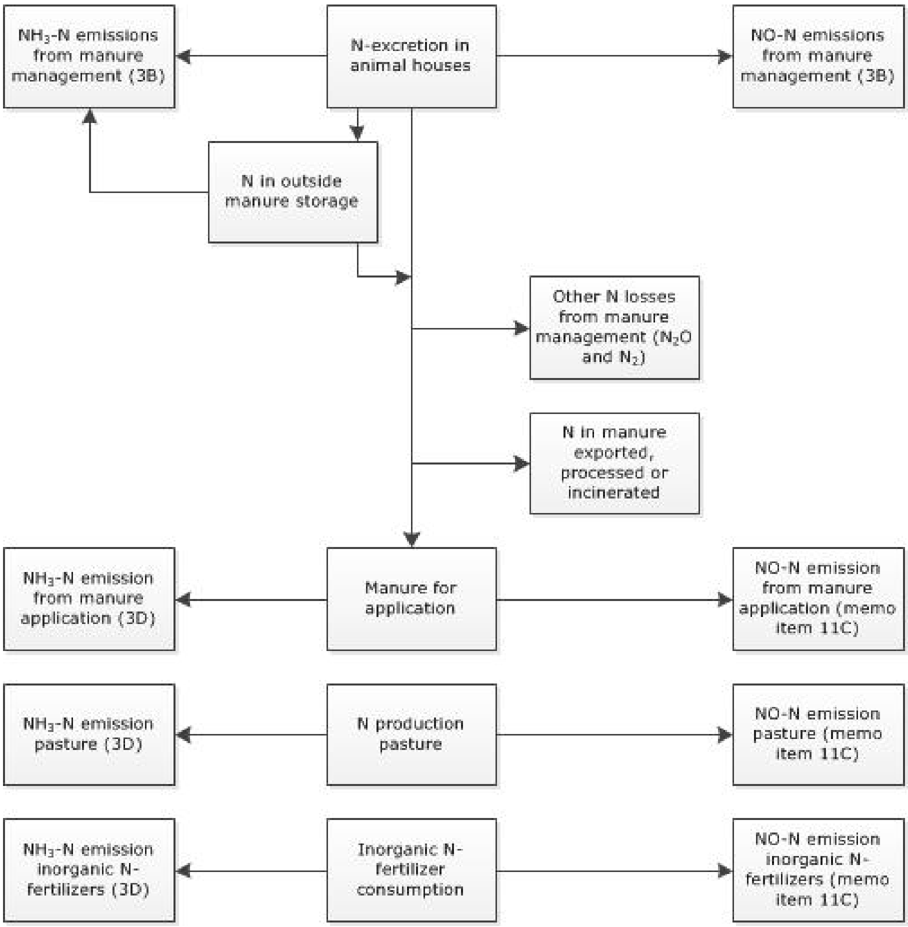


Figure 6.1 Nitrogen flows in relationship to NH_3 and NO emissions

Table 6.3 Nitrogen flows related to NH_3 and NO emissions in NFR sector 3B Manure management (in Gg N)

3B Manure management	1990	1995	2000	2005	2010	2011	2012	2013	Change 2013 - 1990
Nitrogen excretion in animal housing	506.5	508.1	424.5	385.5	416.0	415.9	403.3	412.3	-19%
of which in solid manure	94.1	96.3	86.8	80.4	89.2	86.5	82.2	85.1	-10%
of which in liquid manure	412.4	411.8	337.7	305.1	326.8	329.4	321.2	327.2	-21%
NH_3-N emissions from animal housing	81.7	80.0	63.1	53.4	53.5	49.8	47.1	43.8	-46%
NO-N emissions from animal housing	1.1	1.1	0.9	0.8	0.9	0.9	0.8	0.9	-21%
N_2O-N emissions from animal housing	1.1	1.1	0.9	0.8	0.9	0.9	0.8	0.9	-21%
Other N losses from animal housing[1]	9.5	9.5	7.8	8.4	10.8	13.6	13.7	16.1	69%
Nitrogen in manure used outside agriculture[2]	9.6	12.5	6.9	14.7	5.5	12.8	14.0	15.3	59%
Nitrogen in exported/incinerated manure	12.2	28.4	24.4	34.1	58.3	56.8	62.2	61.5	403%
Available manure for application (to 3D)	391.2	375.6	320.5	273.4	286.2	281.2	264.6	273.9	-30%
(N excretion in animal housing - total N losses in animal housing – exported/incinerated manure)									

[1] includes N_2-N losses from animal housing, N in the washing liquid of air scrubbers and N produced in the free-range of poultry.
[2] hobby farms, application on nature terrains and use by private parties; emissions are allocated to sector 6A Other.

The N excreted by animals decreased considerably over the 1990–2013 period, while the manure exported or incinerated increased fourfold. Other N losses from animal housing and nitrogen in manure outside agriculture also increased, leading to 30 percent less nitrogen in manure to be applied on agricultural soils. Since the other N losses from animal housing also comprise washing liquid of air scrubbers which is used as an inorganic N-fertilizer, some emissions shifted to category 3D Crop production and agricultural soils. The same goes for nitrogen in manure used outside agriculture, as emissions are allocated to category 6A Other.

Particulate matter emissions from agriculture mainly consist of animal skin, manure, feed and bedding particles originating in animal housings.

The general input data used for calculating the emissions are animal numbers and housing systems taken from the annual agricultural census and environmental permits. For several animal categories, country-specific emission factors are available (see Subsection 6.2.4).

6.2.6 *Uncertainties and time-series consistency*

A propagation of error analysis on NH_3 emissions was completed this year. Using reassessed uncertainty estimates of input data (CBS, 2012) and expert judgment, an uncertainty of 16% in the total NH_3 emission from Manure management has been calculated. Including the emissions in sector 3D Crop production and agricultural soils, the combined uncertainty in NH_3 emission becomes 20%. It will be evaluated whether a Monte Carlo-analysis could improve the estimate further by taking dependent variables into account.

As annual censuses have been conducted the same way for many years (even decades), and the same calculations were used for the whole series, the time-series consistency is very good. This year a web-based application will be implemented for the agricultural census, which will enable more specific questioning and thus enhance the data being obtained.

6.2.7 *Source-specific QA/QC and verification*

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

6.2.8 *Source-specific recalculations*

Ammonia emission factors for the animal housing of fattening pigs were updated (Groenestein *et al.*, 2014b and Mosquera *et al.*, 2010). As a result emissions increased by 13.7 Gg in 1990 and 3.6 Gg in 2012. In the submission of last year new EFs for dairy cattle were already implemented, and factors for other cattle categories were derived from those. In their final report Ogink *et al.* (2014) suggested to do so based on the proportion of TAN excretion. This was implemented for the whole time-series to ensure consistency, and factors for meat calves were also updated (Groenestein *et al.*, 2014a). As a result, ammonia emissions from non-dairy cattle housing decreased by 2.4 Gg in 1990 and increased by 0.7 Gg in 2012, since in historic years the factors were relatively high in comparison to dairy cattle. For later years the EFs now gradually increase to account for the trend towards a larger living space per animal, explaining the higher emissions in recent years.

Until now ammonia emissions from animal housing, manure storage and the application of animal manure to agricultural soils were all to be reported under source category 3B Manure management. Nevertheless the Guidebook indicates that emissions following the application of animal manure are actually to be contributed to source category 3D Crop production and agricultural soils, as is already the case for emissions following grazing. In the new NFR there is also the possibility to do so, with the introduction of the category 3Da2a Animal manure applied to soils. In order to improve transparency and enhance consistency with the reporting of greenhouse gases (NIR) it was decided to reallocate these emissions. Following table 7.4 presents a detailed breakdown of the ammonia emissions from animal houses, manure storages, application of animal manure and grazing for the animal categories in the NFR.

Table 6.4 NH_3 emissions (Gg) in each stage of the manure management chain for the base year 1990 and current year 2013, per NFR category

NFR code	category	Animal housing			Outside storage			Application			Pasture		
3B1a	Dairy cattle	19.4	16.9	-13%	2.2	0.5	-80%	89.8	19.6	-78%	9.0	0.5	-94%
3B1b	Non-dairy cattle	9.1	8.8	-3%	1.5	0.4	-76%	46.3	9.0	-81%	7.0	0.5	-93%
3B2	Sheep	0.5	0.1	-79%	0.1	0.0	-82%	0.8	0.2	-80%	1.7	0.1	-91%
3B3	Swine	48.6	14.2	-71%	0.6	0.4	-33%	52.8	8.2	-84%	NA	NA	
3B4a	Buffalo	NO	NO		NO	NO		NO	NO		NO	NO	
3B4d	Goats	0.1	0.4	374%	0.0	0.1	287%	0.2	0.8	287%	NA	NA	
3B4e	Horses	0.3	0.5	69%	0.0	0.1	36%	0.6	0.6	5%	0.2	0.1	-54%
3B4f	Mules and asses	NO	0.0		NO	0.0		NO	0.0		NO	0.0	
3B4gi	Laying hens	9.2	6.5	-29%	0.6	1.4	147%	13.6	0.0	-100%	NA	NA	
3B4gii	Broilers	5.8	2.5	-56%	0.8	0.2	-76%	6.1	1.1	-83%	NA	NA	
3B4giii	Turkeys	IE	IE		IE	IE		IE	IE		NA	NA	
3B4giv	Other poultry	NO	NO		NO	NO		NO	NO		NO	NO	
3B4h	Other animals	0.5	0.3	-45%	0.0	0.0	-25%	1.3	0.2	-83%	NA	NA	
	TOTAL	93.4	50.2	-46%	5.8	3.0	-49%	211.6	39.7	-81%	17.8	1.3	-93%

Emissions from animal housing and outside storage are now reported per animal category under their respective NFR codes within 3B Manure management, and the total of manure application and grazing under source category 3Da2a and 3Da3 respectively.

6.2.9 *Source-specific planned improvements*

None.

6.3 Crop production and agricultural soils

6.3.1 *Source category description*

This category consists of all emissions related to the agricultural use of land:

3Da1 Inorganic N-fertilizers (includes also urea application)
3Da2a Animal manure applied to soils
3Da2b Sewage sludge applied to soils
3Da2c Other organic fertilizers applied to soils (including compost)
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
3F Field burning of agricultural residues
3I Agriculture other

Emissions within the categories 3Db (Indirect emissions from managed soils), 3Dd (Off-farm storage, handling and transport of bulk agricultural products) and 3F (Field burning of agricultural residues) do not occur in the Netherlands, and no emissions have been allocated to category 3I (Agriculture other). Category 3Dc Farm-level agricultural operations including storage, handling and transport of agricultural products 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 allotted to category 3De Cultivated corps and Zn emissions to category 3Df Use of pesticides.

6.3.2 *Key sources*

Animal manure applied to soils (3Da2a) is the largest key source for NH_3 with 29.7% of the national total. Inorganic N-fertilizers (3Da1) also is one of the key sources of NH_3 with a contribution of 10.2%.

Farm-level agricultural operations including storage, handling and transport of agricultural products (3Dc) is a key source for PM_{10} emissions at 2.3% of the national total.

6.3.3 *Overview of shares and trends in emissions*

Table 6.5 presents an overview of emissions of the main pollutants NH_3, NMVOC and NO, together with the particulate matter fractions PM_{10} and $PM_{2.5}$ and the other heavy metal Zn that originate from the category of Crop production and agricultural soils (3D).

Table 6.5 Emissions of main pollutants and particulate matter from the category of Crop production and agricultural Soils (3D)

	Main Pollutants			Particulate Matter		Other Heavy Metals
	NO_x	NMVOC	NH_3	$PM_{2.5}$	PM_{10}	Zn
Year	Gg	Gg	Gg	Gg	Gg	Mg
1990	0.3	0.2	251	0.1	0.8	0
1995	0.4	0.2	112	0.1	0.8	0
2000	0.4	0.2	85	0.1	0.8	0
2005	0.4	0.2	72	0.1	0.8	6.8
2010	0.3	0.2	59	0.1	0.8	4.5
2013	0.3	0.2	59	0.1	0.7	4.1
1990-2013 period [1)]	0.0	0.0	-192	0.0	0.0	4.1
1990-2013 period [2)]	16%	18%	-76%	-1%	-2%	

[1)] Absolute difference in Gg
[2)] Relative difference to 1990 in %

Emissions of NH_3 decreased with 76% between 1990 and 2013, with an initial sharp decrease in the 1990-1995 period. This was mainly the result of mandatory changes in application methods that came into force in the early nineties (i.e. incorporation of the manure into the soil instead of spreading it over the surface). Also the use of inorganic N-fertilizer has been decreasing over the years, following policy measures aimed at reducing nutrient supply to soils.

The particulate matter emissions reported in this source category originate from inorganic N-fertilizer use, but also pesticides, supply of concentrate feed to farms, haymaking and crop harvesting contribute to the reported emissions of PM_{10} and $PM_{2.5}$.
Since NO emissions from Crop production and agricultural soils are not accounted for under the NEC, they are reported as a memo item under the category of Other natural emissions (11C). NO emissions from animal manure application, inorganic N-fertilizer use and grazing are thus included in this category (see also Subsection 6.2.3). Emissions reported under category 3D therefore originate from the application of sewage sludge and compost.

6.3.4 *Activity data and (implied) emission factors*

After subtracting the amounts of manure removed from agriculture, exported or incinerated, the remaining amount was allocated to pasture and arable land. Implementation grades of application techniques were derived from the agricultural census, and associated ammonia emission factors have been reported in Velthof *et al.*, 2009. NO emissions related to manure application were being calculated using the EMEP default factor.

Ammonia emissions from the use of inorganic N-fertilizers were calculated using data on the amount of inorganic N-fertilizer sold, corrected for non-agricultural use. Several types of inorganic N-fertilizer were distinguished – each with their own specific ammonia emission factor (Velthof *et al.*, 2009). These emission factors were used in NEMA model calculations of NH_3 emissions from inorganic N-fertilizers.

The NEMA calculations also included the associated NO and PM emissions, using EMEP default emission factors for the former, and fixed annual amounts for the latter. PM from other agricultural processes (e.g. the supply of concentrate feed to farms, use of pesticides and haymaking), were also estimated using fixed amounts. Crop harvesting was calculated based on acreage from the agricultural census and EMEP default emission factors.

6.3.5 *Methodological issues*

NH_3, NO and PM emissions from the use of inorganic N-fertilizer were calculated in the NEMA model (see Subsection 6.2.5 for a general description). Specific activity data and emission factors related to inorganic N-fertilizer use are discussed in the previous Section.

Table 6.6 provides a summary of associated N flows (in Gg N), over the 1990–2013 period for Crop production and agricultural soils.

Table 6.6 Nitrogen flows related to NH_3 and NO emissions in NFR sector 3D Crop production and agricultural soils (in Gg N)

3D Agricultural soils	1990	1995	2000	2005	2010	2011	2012	2013	Change 2013 - 1990
Available manure for application (from 3B)	391.2	375.6	320.5	273.4	286.2	281.2	264.6	273.9	-30%
(N excretion in animal housing - total N losses in animal housing - exported/incinerated manure)									
NH_3-N emissions from manure application	174.2	62.8	51.1	42.3	34.7	34.4	31.4	32.7	-81%
NO-N emissions from manure application	4.7	4.5	3.8	3.3	3.4	3.4	3.2	3.3	-30%
N_2O-N emissions from manure application	1.6	3.3	2.9	2.4	2.6	2.5	2.4	2.5	57%
Nitrogen excretion on pasture land	188.0	171.9	124.6	93.2	73.8	61.5	57.5	60.6	-68%
NH_3-N emissions excretion on pasture land	14.7	13.2	4.2	2.7	1.6	1.1	1.0	1.0	-93%
NO-N emissions excretion on pasture land	2.3	2.1	1.5	1.1	0.9	0.7	0.7	0.7	-69%
N_2O-N emissions excretion on pasture land	6.2	5.7	4.1	3.1	2.4	2.0	1.8	1.9	-69%
Nitrogen from fertilizer application[1]	395.0	388.4	322.1	261.8	205.2	200.4	199.5	191.7	-51%
NH_3-N emissions from fertilizer application	11.5	11.5	9.9	10.7	8.4	8.7	11.3	11.2	-2%
NO-N emissions from fertilizer application	4.7	4.7	3.9	3.2	2.5	2.5	2.5	2.4	-50%
N_2O-N emissions from fertilizer application	5.1	5.0	4.2	3.4	2.7	2.7	2.7	2.6	-50%

[1] including N in the washing liquid of air scrubbers.

N in manure available for application decreased considerably over the 1990-2013 period (see further Subsection 6.2.5). From this amount a much smaller proportion nowadays volatilizes as NH_3 compared to the first years of the time-series, as a result of mandatory incorporation into the soil during or shortly after application. On the other hand emissions of the greenhouse gas N_2O (with a high global warming potential) have increased considerably, since formation of this compound is enhanced under anaerobic conditions.

Grazing emissions decreased over the time-series with changing management, especially in dairy cattle. As they tend to be kept indoors for a longer part of the day or completely, the N excreted on pasture land dropped by 68%. Since with lower N content of the rations emission factor (expressed as percentage of TAN) also decreases, total NH_3 emissions from grazing were reduced even more.

Inorganic N-fertilizer use reduced considerably between 1990 and 2013, as a result of maximum application standards. Emissions of NH_3 however remain at comparable level, as more urea with a relatively high emission factor is being used in recent years.
Small sources of PM emissions to be reported under category 3D, include applications of inorganic N-fertilizers and pesticides, the supply of concentrate feed to farms, haymaking and crop harvesting.

6.3.6 *Uncertainties and time-series consistency*

A propagation of error analysis on NH_3 emissions was completed this year. Using reassessed uncertainty estimates of input data (CBS, 2012) and expert judgment, an uncertainty of 31% was calculated for NH_3 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 NH_3 emission becomes 20%. It will be evaluated whether a Monte Carlo-analysis could improve the estimate further by taking dependent variables into account.

As annual censuses have been performed the same way for many years (even decades), and the same calculations were used for the whole series, the time-series consistency is very good. This year a web-based application will be implemented for the agricultural census, which will enable more specific questioning and thus enhance the data being obtained.

6.3.7 *QA/QC and verification*

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

6.3.8 *Recalculations*

Emissions of NH_3 from ripening crops, crop residues, use of compost and application of sewage sludge have been added to the inventory. These are new sources identified by the EMEP Guidebook 2013. In table 6.7 an overview is presented of the level and trend in emissions over the 1990-2013 period.

Calculations of the emissions from crop residues and ripening crops are based on the research of De Ruijter *et al.* (2013). N contents of the residues decreased over time with lower fertilization grades, leading to reduced emissions. This is however not a factor influencing emissions from ripening crops, and therefore a fixed estimation was used. Emissions from sewage sludge application reduced strongly as usage dropped by a factor five and incorporation into the soil became mandatory. Compost use and thus associated NH_3 emission tripled over the 1990-2013 period, however this is still a relatively small source.

For compost use and sewage sludge application also NO emissions are being calculated, using the default EMEP emission factor.

Table 6.7 New sources of NH_3 emissions in category 3D Crop production and agricultural soils (in Gg NH_3)

NFR code	Description	1990	1995	2000	2005	2010	2011	2012	2013	%
3Da4	Crop residues applied to soils	4.15	3.96	3.12	2.36	2.46	2.24	2.06	2.25	-46
3De	Cultivated crops	1.82	1.82	1.82	1.82	1.82	1.82	1.82	1.82	0
3Da2c	Other organic fertilizers applied to soils (including compost)	0.15	0.30	0.39	0.37	0.41	0.39	0.44	0.44	190
3Da2b	Sewage sludge applied to soils	1.47	0.12	0.13	0.11	0.09	0.07	0.08	0.08	-95
	TOTAL	7.59	6.21	5.47	4.67	4.77	4.52	4.40	4.59	-40

6.3.9 *Planned improvements*

The current inventory report only includes NO emissions from housing and storage in the reported national totals. NO emissions from the application of inorganic N-fertilizer or animal manure and manure produced on pasture were also assessed, but these are 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 this new emission source.

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 Small combustion (1A4)).
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 NH_3, SO_x and NO_x occur. The produced biogas is used for energy prurposes, 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 (1A4).
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. WWPTs produce methane, among others. Around 80% of this methane is captured and is either used in energy production or is flared. For this reason, the WWPT 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 *Methodological issues*

There are no specific methodological issues.

7.1.3 *Uncertainties and time-series consistency*

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

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

	Main Pollutants		Particulate Matter			Heavy Metals/POPs	
	NMVOC	NH_3	TSP	$PM_{2.5}$	PM_{10}	Hg	DIOX
Year	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	0.8	0.34	0.006	0.006	0.006	0.09	0.25
2010	0.6	0.25	0.003	0.003	0.003	0.05	0.09
2012	0.5	0.24	0.002	0.001	0.001	0.03	0.02
2013	0.5	0.24	0.003	0.001	0.001	0.01	0.02
1990-2013 period [1)]	-1.0	0.19	-0.002	-0.005	-0.005	-0.05	0.02
1990-2013 period [2)]	-68%	417%	-44%	-85%	-85%	79%	-

1) Absolute difference
2) Relative difference to 1990 in %

7.1.4 *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.

7.1.5 *Source-specific recalculations*

There were no source-specific recalculations in this sector.

7.1.6 *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 Small combustion (1A4)).

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 wich 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). Its assumed that 10% of the non-extrated methane wil 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 et al., 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 et al., 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 et al., 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 et al., 1993], determined by [Spakman et al., 1997] and published in [Klein Goldewijk et al., 2004]
F (fraction of CH4 in landfill gas)	0.6 from 1945 through 2000; from 2000 reducing to 0,5 in 2005, thereafter constant 0,5	[Oonk et al., 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 8.3).

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 0.41 Gg in 1990 and 2013, 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.

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).

8.3 Emission factors used.

compound	Emission factor and unit		
	Combusted landfill gas		Landfill gas
	Flared	Gas engine	
Total hydrocarbons (incl. methane)			0.407415 kg/m^3
Hydrocarbons (CxHy)	0.27% hydrocarbons	6 g/m3	
Dioxins	0.9E-9 g/m3	0.3E-9 g/m3	
SO_2 (based on all sulphur)			104 mg/m3
NO_x (as NO_2)	0.3 g/m3	3 g/m3	
CO	2.7% C	3.4 g/m3	
Soot	0.05% hydrocarbons		
CO_2 (biogenic)	total C minus CO minus CxHy – soot		
Other aliphatic non-halogenated hydrocarbons			700 mg/m3
Diclhoromethane			20 mg/m3
Trichloromethane			1 mg/m3
Chlorodifluormethane (HCFC-22)			10 mg/m3
Dichlorodifluormethane (CFC-12)			20 mg/m3
Trichlorofluormethane (CFC-11)			5 mg/m3
Chloroethene			10 mg/m3
Cis-1,2-Dichloroethene			1 mg/m3
1,1,1-Trichloroethene			2 mg/m3
Trichloroethene (Tri)			10 mg/m3
Tetrachloroethene (Per)			10 mg/m3
Chloropentafluorethane			1 mg/m3
1,2-dichloro-1,1,2,2-tetrafluoroethane (CFC-114)			2 mg/m3
1,1,2-Trichloro-1,2,2-trifluoroethane (CFC-113)			1 mg/m3
Mercaptan, non-specified			10 mg/m3
Benzene			7 mg/m3
Toluene			120 mg/m3
H_2S			100 mg/m3

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 NH_3, SO_x and NO_x occur.

In the Netherlands, biodegradable organic waste (i.e. garden waste, horticulture waste and household waste from fruits and vegetables) is collected 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 filteredthrough 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 optimism 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

NH_3, NO_x and SO_2 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 2013 respectively 0,236 Gg, 0,003 Gg and 0.067 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 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.

Emissionfactors 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 infomration in this report is based om a monitoring programme in the Netherlands (DHV, 1999).
The emissionfactors for composting of other organic waste are based on an Austrian study (UBA, 2011). These are seen as the best available data for installations comparable with installation in the Netherlands.

The following emission factors have been used used:

- NH_3 from fermentation, 2.3 g per ton of biodegradable and other organic waste;
- NO_x from fermentation, 180 g per ton of biodegradable and other organic waste;
- SO_2 from fermentation, 10.7 g per ton 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. For the years before 2010 it is not possible to get information on amounts of other organic waste from LMA.

The amount for the period 1996-1999 is estimated based on the amount in 2010-2012 and is 250,000 ton. Just as the separate collection of biodegradable waste, the other organic waste also started in the '90's Thus the amount is assumed null ton in 1990 and increased linear to 1996 when the estimated amount is 250,000 ton.

7.4 Waste incineration

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 is 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)).
Because of a ban on both other (5C1bvi) and open waste burning (5C2), these emission sources do not occur in the Netherlands.

7.4.2 Key sources

The relevant substances that are emitted during the cremation of human remains are mercury, dioxin, PM_{10} and $PM_{2.5}$.
Up to 2010, cremations were a relevant key source for Hg. By 2012, all cremation centres complied with the Dutch Atmospheric Emissions

Guideline (NeR) and were 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, 2014).

Table 7.3 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	140,709	83,379	59	100
2013	141,100	88,018	60	100

* Interpolation using year 2011
** Calculation based on an accurate list of crematoria under the NeR (LVC, 2014)

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 volatilised 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 (Elzinga, 1996). Based on this result, an emission factor of 0.1 gHg/cremation (0.05 mgHg/m^3 fume) was assumed when in compliance with the NeR.

Emission factor for TSP, PM_{10} and $PM_{2.5}$
When no emission reduction measures were in place, an emission factor of 100 gTSP/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 gTSP/cremation or less (Elzenga, 1996). However, measurements carried out at the crematorium in the Dutch city of Geleen showed concentrations of <6 mgTSP/m^3 (~13 gTSP/cremation), and at the crematorium in Bilthoven concentrations of less than 0.7 mgTSP/m^3 were measured. For facilities with NeR measures in place, calculations were done under the assumption of an emission level of 10 gTSP/cremation.
PM_{10} and $PM_{2.5}$ are calculated as a fraction of TSP. Due to the lack of information the fraction for both was set to 1.

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, 1993).

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

7.5 Waste-water handling (5D)

WWPTs produce methane, among other things. 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 in undried form as fertilizer in agriculture (Legislation on the use of fertilizers in the Netherlands). 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 specialised 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 Subsection 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 parks. Category 6A describes a key source for the following components: NH_3 (9.4%) as percentage of national total in 2013. Please note that the Netherlands has included these NH_3 sources in the national total, whereas other parties have not. There is no clear guidance on whether or not these emissions should be included in the national total for NH_3.

9 Recalculations and other changes

9.1 Recalculations of certain elements of the 2013 inventory report

Compared to the 2014 inventory report (Jimmink et al., 2014), several methodological changes were implemented in the Pollutant Release and Transfer (PRTR) system:

- EC emissions were calculated for all years and all relevant sources (Transport, Refineries, Industry and Consumers (wood combustion)) and included in the inventory. During the process earlier minor errors in the PM inventory were corrected.
- The NH_3 emissions from road transport were recalculated on the basis of new research. Also estimates for the emissions of busses and mopeds were adapted according to the most recent scientific research.
- The NH_3 emission levels from agriculture increased due to improved emission factors for the different husbandry systems and manure application. Furthermore the sources; application of sewage sludge and compost and emissions from crop residues were added to the inventory.
- HCB emissions in the Dutch inventory were completed by adding emission estimates for all years in the sectors (a.o. Energy (coal fired) and Consumers (wood combustion)).

The above changes are elaborated in Chapter 4 and affected the emissions of all relevant pollutants in all reported years.

9.2 Improvements

9.2.1 Included improvements

During the compilation of the previous IIR minor errors were detected, which have been repaired in this inventory report. The following significant improvements were carried out during the improvement process of the Dutch PRTR:

- As every year, fuel emissions in the road transport sector were recalculated based on the updated VERSIT+ LD model (Ligterink and De Lange, 2009).
- Update of the model for the calculation of emissions from small vehicles (a.o. mopeds).
- Recalculation of wood combustion emissions based on new insights in the activity data.

9.2.2 Planned improvements

During the compilation process of inventory reports, activities are initiated for future improvements. However, at this moment, there’s no finalised improvement plan available.

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 2013.

Table 9.1 Differences in total national emission levels between current and previous inventory reports, for the years 1990, 2000, 2010 and 2012.

National total		**NO_x (as NO_2) Gg NO_2**	**NMVOC Gg**	**SO_x (as SO_2) Gg SO_2**	**NH_3 Gg**	**$PM_{2.5}$ Gg**	**PM_{10} Gg**	**TSP Gg**	**BC Gg**	**CO Gg**
1990	IIR 2014	575.2	481.5	191.6	354.9	46.5	69.3	91.5	NE	1145.0
	IIR 2015	573.7	483.1	191.8	372.5	46.4	69.6	93.1	13.6	1140.6
Difference	absolute	-1.5	1.5	0.2	17.6	-0.1	0.3	1.6	13.6	-4.3
	%	*-0.3%*	*0.3%*	*0.1%*	*5.0%*	*-0.2%*	*0.4%*	*1.8%*		*-0.4%*
2000	IIR 2014	394.9	238.1	73.0	161.5	24.5	39.3	46.1	NE	791.9
	IIR 2015	395.4	238.9	73.1	181.7	25.5	40.2	48.7	8.9	754.5
Difference	absolute	0.6	0.8	0.1	20.2	1.0	0.9	2.6	8.9	-37.4
	%	0.1%	0.3%	0.1%	12.5%	4.1%	2.3%	5.6%		-4.7%
2010	IIR 2014	271.9	149.7	34.0	127.5	14.6	28.3	33.9	NE	605.5
	IIR 2015	274.2	158.0	34.1	143.7	15.2	29.0	35.8	4.6	679.0
Difference	absolute	2.3	8.3	0.1	16.3	0.6	0.6	1.9	4.6	73.5
	%	*0.8%*	*5.5%*	*0.4%*	*12.8%*	*4.3%*	*2.2%*	*5.5%*		*12.1%*
2012	IIR 2014	248.0	145.7	33.9	120.2	12.9	26.6	31.4	NE	560.9
	IIR 2015	247.5	153.7	34.1	135.6	13.2	27.0	35.1	3.8	636.1
Difference	absolute	-0.4	8.0	0.1	15.3	0.3	0.5	3.8	3.8	75.2
	%	*-0.2%*	*5.5%*	*0.4%*	*12.8%*	*2.2%*	*1.7%*	*11.9%*		*13.4%*

The changes in NH_3 emissions originate from the recalculations on the agricultural sector. EC emissions are now added to the inventory for all reported years. Changes in PM species emissions relate to the recalculation based on improved activity data for wood combustion in households. The latter also affected the NMVOC and CO emissions. The

increase in CO emissions is also the result of higher values due to recalculations for small vehicles (i.e. mopeds).
Changes in the 2012 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 2012 (metals).

National total		Pb	Cd	Hg	As	Cr	Cu	Ni	Se	Zn
		Mg	Mg	Mg	Mg	Mg	Mg	Mg	Mg	Mg
1990	IIR 2014	331.0	2.1	3.5	1.5	11.8	37.2	75.7	0.4	223.1
	IIR 2015	336.9	2.1	3.5	1.5	11.8	37.5	74.9	0.4	224.0
Difference	absolute	5.9	0.0	0.0	0.0	0.0	0.3	-0.8	0.0	0.9
	%	*1.8%*	*0.0%*	*0.0%*	*0.1%*	*0.1%*	*0.8%*	*-1.1%*	*-0.1%*	*0.4%*
2000	IIR 2014	28.2	0.9	1.0	1.1	4.9	39.6	19.2	0.5	93.5
	IIR 2015	28.4	0.9	1.0	1.1	5.0	39.9	18.9	0.5	95.2
Difference	absolute	0.1	0.0	0.0	0.0	0.0	0.3	-0.2	0.0	1.7
	%	*0.5%*	*1.6%*	*0.9%*	*0.3%*	*0.6%*	*0.9%*	*-1.3%*	*0.0%*	*1.8%*
2010	IIR 2014	38.1	2.5	0.5	0.8	3.8	46.9	2.2	1.5	107.9
	IIR 2015	38.2	2.5	0.5	0.8	3.7	46.0	2.2	1.5	109.6
Difference	absolute	0.1	0.0	0.0	0.0	0.0	-0.9	0.0	0.0	1.7
	%	*0.3%*	*0.6%*	*1.3%*	*0.2%*	*-0.9%*	*-1.8%*	*0.2%*	*0.0%*	*1.6%*
2012	IIR 2014	16.2	0.8	0.5	1.1	3.6	45.1	2.2	0.8	105.7
	IIR 2015	16.3	0.8	0.6	1.1	3.6	43.5	2.2	0.8	106.8
Difference	absolute	0.2	0.0	0.0	0.0	0.0	-1.6	0.0	0.0	1.1
	%	*1.0%*	*1.9%*	*1.6%*	*0.0%*	*0.2%*	*-3.5%*	*0.1%*	*0.0%*	*1.0%*

The major cause of the changes in the heavy metal emissions is the result of recalculations in the road transport sector. Furthermore the recalculations of combustion emissions in the residential sector affected the emissions.

Table 9.3 Differences in the total national emission level between the current and previous inventory reports for the years 1990, 2000, 2010 and 2012 (PCDD/F, PAHs and HCB).

National total		PCDD/ PCDF (dioxines/ furanes)	PAHs					HCB
			benzo(a) pyrene	benzo(b) Fluor-anthene	benzo(k) Fluor-anthene	Indeno (1.2.3 -cd) pyrene	Total 1-4	
		g I-Teq	**Mg**	**Mg**	**Mg**	**Mg**	**Mg**	**kg**
1990	IIR 2014	742.6	5.2	8.0	4.0	2.8	20.1	44.7
	IIR 2015	742.3	12.5	15.2	11.2	10.0	20.3	45.3
Difference	absolute	-0.3	7.2	7.2	7.2	7.2	0.2	0.6
	%	*0.0%*	*138.0%*	*90.4%*	*179.0%*	*253.5%*	*1.0%*	*1.3%*
2000	IIR 2014	29.7	1.3	1.2	0.7	0.6	3.8	1.0
	IIR 2015	31.0	1.8	1.7	0.9	0.9	5.1	1.5
Difference	absolute	1.3	0.5	0.5	0.3	0.3	1.4	0.5
	%	*4.5%*	*39.3%*	*40.6%*	*42.9%*	*48.0%*	*35.7%*	*54.9%*
2010	IIR 2014	30.2	1.2	1.2	0.6	0.6	3.7	1.4
	IIR 2015	31.3	1.6	1.6	0.8	0.8	4.9	2.4
Difference	absolute	1.1	0.4	0.4	0.2	0.2	1.2	1.0
	%	*3.7%*	*32.1%*	*30.1%*	*31.5%*	*31.0%*	*31.2%*	*68.7%*
2012	IIR 2014	23.3	1.2	1.1	0.6	0.6	3.5	1.7
	IIR 2015	24.6	1.6	1.5	0.8	0.8	4.6	2.7
Difference	absolute	1.3	0.4	0.4	0.2	0.2	1.1	1.0
	%	*5.5%*	*31.5%*	*31.6%*	*32.2%*	*31.5%*	*31.6%*	*61.4%*

All changes shown in Table 10.3 for PCDD/F and PAH are due to recalculations of combustion emissions in the residential sector. Also improvements made in the estimation methods for the transport sector affected the emissions.
Changes in the 2012 figures are also the result of using improved activity data for that year.
The table does show major changes in HCB emissions for all years. The changes are explained by the inclusion of HCB emission from coal and wood combustion. These were up to 2014 not included in the inventory.

10 Projections

This chapter is the same as Chapter 11 in IIR2014 and 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. Where available, references to detailed documentation were included. An overview of the historical and projected total emissions for the Netherlands per pollutant is given in Table 10.1.

Table 10.1. Historical and projected emissions from the Netherlands (PBL, 2012; RIVM, 2014a)

		Historical (RIVM, 2014a)					***NEC***	**Projected (Verdonk and Wetzels, 2012)**	
Pollutant/year		1990	2000	2005	2010	2012	*2010*	2020	2030
SO_2	Gg	192	73	64	34	34	*50*	37	34
NO_x	Gg	574	395	341	274	248	*260*	187	165
NH_3	Gg	373	182	160	144	136	*128*	109	110
NMVOC	Gg	483	239	178	158	154	*185*	149	158
PM_{10}	Gg	70	40	34	29	27	*NA*	27	27
$PM_{2.5}$	Gg	46	24	19	15	13	*NA*	12	11

A study by Verdonk & Wetzels (2012) examines the future development of Dutch energy use, greenhouse gas emissions and air pollution, and was based on a consistent set of assumptions about economic, structural, technological and policy developments. The most important methods and principles are presented here.

Physical developments determine emissions
Starting from a macro-economic point-of-view, an estimation is made of the production and consumption of goods and services. 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.

Model system
A collection of models simulated the energy use in the Netherlands (Volkers, 2006). The assumptions, e.g. economic growth and policies, are input to the models. The model system also takes the import and export of electricity into account, ensuring the making of a complete national energy balance.

Uncertainties
Future economic growth, energy price developments and policy efficacy are important uncertain factors, influencing the outcome of the models. In addition, there are monitoring uncertainties, because it is impossible to exactly measure or calculate the emissions of air pollutants. For the

year 2020, Verdonk & Wetzels (2012) calculated uncertainty margins, giving a 90-percent confidence interval.

This year's projection data delivery is the same as last year's and only includes the policy variant with policies already implemented and instrumented (with measures; WM scenario). In this report, policies refer to Dutch, as well as European policies.

The emission projections scenario in the IIR includes the effects of the economic recession of 2008 to 2010, the implementation of the European climate and energy measures, as well as effects of the proposed Industrial Emissions Directive. Based on assumed CO_2 and energy prices, Verdonk & Wetzels (2012) estimated the number of additional power plants and CHP installations, planned for the coming decade, in industry and glasshouse horticulture, as well as the share of renewable energy in electricity production.

An overview of the parameters and energy data used for emission projections for the Netherlands is given in Table 10.2

Table 11.2 Assumptions and activity data used for national emission projections.

Activity	***2010***	***2011***	***2020***	***2030***	***Units (energy units are in NCV)***	***Notes on Measures included excluded.***
Assumptions for general economic parameters:						
1. Gross Domestic Product (GDP)	589	602	701	829	10^9 €	G€
2. Population	16575	16656	17229	17688	Thousand People	
3. International coal prices	74		80	85	€ per tonne or GJ (Gigajoule), Other please specify	€ per tonne
4. International oil prices	60		91	105	€ per barrel or GJ	€ per barrel
5. International gas prices	0.184		0.28	0.32	€ per m3 or GJ	€ per m3
Assumptions for the energy sector:						
Total gross inland consumption						
1. - Oil (fossil)	725	748	803	774	Petajoule (PJ)	energetic use
2. - Gas (fossil)	1526	1344	1115	1101	Petajoule (PJ)	energetic use
3. – coal	244	249	447	347	Petajoule (PJ)	energetic use
4. – biomass without liquid biofuels (e.g. wood)	98	81	48	90	In tonnes or %: Mton	biomass without liquid biofuels for transport, avoided primary use
5. - liquid biofuels (e.g. bio-oils)	10	13	37	36	Petajoule (PJ)	liquid biofuels transport
6. – solar	1	1	12	37	Petajoule (PJ)	solar PV + thermal, avoided primary
7. - Other renewable (wind, geothermal etc)	126	133	251	368	Petajoule (PJ)	avoided primary energy
Total electricity production by fuel type						
8. - Oil (fossil)	59	19	908	1103	GWh	
9. - Gas (fossil)	69972	63280	52528	58917	GWh	
10. – coal	23722	22106	43111	30472	GWh	
11. – Renewable	10442	11534	19922	31300	GWh	

10.1 Energy

Emissions are linked to energy use, which, in turn, is connected to fuel and CO_2 prices. The ECN Reference projection assumes a climbing oil price from 78 USD per barrel in 2010 to 118 USD per barrel in 2020 and 135 USD in 2030. The exchange rate in the 2012-2030 period is assumed to be 1.29 US dollars per euro. The direct impact from higher energy and CO_2 prices on final and primary energy use is projected to be relatively low. In 2008 the Energy research Centre of the Netherlands (ECN), on the basis of an analysis of the electricity market, concluded that in the coming decade strong climate policies and high CO_2 prices would be likely to improve the internationally competitive position of Dutch electricity generation (See http://www.ecn.nl/docs/library/report/2008/e08026.pdf). Higher CO_2 prices, paradoxically, are thought to increase the share of coal in Dutch electricity generation and limit the share of renewable energy in electricity production. The capacity of wind power is assumed to increase from 2000 MW in 2005 to the government target of 15400 MW by 2020. This includes the introduction of a wind farm of 6000 MW in the North Sea. However, restricted available and appointed budgets, until now, have limited the growth in wind energy on land as expected for 2020 to 4000 MW, and at sea to 1750 MW.

After the economic dip in 2009 and 2010, a moderate growth rate of 1.7 % averaged per annum from 2011 to 2020 is assumed. As a consequence of this, total domestic energy demand will rise only from 120 TWh in 2008 to 131 TWh by 2020.

Table 10.3 GDP yearly growth rate in the 2007-2020 period (%)

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016-2020
Reference Projection 2010	3.5	2.0	-3.5	-0.3	1.7	1.7	1.7	1.7	1.7	1.7
Reference Projection 2012	3.9	1.8	-3.5	1.7	1.2	-0.75	1.25	1.5	1.5	1.9

The electricity market is a European market. Therefore, the projection of production capacity in the north-western European electricity market is mostly based on the EU baseline scenario 'Trends to 2030', corrected for recent developments, such as the postponement of the phasing out of nuclear plants in Germany and Belgium. Table 10.4 provides an overview of the net additional capacity in the Netherlands and interconnected countries. Clearly, the trend for the Netherlands is going towards much more production capacity. Relatively speaking, this growth in capacity is greater than in other countries. In general, the GW increase will be greater than the TWh demand; average operating hours will reduce. Partly because renewable GW provides less TWh than conventional capacity and partly because a period in which relatively few new plants were developed in north-western Europe, has to be made up for ('boom & bust' cycle).

Table 10.4 Growth of production capacity in place for north-western Europe. Both conventional and renewable extras were considered.

	extra after 2005			extra after 2005			growth demand after 2005	
	2020	2025	2030	2020	2025	2030	2020	2030
	[GW]	[GW]	[GW]	[%]	[%]	[%]	[%]	[%]
Netherland	12.2	14.2	16.1	61	72	81	34	41
Germany	28.1	32.7	29.2	23	27	24	13	16
Belgium	5.3	6.6	6.9	35	43	45	25	31
France	5	0.2	1.9	4	0	2	15	18
Norway	12.6	15.2	18	42	51	61		
United Kingdom	5.4	12.5	18	6	14	20	14	18
Denmark	-0.8	0	0.2	-6	0	1	13	16

Apart from price differences, the physical interconnections to foreign electricity markets, determine the import and export of electricity. For some considerable time, electricity connections have existed to Belgium, France and Germany. The connection to Germany has been expanded (1000-2000 MW) in 2013. Connections to Norway (700 MW) and United Kingdom (1000 MW) have become operational since 2008 and 2011, respectively.

The Netherlands have a high and still increasing degree of interconnection with Germany as a neighbouring country. Although currently, the Netherlands are still a net importer of German electricity, in the near future a switch to becoming a net exporter of electricity is foreseen.

The Netherlands, from their geographical location, have several business advantages. The coast and rivers provide good cooling possibilities and relatively low supply costs for coal. This advantage is expressed in the present power plant development boom in the Netherlands, among others by producers from German origin (E.ON, RWE). In addition, German power plants have a higher average CO_2 emission factor and are consequently more vulnerable to fluctuations in the CO_2 price.
In this projection, the German Government decision to postpone the phasing out of nuclear power plants has been taken into account. Keeping the nuclear plants in operation and simultaneously investing less in new fossil-fuel generation capacity in Germany, provides a cushioning effect on Dutch export to Germany. New projections estimate the import for the year 2020 to be 16 TWh. If Germany would phase out their nuclear plants would substantially before 2020, this would lead to approximately 6 TWh in additional export to Germany.

10.1.1 *NO_x*

In 2005 the NO_x trading system entered into operation for installations with a capacity of more than 20 MWth (unless exempted) and installations with high process emissions. Since its implementation, there has been a surplus of emission allowances (NEA, 2011). In 2010, the surplus was 1.5 Gg. The allowed amounts will be lowered step by step, over the course of time. For incineration installations the maximum emission level (Performance Standard Rate; PSR) will be gradually tightened. This will reduce the permitted NO_x emission in the trading system by a further 2.5 Gg in 2013. Process emissions carry a reduction target. The recent closure of several companies with NO_x process emissions and a further reduction in emissions from small combustion sources, accounts for the (permitted) emissions in 2020 superseding the 2011 level.

Table 10.5 Development of the NO_x emission from Industry, Energy and Refineries

NO_x emission in [Gg]	1990	2000	2005	2010	2012	2020	2030
Industry	79.0	35.0	35.1	30.1	29.6	30.4	32.5
Refineries	18.8	10.3	9.1	5.6	5.3	5.1	4.9
Energy sector	82.7	52.1	43.1	26.1	21.4	27.8	24.3

10.1.2 SO_2

SO_2 emissions in the Netherlands are expected to increase from 34 to 37 Gg between 2011 and 2020 and subsequently decrease to 34 Gg in 2030. Companies in the industry, energy and refineries are responsible for almost all of the emissions (96% in 2011).

Development of emission of sulphur dioxides (SO2) stationary sources

SO_2 emissions from stationary sources decreased significantly up to 2000, but there has been little change in these emission levels since then. In recent years, emissions have decreased again, due to measures in coal-fired plants, the transition of refineries to gas-firing instead of (a part of) oil, and a decreasing sulphur content of oil products. For government policy, the SO_2 covenant with the electricity sector plays an important role, as does the agreement to enter a maximum emission level of 16 Gg in the permits for refineries, divided over various companies.

Relevant developments in SO_2 emissions in the various sectors include:

- The development of process emissions in industry is assumed to equal the physical growth of the sector. However, the emission developments in this sector have been examined over the past years. For example, emissions in the base metal industry, in the last few years, were 0.4 Gg lower. Moreover, for several situations it is assumed that emissions will increase less rapidly than a linear relation with the physical production would imply.
- Refineries have agreed to switch from burning heavy fuel oil to burning gas. Furthermore, they agreed to limit the maximum emission amount to 16 Gg in 2010 and subsequent years, and establish a permitted emission level per company. If refineries would stop burning oil and keep their installations in the BAT (Best Available Technique) range of the IPCC guideline, then emissions would be significantly lower than in 2005. To comply with the new sulphur demands for sea-going vessels, Dutch refineries will have to make large investments in additional secondary production capacity and desulphurisation installations before 2020. As this will lead to higher energy use and additional desulphurisation capacity (with corresponding process emissions) this might put pressure on the 16 Gg agreement.

- The electricity sector agreed to reduce SO_2 emissions, over the period from 2010 to 2019, down to 13.5 Gg. The agreement does not include the year 2020 because future European agreements could possibly demand a further emission reduction. According to these scenario calculations, emissions in 2010 were well below the agreed ceiling, as the sector, over the years, already has taken various measures years to reduce SO_2 emissions. On balance, this leaves ample space for new construction plans while remaining below the emission ceiling for 2019.
- In households and the services sector (TSG), emission levels have decreased, due to a decreasing sulphur content of domestic fuel oil, from 0.2% to 0.1%.

10.1.3 *Policy measures*

For NO_x trading in industry, the performance standard rate of 40 g/GJ has been sharpened to 37 g/GJ. Moreover, emission standards for medium-sized heating systems have been sharpened under BEMS legislation. The refinery sector has agreed to an SO_2 emission cap of 16 Gg. Additional policies envisage a sharpening of this cap to 14.5 Gg.

10.1.4 *Transport*

Emission projections for the transport sector were updated based on new assumptions on future oil prices and economic and demographic developments. Since economic growth is expected to be lower on the short term and oil prices are higher than previously expected, transport volumes in general are lower in the updated Reference projections. Fleet renewal is also slower though, resulting in higher emissions per unit of transport volume (vehicle kilometre, MJ, etc.).

10.1.5 *Projected transport volumes*

The projected growth in passenger transport in the Netherlands was derived from the Dutch National Model System for Traffic and Transport (LMS). The LMS is regularly used in The Netherlands to forecast national transport volumes taking into account the impact of transport infrastructure projects (i.e. new roads, wider roads, new railway connections), transport policies, demographic and economic trends, car ownership and transport cost. Passenger car use (vehicle kilometres) is expected to increase by approximately 1% annually between 2011 and 2020. This is slightly lower than pre-crisis growth rates and slightly lower than in the 2010 Reference projections, reflecting slower economic recovery combined with higher future oil prices.

The future composition of the Dutch passenger car fleet was derived from Dynamo, the Dutch dynamic automobile market model (Meurs et al., 2006; MuConsult, 2010). Dynamo models the impact of trends in demographics, household incomes, car prices and government policies on the size, composition and usage of the Dutch passenger car fleet up to 2040. Car ownership is expected to increase from 7.9 million cars in 2012 to 8.7 million cars in 2020, resulting mainly from an expected increase in the number of households in The Netherlands. The share of diesel cars in the car fleet is expected to increase from 17% in 2012 to 21% in 2020. This is still well below EU average, with passenger car taxation in The Netherlands still favoring gasoline over diesel.

Projections of future freight transport in the Netherlands, by road, rail and inland shipping were derived by TNO using the TRANS-TOOLS model (TNO, 2009). TRANS-TOOLS is a European transport network model that covers both passenger and freight transport, although for the Reference projections the model was only used for freight transport projections. To take into account the lower economic growth projections and higher oil prices in the new Reference projections, transport volumes were adjusted downwards using elasticities of demand which reflect the effect of changes in economy (GDP) and transport prices on transport volumes (PBL, 2012).

Freight transport in the Netherlands (expressed in ton kilometres) is expected to increase by 17% between 2011 and 2020 in the new Reference projections. Rail transport shows the largest growth in this time span with transport volumes increasing by 39%. Freight transport by road and by inland ship is expected to increase by 19% and 12% respectively between 2011 and 2020. Even though rail transport shows the highest growth rates, most freight is still being transported by road (51% of tonne-kilometres) or by ship (42%) in 2020, with rail transport only being responsible for 7% of total freight transport. Electrification of rail transport is also expected to continue in future years, therefore diesel fuel consumption by rail transport is expected to stabilize at current rates even though transport volumes continue to grow.

The future composition of the light- and heavy-duty truck fleet in The Netherlands was derived from trend extrapolation, taking into account the lower expected growth in total transport volumes as well as policy measures related to different vehicle types (e.g. subsidy programmes for light-duty trucks with diesel particulate filters and Euro-VI heavy-duty trucks).

Transport growth in other transport related categories has been derived from existing studies or by extrapolating the historical trends of the 2000–2011 period. The projected growth in air travel was derived from a study by Significance (2008), for the Dutch Ministry of Transport, on growth projections for Schiphol Amsterdam Airport. The results from this study were corrected for differences in assumptions on future economic growth in the Reference projections, using price elasticities of demand derived from international literature (Hoen et al., 2010). The number of flights to and from Schiphol Amsterdam Airport is expected to increase by approximately 19%, between 2008 and 2020. Projections on the composition of the future aircraft fleet were also derived from the study by Significance (2008).

The projected use of non-road mobile machinery in the Netherlands is coupled to projected economic growth in the various, related economic sectors. Total energy use by non-road mobile machinery is expected to grow by 14%, between 2010 and 2020. Energy use by fisheries is expected to further decrease up to 2020, in line with historic trends.

10.1.6 *Policy measures and emission projections*

Relevant policy measures that were agreed upon at the start of 2012 in the EU or in the Netherlands were taken into account in the Reference projections. For road traffic, emissions of NO_x PM and NMVOC are expected to decrease further between 2011 and 2020 reflecting fleet renewal in combination with more stringent emission standards for new vehicles, e.g. the Euro-5 and Euro-6 emission standards for light duty vehicles and the Euro-VI standards for heavy-duty vehicles. Euro-5 emission standards for light duty vehicles require all new diesel cars to be equipped with a diesel particulate filter (DPFs), resulting in substantial reductions in PM_{10} and $PM_{2.5}$ exhaust emissions as more DPFs enter the Dutch vehicle fleet in coming years. PM_{10} exhaust emissions from passenger cars and light duty trucks are expected to decrease from 3.2 Gg in 2010 to 0.9 Gg in 2020.

Euro-6 and Euro-VI emission standards should result in major reductions of NO_x emissions from light- and heavy-duty vehicles, although real-world effectiveness of the new emission standards is still uncertain. In the Reference projections, it is assumed that Euro-6 and Euro-VI will indeed result in major (real-world) emission reductions. As a consequence, total NO_x emissions from road transport are expected to decrease from 99 Gg in 2011 to 44 Gg in 2020.

PM_{10} emissions due to brake and tyre wear and road abrasion are expected to increase due to the projected growth in road traffic. By 2020, non-exhaust PM_{10} emissions will be responsible for 69% of total PM_{10} emissions by road traffic (currently this share is below 50%). The share of non-exhaust emissions in $PM_{2.5}$ emissions from road transport is much smaller, therefore the decrease in $PM_{2.5}$ emissions from road transport is larger than for PM_{10}. $PM_{2.5}$ emissions from road transport are projected to decrease by 56%, between 2011 and 2020.

NO_x and PM emissions from inland shipping are expected to remain fairly stable, with the expected growth in transport volumes being compensated by the EU emission standards for diesel engines used in inland shipping. NMVOC emissions are expected to decrease slightly due to the same emissions standards. NO_x and PM emissions from NRMM are expected to decrease significantly, resulting from increasingly stringent emission standards for new diesel engines.

10.2 Industry

In 2011, industry, energy and refineries (IER) emitted 10.4 Gg PM_{10}, which is a share of 36% in total PM_{10} emissions in the Netherlands. Nearly all industrial sectors have PM_{10} emissions. PM_{10} is emitted during various industrial processes, such as combustion emission from fuel burning. PM and NMVOC emissions from industry are dominated by process emissions.

Industry has been more severely affected by the credit crisis than other sectors, so industrial production has decreased. This is especially true for the chemical industry, the metal industry and refineries. For 2010 to 2020, industrial growth is expected to be more or less equal to the growth of the economy. For the chemical industry, growth is expected to be considerably higher, whereas for the food and stimulants industry and the refineries it is thought to be lower.

10.2.1 *PM_{10}*

Successful emission curbing policy has lowered PM_{10} emissions in industry with about 70%, between 1990 and 2011. Agreements with the refinery sector about switching to gas-firing instead of oil-firing will further decrease the PM_{10} emissions in this sector.

10.2.2 *NMVOC*

The NMVOC emissions from industry and energy have decreased between 2000 and 2010 from 86 Gg to 50 Gg. Most of the reduction is due to lower NMVOC content in industrial coating application and general reducing measures in industry, energy and refineries. In 2020 and 2030 the emissions are expected to be 50 and 49, respectively. Whereas some sector show a light growth, other sectors are expected to show a slight reduction, so on average the emission is expected to remain at about the 2010 level.

10.2.3 *Solvents and Product use*

NMVOC emissions from households mostly come from use of luxury products, such as cosmetics and other toiletries and paints. Expenditure on luxury products is increasing more rapidly than the average household expenditure. The use of fireplaces and wood-burning stoves is also increasing, however, at a slower pace. The solvents in luxury products are not reduced like in the painting products. Therefore the NMVOC emissions from consumers increases by 5 Gg between 2010 and 2020, to about 37 Gg. After 2020 an increase to about 46 Gg is expected.

10.2.4 *Agriculture*

The NH_3 emissions are expected to decrease from 122 Gg in 2010 to 109 Gg in 2020, and 110 Gg in 2030. The agricultural sector has by far the greatest share (86% in 2011) in the national total NH_3 emissions. This mostly comes from animal manure.

Between 2010 and 2020, ammonia emissions from agriculture are expected to go down by about 13 Gg from 105 Gg to 92 Gg (Van Schijndel & Van der Sluis, in prep.). This decline is mostly due to the implementation of low emission housing for pigs and poultry (-8 Gg) and due to a further reduction in the use of animal manure (-6 Gg).
NH_3 emissions are expected to increase slightly between 2020 and 2030, by 0.3 Gg (Van Schijndel & Van der Sluis, in prep.). This is the combined effect of a reduction in housing emissions, mostly by lower pig numbers (-1.6 Gg), a reduction in grazing emissions by further permanent housing of dairy cattle (-0.2 Gg) and an increase of ammonia emissions from manure application (+2.1 Gg).

Table 11.6 Projected animal numbers in the Netherlands (in 1000 heads).

Activity	**2000**	**2010**	**2012**	**2020**	**2030**
Beef Cattle	2565	2497	2395	2236	2181
Dairy Cows	1504	1479	1484	1475	1418
Sheep	1305	1130	1043	1483	1491
Goats	179	353	397	1483	1491
Swine	13118	12255	12234	10273	9423
Laying hens	53078	56500	51427	59099	61610
Broilers	53439	46871	45589	47378	48231
Horses	417	441	431	428	432
Rabbits and mink	641	1001	1061	1001	911

As a consequence of further manure and ammonia policies (in order to comply with the EU Nitrate Directive), more manure will become available on the market for processing. It is unlikely that unprocessed manure will be exported, because transport costs are high (Hoogeveen *et al.*, 2011).

Although it is assumed that the costs of manure processing will be lower than the present level, some farmers will face high costs and consequently run out of business. Scaling in the agricultural sector is anticipated to continue.

As dairy cattle farmers typically own lands to put manure on, they have possibilities to adapt to future manure policies, albeit at slightly higher costs. The sector is expected to remain competitive on the world market through higher productivity and scaling. As a rule, swine farmers have a less competitive position compared to dairy cattle farmers, since they do not own any or enough land to spread their manure on. In addition, the value added per unit of manure production is relatively low. Poultry farmers often also do not own any land to unload manure on. However, their competitiveness is relatively less dependent on the costs of manure processing, since combustion in this sector is a very cheap technique.

10.2.5 Policy measures

The introduction of air scrubbers has been assumed for NH_3 and $PM_{2.5}$ emissions from very large animal houses.

11 Spatial distributions

11.1 Background for reporting

In 2012 the Netherlands has reported geographically distributed emissions and LPS data to the UNECE LRTAP Convention for the years 1990, 1995, 2000, 2005 and 2010. Emission data are disaggregated to the standard EMEP grid with a resolution of 50km x 50km. Reporting is mandatory for the following air pollutants: SO_x, NO_x, NH_3, NMVOC, CO, PM_{10}, $PM_{2.5}$, 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. RAINS/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 2012 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 methods 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.
There are three methods 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 that are 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 (PM_{10}) 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 (2011, http://www.emissieregistratie.nl/ERPUBLIEK/bumper.en.aspx). The selected air pollutants are ammonia (NH_3), sulphur dioxide (SO_2), nitrogen dioxide (NO_x) and fine particulates ($PM_{2.5}$). Figures 12.1-12.4 show the geographically distributed emissions for these air pollutants. Even from the national distributed totals, spatial patterns from the major sectors are recognizable.

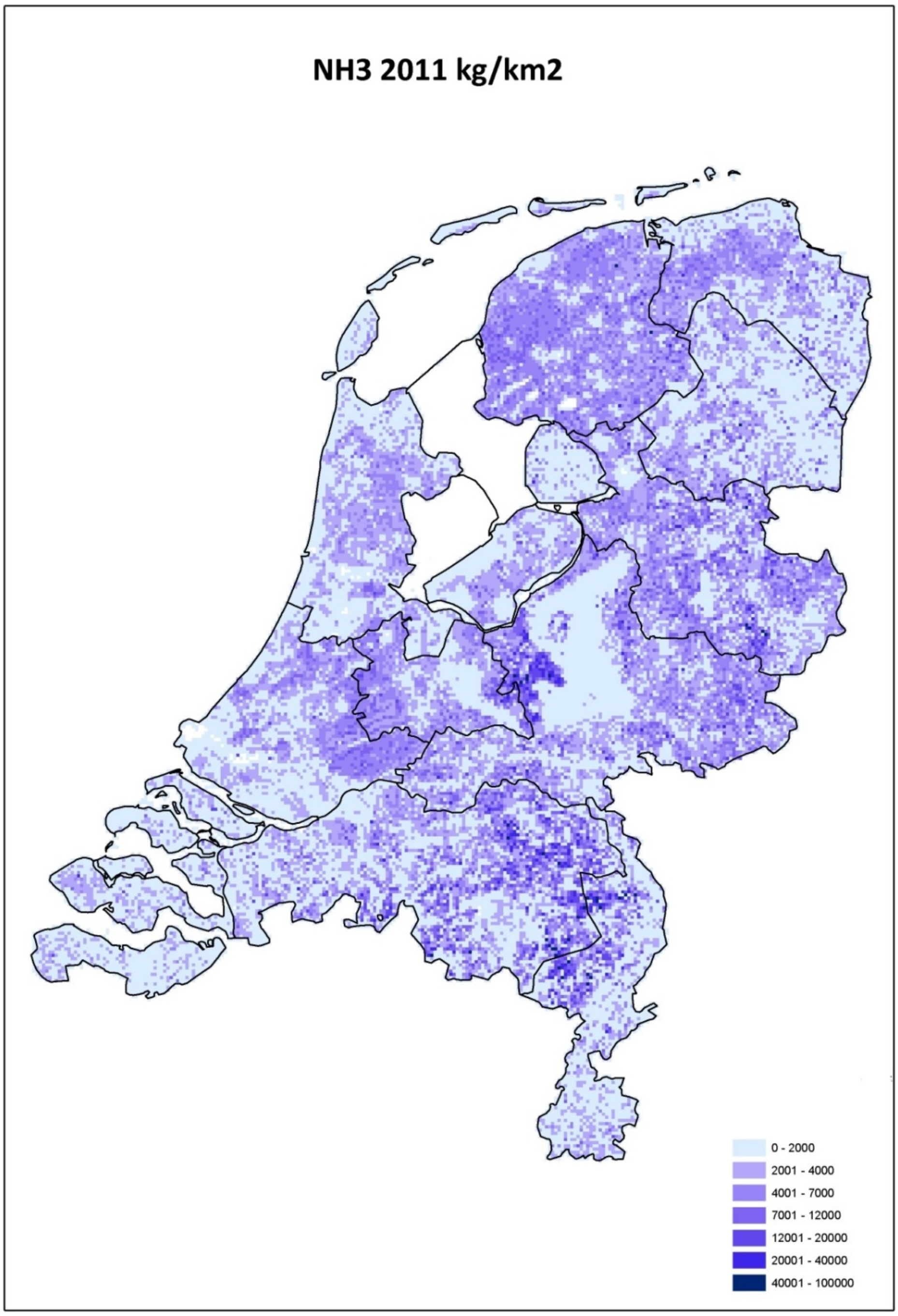


Figure 11.1 Geographical distribution of NH_3 emissions in the Netherlands in 2011

The agricultural sector is the major contributor to the national total NH_3 emission. Emissions of NH_3 are mainly related to livestock farming and especially to the handling of manure from the animals. Emissions of NH_3 are therefore related to storage and spreading of manure as well as emissions from stables (Luesink *et al.*, 2008).

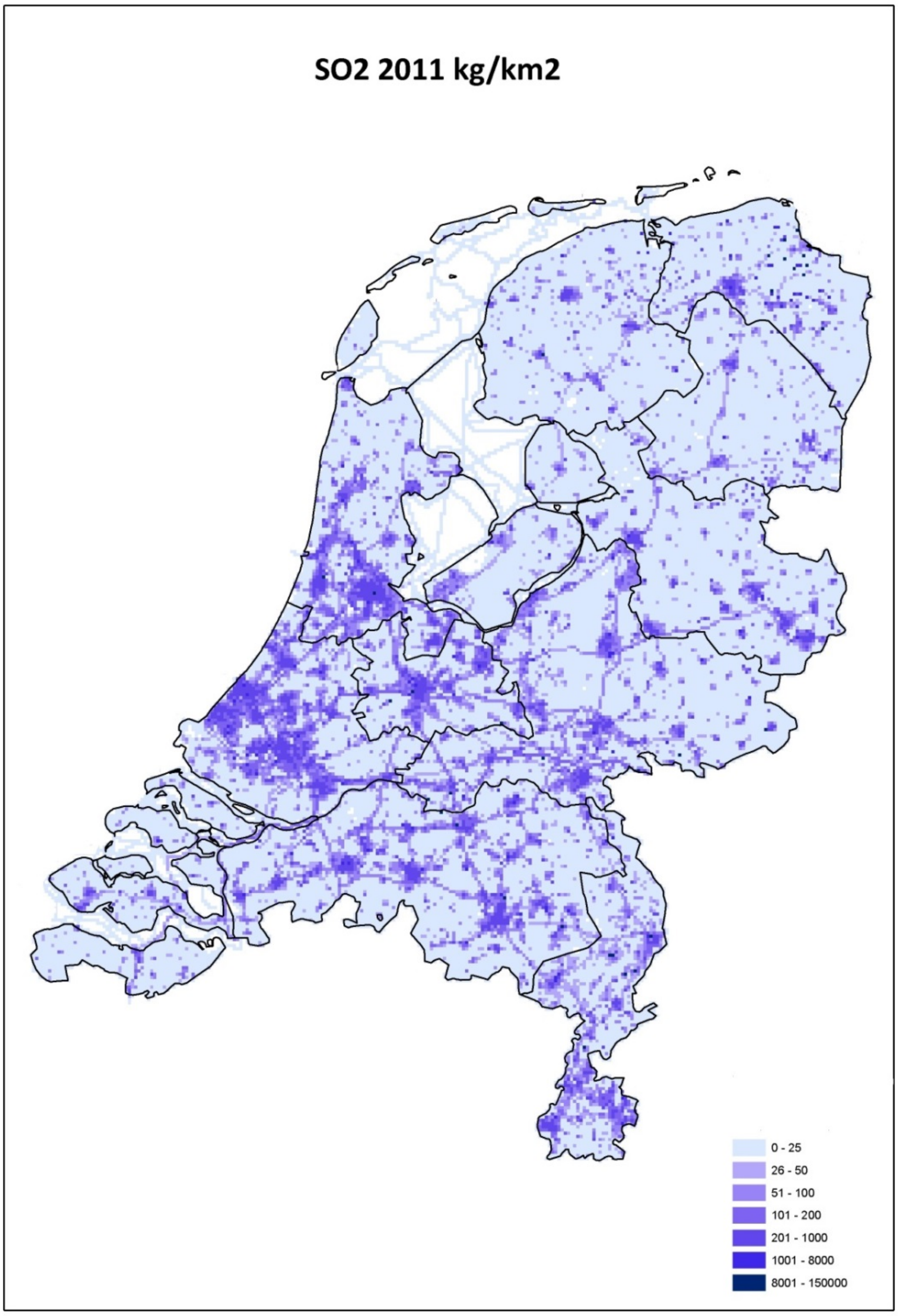


Figure 11.2 Geographical distribution of SO_2 emissions in the Netherlands in 2011

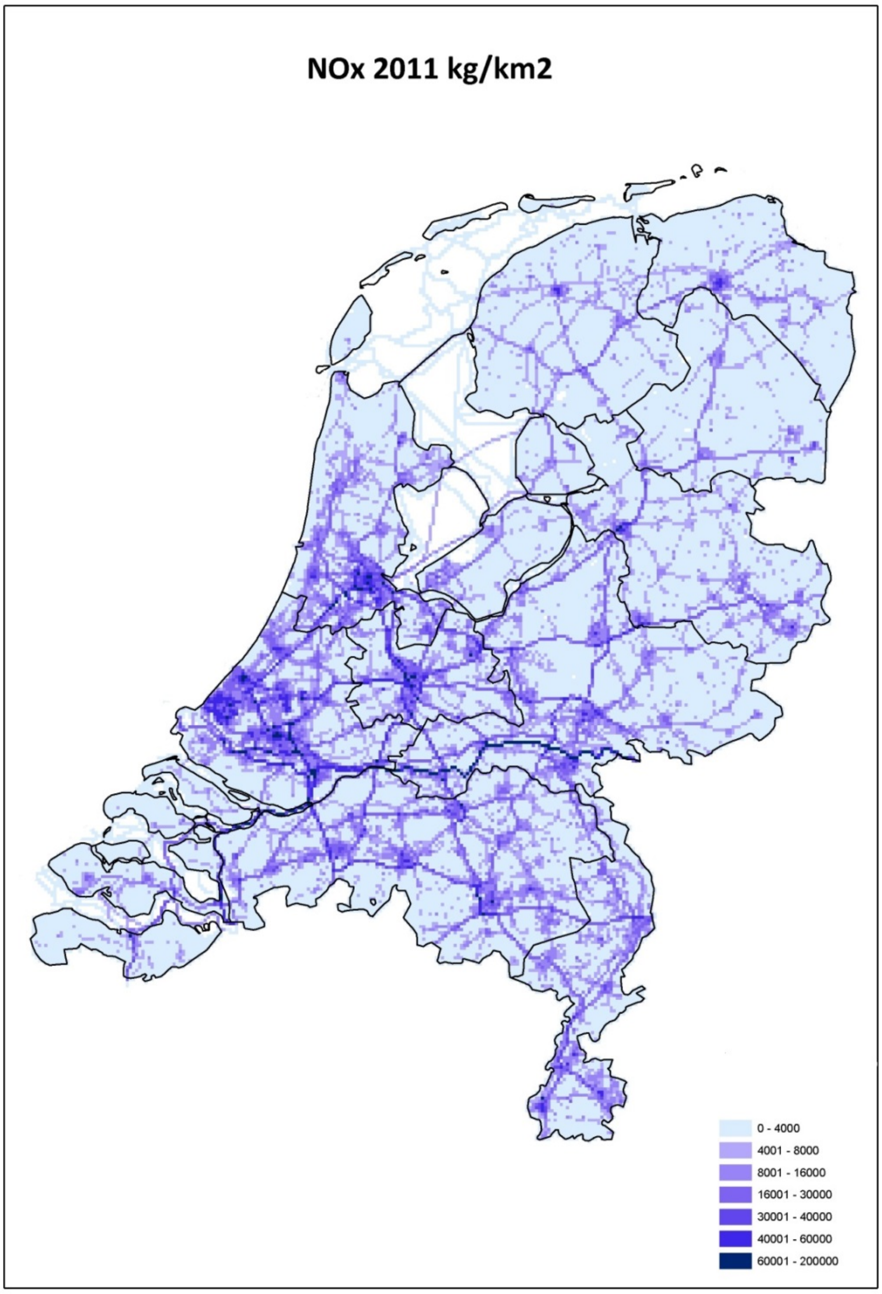


Figure 11.3 Geographical distribution of NO_x emissions in the Netherlands in 2011

Both SO_2 and NO_x are predominantly emitted by the (road) transport sector: cities, main roads and shipping routes are clearly visible. Inland shipping routes are more visible in SO_2 emissions as more reduction measures were taken in other sectors compared to inland shipping.

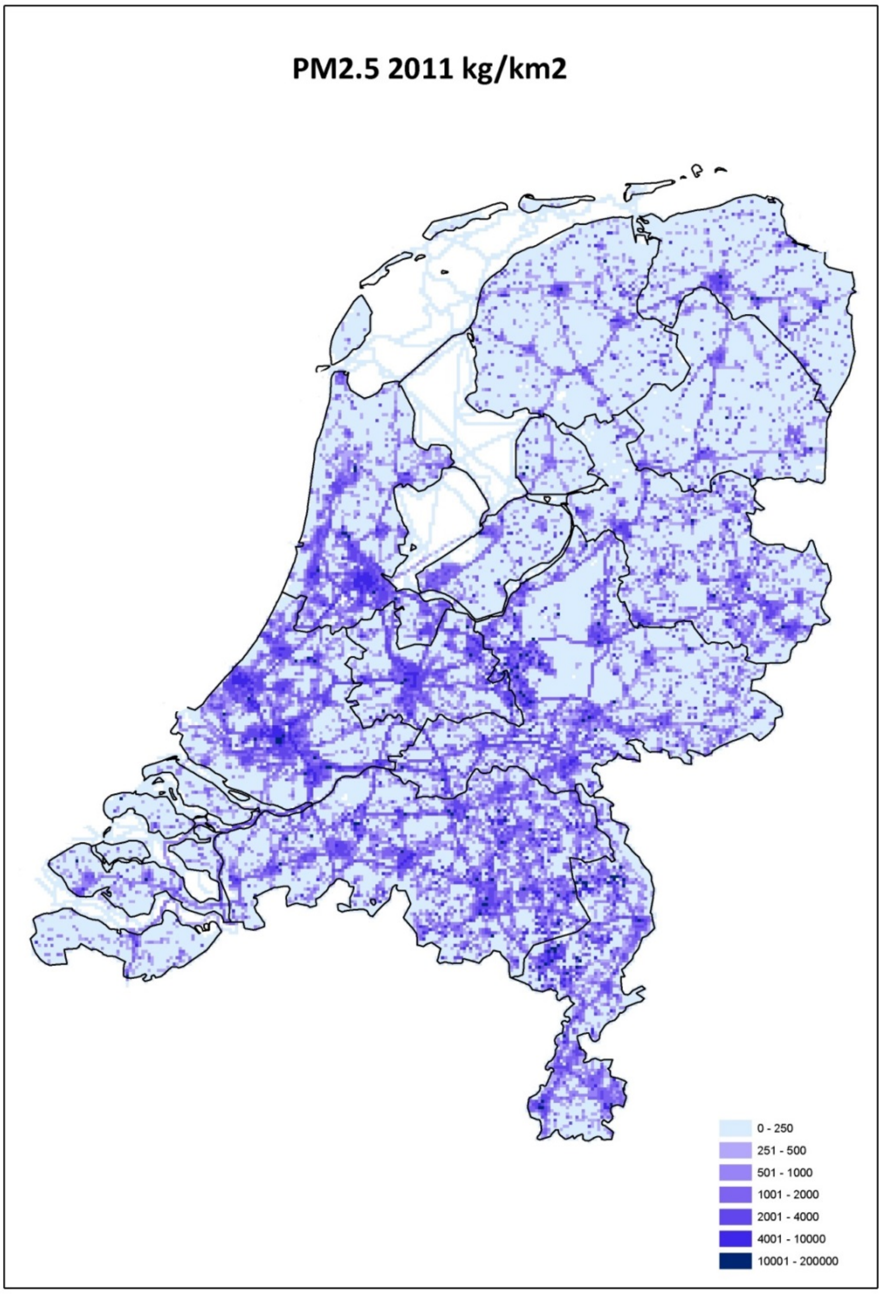


Figure 11.4 Geographical distribution of $PM_{2.5}$ emissions in the Netherlands in 2011

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 emissions of residential heating, agricultural animal housing, road traffic and shipping, all known as important sources of PM.

12 References

Agrawal, H., A.A. Sawant, K. Jansen, J. Wayne Miller and 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 and risk-the PRIMA approach to decision-support, PhD thesis, Universiteit Maastricht.

Boer, E. den, M.J.J. 't Hoen, and M.B.J. Otten (2015). Update Rekenmodule emissies autobussen, Ten behoeve van de emissieregistratie, CE Delft, Delft (in Dutch).

Bremmer, H.J., L.M. Troost, G. Kuipers, J. de Koning and A.A. Sein (1993). Emissies van dioxinen in Nederland, RIVM rapportnummer 770501003, National Institute for Public Health and the Environment RIVM, Bilthoven (in Dutch).

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

Bruggen, C. van, A. Bannink, C.M. Groenestein, B.J. de Haan, J.F.M. Huijsmans, H.H. Luesink, S.M. van der Sluis, G.L. Velthof and J. Vonk (2014). Emissies naar lucht in 2012. Berekeningen met NEMA van ammoniak, stikstofoxide, lachgas, methaan en fijn stof. WOt-Technical report 3. WOT Natuur & Milieu, Wageningen (in Dutch).

Bruggen C. van, C.M. Groenestein, B.J. de Haan, M.W. Hoogeveen, J.F.M. Huijsmans. S.M. van der Sluis and G.L. Velthof (2011). Ammoniakemissie uit dierlijke mest en kunstmest, 1990-2008. Berekeningen met het Nationaal Emissiemodel voor Ammoniak (NEMA) . WOt-werkdocument 250. WOT Natuur & Milieu, Wageningen (in Dutch).

CBS (2014a). Nieuwsbrief verkeersprestaties, December 2014 (in Dutch), Statistics Netherlands, http://www.cbs.nl/NR/rdonlyres/B09F1F4D-697F-4892-889B-3672C44A847C/0/2014nieuwsbriefverkeersprestaties.pdf , Voorburg/Heerlen, Nederland (in Dutch).

CBS (2014b). www.cbs.nl, Statline – Landbouwcijfers. CBS, Voorburg/Heerlen, Nederland (in Dutch).

CBS (2014c). Dierlijke mest en mineralen 2013, CBS, Den Haag/Heerlen (in Dutch).

CBS (2012). Uncertainty analysis of mineral excretion and manure production, ISBN 978-90-357-1380-2, The Hague/Heerlen.

CBS (2012a). Standardised calculation methods for animal manure and nutrients. Standard data 1990-2008. The Hague/Heerlen.

Coenen P.W.H.G. and B. Hoekstra (1997). Onderzoek naar de kwikemissies van crematoria en beschikbare reinigingstechnieken, Tauw Milieu Rapport R3517616.W02/BWH, Deventer (in Dutch).

Coenen, P.W.H.G. and J.H.J. Hulskotte (1998). Onderzoek naar de emissies naar oppervlaktewater van railverkeer in de provincie Zuid-Holland, TNO, Apeldoorn (in Dutch).

Denier van der Gon, H.M. ten Broeke and J.H.J. Hulskotte (2008). Emissies door wegdekslijtage ten gevolge van het wegverkeer, TNO, Utrecht (in Dutch).

Denier van der Gon, H. and J.H.J. Hulskotte (2010). Methodologies for estimating shipping emissions in the Netherlands. A documentation of currently used emission factors and related activity data, TNO, Utrecht.

DHV (1999). Eindevaluatierapport meetprogramma GFT-verwerkingsinstallaties SMB, SOW/CAW en Arcadis (Final evaluation report of the measurement programme for biodegradable waste processing facilities of SMB, SOW/CAW and Arcadis). Final report by DHV, January 1999.

Dröge, R. and H.M. ten Broeke (2012). Emissie van individuele industriële bedrijven, TNO-060-UT-2012-00756, TNO, Utrecht (in Dutch).

EEA (2009). EMEP/EEA air pollutant emission inventory guidebook, Technical report No 9, European Environment Agency (EEA), Copenhagen. http://www.eea.europa.eu/publications/emep-eea-emission-inventory-guidebook-2009.

Elzenga, J.G. (1996). Crematoria, RIVM report nr. 772414009, National Institute for Public Health and the Environment. Bilthoven (In Dutch).

ENINA (2014: in preparation). (In Dutch), Bilthoven.

EPA (1985). Compilation of air pollution emission factors, volume 2, Mobile sources, 4th edition, US Environmental Protection Agency, Research Triangle Park, North Carolina.

Eurocontrol (2001). Forecasting civil aviation fuel burn and emissions in Europe, Eurocontrol Experimental Centre, Bruxelles.

Gijlswijk, R. van, P.W.H.G. Coenen, T. Pulles, and J.P. van der Sluijs, (2004). Uncertainty assessment of NO_x, SO_2 and NH_3 emissions in the Netherlands, TNO report R2004/100, TNO, Apeldoorn, Available:

http://www.rivm.nl/bibliotheek/digitaaldepot/TNOreportRa2004.pdf.

Goudappel Coffeng (2010). Onderzoek naar de wegtype-verdeling en samenstelling van het wegverkeer, Goudappel Coffeng, Deventer (in Dutch).

Groenestein, C.M., S. Bokma and N.W.M. Ogink (2014a). Actualisering ammoniakemissiefactoren vleeskalveren tot circa 8 maanden: advies voor aanpassing in de Regeling ammoniak en veehouderij, Livestock Research Rapport 778, Wageningen UR, Lelystad (in Dutch).

Groenestein, C.M., A.J.A. Aarnink and N.W.M. Ogink (2014b). Actualisering ammoniakemissiefactoren vleesvarkens en biggen: advies herberekening op basis van welzijnseisen, Livestock Research Rapport 786, Wageningen UR, Lelystad (in Dutch).

Hausberger, S., J.Rodler, P.Sturm, and M.Rexeis (2003). Emission factors for heavy-duty vehicles and validation by tunnel measurements, Atmospheric Environment 37, p. 5237-5245.

Hensema, A., P. van Mensch and R. Vermeulen (2013). Tail-pipe emissions and fuel consumption of standard and tampered mopeds, TNO report 2013 R10232, TNO, Delft.

Hoen, A., S.F. Kieboom, G.P. Geilenkirchen and C.B. Hanschke (2010). Verkeer en vervoer in de Referentieraming Energie en Emissies 2010-2020, PBL report 500161003, Bilthoven (in Dutch).

Hoogeveen, M.W., H.H. Luesink and P.W. Blokland (2011). Ammoniakemissie uit de landbouw in 2020; Raming en onzekerheden, LEI - Rapport 2010-080, Den Haag (in Dutch).

Hulskotte J.H.J., W.F. Sulilatue, and A.J. Willemsen (1999). Monitoringsystematiek openhaarden en houtkachels, TNO-MEP-R99/170, Apeldoorn (in Dutch).

Hulskotte, J.H.J. and W.W.R. Koch, (2000). Emissiefactoren zeeschepen, TNO-MEP-R2000/221, Apeldoorn (in Dutch).

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

Hulskotte, J.H.J., J. Oonk and J.C. van den Roovaart (2005). Emissieschattingen diffuse bronnen, Waterverontreininging door motoremissies uit de recreatievaart, TNO-MEP, Apeldoorn (in Dutch).

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

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

Jansen, B.I. and 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, C.J. Peek, J. Vonk and D. Wever (2014). The Netherlands Informative Inventory Report 2014, RIVM report nr. 680355015, National Institute for Public Health and the Environment. Bilthoven.

Klein, J., Geilenkirchen, G., Hulskotte, J., Duynhoven, N., Lange, R. de, Hensema, A., Fortuin, P., Molnár-in 't Veld, H. (2015), Methods for calculating the emissions of transport in the Netherlands. Task Force traffic and Transport of the National Emissions Inventory, Bilthoven.

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, and A. Hensema (2014). Uncertainties in emissions of road traffic: Euro-4 diesel NOx emissions as case study, TNO report 2012 R11316, TNO, Delft.

Kugele, A., F. Jelinek and R. Gaffal (2005). Aircraft particulate matter estimation through all phases of flight, Eurocontrol Experimenal Centre, Brétigny sur Orge, France.

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

Ligterink, N.E., R. de Lange, R. Vermeulen and H. Dekker (2009). On-road NO_x emissions of Euro-V trucks, TNO Science and Industry, Delft.

Luesink, H., P.W. Blokland, M.W. Hoogeveen and J.H. Wisman (2008). Ammoniakemissie uit de landbouw 2006 en 2007, WOT werkdocument 144, Wageningen UR, Wageningen (in Dutch).

LVC (2014), http://www.lvc-online.nl/viewer/file.aspx?FileInfoID=105

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

MARIN and TNO (2014). Sea shipping emissions 2012: Netherlands Continental Shelf, port areas and OSPAR Region II, MARIN, Wageningen.

Molnár-in ‘t Veld, H. and A. Dohmen-Kampert (2010). Methoderapport 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

Mosquera, J., J.M.G. Hol, A. Winkel, E. Lovink, N.W.M. Ogink and A.J.A. Aarnink (2010). Fijnstofemissie uit stallen: vleesvarkens, Livestock Research Rapport 292, Wageningen UR, Lelystad (in Dutch).

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. and Z. Samaras (2000). COPERT III, Computer Programme to calculate emissions from road transport, methodology and emission factors (version 2.1), European Environmental Agency, Copenhagen.

Oenema, O., G.L. Velthof, N. Verdoes, P.W.G. Groot Koerkamp, G.J. Monteny, A. Bannink, H.G. van der Meer and 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).

Ogink, N.W.M., C.M. Groenestein and J. Mosquera (2014). Actualisering ammoniakemissiefactoren rundvee: advies voor aanpassing in de Regeling ammoniak en veehouderij, Livestock Research Rapport 744, Wageningen UR, Lelystad (in Dutch).

PBL (2012). Environmental balance 2012, Netherlands Environmental Assessment Agency. Bilthoven (in Dutch).

Pulles, T., and J. van Aardenne, (2001). Good Practice Guidance for CLRTAP Emission Inventories, Draft chapter for the UNECE CORINAIR Guidebook on Emission Inventories, Available: http://reports.eea.eu.int/EMEPCORINAIR4/en/BGPG.pdf

RIVM (2001). Environmental Balance 2000, RIVM report 251701051, National Institute for Public Health and the Environment RIVM, Bilthoven (in Dutch).

RIVM (2013). Werkplan Emissieregistratie 2013, RIVM report M680355011, National Institute for Public Health and the Environment. Bilthoven (in Dutch).

RIVM (2014). Werkplan Emissieregistratie 2014, RIVM report M680355014, National Institute for Public Health and the Environment. Bilthoven (in Dutch).

RIVM (2014a). RIVM website http://www.emissieregistratie.nl/erpubliek/erpub/nec.aspx, d.d. 20-02-2014, National Institute for Public Health and the Environment. Bilthoven.

Ruijter, F.J. de, J.F.M. Huijsmans, M.C. van Zanten, W.A.H. Asman and 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 UR, Wageningen.

RWS (2008). Remslijtage, Waterdienst, Centre for Water Management, Lelystad (in Dutch).

Sluijs, J.P. van der, P. Kloprogge, J. Risbey and J. Ravetz (2003). Towards a synthesis of qualitative and quantita-tive 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, and 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 and 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., Ligterink, N.E. and S. van Zyl (2015). NH_3 emission factors for road transport, TNO, Delft.

Tak, C. van der (2000). Actualisatie T0-emissies, report number 16196.620/2, MARIN, Wageningen (in Dutch).

Umwelt Bundes Amt (2011). Collection and treatment of Biowaste. UBA.

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/Rep_Guidelines_ECE_EB_AIR_97_e.pdf.

UNECE (2010). Report for the Stage 3 in-depth review of emission inventories submitted under the UNECE LRTAP Convention an EU National Emissions Ceilings Directive for The Netherlands, CEIP/S3.RR/2010/Netherlands, Centre on Emission Inventories and Projections, Wien.

Velthof, G.L., C. van Bruggen, C.M. Groenestein, B.J. de Haan, M.W. Hoogeveen en J.F.M. Huijsmans (2009). Methodiek voor berekening van ammoniakemissie uit de landbouw in Nederland. WOt-report nr. 70. Wageningen, the Netherlands (in Dutch).

Verdonk, M. and W. Wetzels (2012), Referentieraming energie en emissies: actualisatie 2012. Energie en emissies in de jaren 2012, 2020 en 2030, Planbureau voor de Leefomgeving, Den Haag (in Dutch).

Visschedijk, A., W, Appelman, J.H.J. Hulskotte and P. Coenen. (2007). Onderhoud van methodieken Emissieregistratie 2006-2007, TNO report nr. A-R0865/B (in Dutch).

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, 2002.

VROM (2008), Milieuverslaglegging en PRTR: veranderingen vanaf het verslagjaar 2009, Ministerie van Infrastructuur en Milieu. Den Haag. http://www.rijksoverheid.nl/documenten-en-publicaties/brochu-res/2009/10/01/milieuverslaglegging-en-prtr-verande-ringen-vanaf-het-verslagjaar-2009.html. (in Dutch).

Zyl, S. van, P. van Mensch, N.E. Ligterink, R. Dröge and G. Kadijk (2015). Update emission model for two-wheeled mopeds, TNO report 2014 R11088, TNO, Utrecht.

13 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 2013 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 2013 level assessment (Emissions in Gg).

NFR14 Code	Longname	2013	Contribution	Cumulative contribution
1A1b	Petroleum refining	9.9	33%	33%
1A1a	Public electricity and heat production	9.4	31%	65%
1A2a	Stationary combustion in manufacturing industries and construction: Iron and steel	3.0	9.9%	75%
1A2gviii	Stationary combustion in manufacturing industries and construction: Other	2.6	8.8%	83%

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	4.8%	75%
1A3biii	Road transport: Heavy duty vehicles and buses	6.3	3.3%	79%
2A6	Other mineral products	5.5	2.9%	82%

Table 1.1.c. SO_x key source categories identified by 1990-2013 trend assessment (Emissions in Gg).

NFR14 Code	Longname	Trend	Trend contribution	Cumulative trend contribution
1A1a	Public electricity and heat production	1.0%	16%	16%
1A2gviii	Stationary combustion in manufacturing industries and construction: Other	0.9%	16%	32%

1A2a	Stationary combustion in manufacturing industries and construction: Iron and steel	0.8%	13%	45%
1A2c	Stationary combustion in manufacturing industries and construction: Chemicals	0.8%	13%	58%
1A3biii	Road transport: Heavy duty vehicles and buses	0.5%	8.2%	66%
1A1b	Petroleum refining	0.3%	4.5%	70%
1A3bi	Road transport: Passenger cars	0.3%	4.5%	75%
1A4bi	Residential: Stationary	0.2%	3.4%	78%
1A2b	Stationary combustion in manufacturing industries and construction: Non-ferrous metals	0.2%	2.9%	81%

Table 1.2.a. NO_x key source categories identified by 2013 level assessment (Emissions in Gg).

NFR14 Code	Longname	2013	Contribution	Cumulative contribution
1A3biii	Road transport: Heavy duty vehicles and buses	44	18%	18%
1A3bi	Road transport: Passenger cars	29	12%	30%
1A1a	Public electricity and heat production	22	9.2%	40%
1A3di(ii)	International inland waterways	17	7.0%	47%
1A3bii	Road transport: Light duty vehicles	13	5.6%	52%
1A4ai	Commercial/institutional: Stationary	12	4.8%	57%
1A4ci	Agriculture/Forestry/Fishing: Stationary	11	4.4%	61%
1A4bi	Residential: Stationary	10	4.2%	66%
1A2c	Stationary combustion in manufacturing industries and construction: Chemicals	10	4.1%	70%
1A3dii	National navigation (shipping)	10	4.0%	74%
1A2gvii	Mobile Combustion in manufacturing industries and construction	9.5	4.0%	78%
1A4cii	Agriculture/Forestry/Fishing: Off-road vehicles and other machinery	8.9	3.7%	81%

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

NFR 14 Code	Longname	1990	Contribution	Cumulative contribution
1A3 bi	Road transport: Passenger cars	143	25%	25%
1A3 biii	Road transport: Heavy duty vehicles and buses	90	16%	41%
1A1 a	Public electricity and heat production	83	14%	55%
1A2c	Stationary combustion in manufacturing industries and construction: Chemicals	36	6.3%	61%
1A3 di(ii)	International inland waterways	22	3.9%	65%
1A3 bii	Road transport: Light duty vehicles	21	3.6%	69%
1A4 bi	Residential: Stationary	20	3.6%	72%
1A2 gviii	Stationary combustion in manufacturing industries and construction: Other	20	3.5%	76%
1A1 b	Petroleum refining	19	3.3%	79%
1A2 gvii	Mobile Combustion in manufacturing industries and construction	19	3.3%	82%

Table 1.2.c. NO_x key source categories identified by 1990-2013 trend assessment (Emissions in Gg).

NFR14 Code	Longname	Trend	Trend contribution	Cumulative trend contribution
1A3bi	Road transport: Passenger cars	5.3%	27%	27%
1A1a	Public electricity and heat production	2.2%	11%	38%
1A3di(ii)	International inland waterways	1.3%	6.6%	45%
1A3dii	National navigation (shipping)	1.2%	6.1%	51%
1A4ci	Agriculture/Forestry/Fishing: Stationary	1.2%	6.1%	57%
1A4ai	Commercial/institutional: Stationary	1.0%	5.2%	62%
1A3biii	Road transport: Heavy duty vehicles and buses	1.0%	5.1%	67%
1A2c	Stationary combustion in manufacturing industries and construction: Chemicals	0.9%	4.5%	72%
1A3bii	Road transport: Light duty vehicles	0.9%	4.3%	76%

1A4cii	Agriculture/Forestry/Fishing: Off-road vehicles and other machinery	0.5%	2.6%	79%
1A2gviii	Stationary combustion in manufacturing industries and construction: Other	0.5%	2.3%	81%

Table 1.3.a. NH_x key source categories identified by 2013 level assessment (Emissions in Gg).

NFR14 Code	Longname	2013	Contribution	Cumulative contribution
3Da2a	Animal manure applied to soils	40	30%	30%
3B1a	Manure management - Dairy cattle	17	13%	43%
3B3	Manure management - Swine	15	11%	54%
3Da1	Inorganic N-fertilizers (includes also urea application)	14	10.2%	64%
6A	Other (included in national total for entire territory) (please specify in IIR)	13	9.4%	73%
3B1b	Manure management - Non-dairy cattle	9.1	6.8%	80%
3B4gi	Manure management - Laying hens	7.9	5.9%	86%

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	212	57%	57%
3B3	Manure management - Swine	49	13%	70%
3B1a	Manure management - Dairy cattle	22	5.8%	76%
3Da3	Urine and dung deposited by grazing animals	18	4.8%	81%

Table 1.3.c. NH_x key source categories identified by 1990-2013 trend assessment (Emissions in Gg).

NFR14 Code	Longname	Trend	Trend contribution	Cumulative trend contribution
3Da2a	Animal manure applied to soils	10%	40%	40%
3B1a	Manure management - Dairy cattle	2.6%	10%	50%
3Da1	Inorganic N-fertilizers (includes also urea application)	2.3%	9.4%	60%
6A	Other (included in national total for entire territory)	2.0%	8.1%	68%
3B1b	Manure management - Non-dairy cattle	1.4%	5.8%	73%

3Da3	Urine and dung deposited by grazing animals	1.4%	5.6%	79%
3B4gi	Manure mangement - Laying hens	1.2%	4.9%	84%

Table 1.4.a. NMVOC key source categories identified by 2013 level assessment (Emissions in Gg).

NFR14 Code	Longname	2013	Contribution	Cumulative contribution
2D3a	Domestic solvent use including fungicides	21	14%	14%
2D3d	Coating applications	17	12%	26%
1A3bi	Road transport: Passenger cars	15	9.9%	35%
1A4bi	Residential: Stationary	11	7.7%	43%
2D3i	Other solvent use	11	7.1%	50%
2H3	Other industrial processes	10	6.8%	57%
1A3biv	Road transport: Mopeds & motorcycles	10	6.8%	64%
1B2aiv	Fugitive emissions oil: Refining / storage	8.8	5.9%	70%
1B2ai	Fugitive emissions oil: Exploration, production, transport	5.4	3.6%	73%
2B10a	Chemical industry: Other	5.4	3.6%	77%
2D3h	Printing	4.0	2.7%	79%
2H2	Food and beverages industry	3.8	2.5%	82%

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	100	21%	21%
2D3d	Coating applications	92	19%	40%
1A3bv	Road transport: Gasoline evaporation	36	7.5%	47%
2B10a	Chemical industry: Other	33	6.9%	54%
1B2aiv	Fugitive emissions oil: Refining / storage	32	6.6%	61%
2H3	Other industrial processes	27	5.6%	66%
1A3biv	Road transport: Mopeds & motorcycles	25	5.2%	71%
2D3i	Other solvent use	15	3.1%	75%
1B2ai	Fugitive emissions oil: Exploration, production, transport	14	3.0%	78%
2D3h	Printing	14	3.0%	81%

Table 1.4.c. NMVOC key source categories identified by 1990-2013 trend assessment (Emissions in Gg).

NFR14 Code	Longname	Trend	Trend contribution	Cumulative trend contribution
2D3a	Domestic solvent use including fungicides	3.5%	17%	17%
1A3bi	Road transport: Passenger cars	3.4%	17%	34%
2D3d	Coating applications	2.3%	11%	45%
1A3bv	Road transport: Gasoline evaporation	1.9%	9.4%	54%
1A4bi	Residential: Stationary	1.5%	7.4%	62%
2D3i	Other solvent use	1.2%	6.0%	68%
2B10a	Chemical industry: Other	1.0%	5.0%	73%
1A3bii	Road transport: Light duty vehicles	0.5%	2.6%	75%
1A3biv	Road transport: Mopeds & motorcycles	0.5%	2.4%	78%
1A1a	Public electricity and heat production	0.4%	2.2%	80%

Table 1.5.a. CO key source categories identified by 2013 level assessment (Emissions in Gg).

NFR14 Code	Longname	2013	Contribution	Cumulative contribution
1A3bi	Road transport: Passenger cars	265	43%	43%
1A4bi	Residential: Stationary	78	13%	55%
1A3biv	Road transport: Mopeds & motorcycles	65	11%	66%
1A2a	Stationary combustion in manufacturing industries and construction: Iron and steel	62	10%	76%
1A4bii	Residential: Household and gardening (mobile)	30	4.8%	81%

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	593	52%	52%
1A2a	Stationary combustion in manufacturing industries and construction: Iron and steel	187	16%	68%
1A4bi	Residential: Stationary	76	6.7%	75%
1A3bii	Road transport: Light duty vehicles	47	4.1%	79%
1A3biv	Road transport: Mopeds & motorcycles	46	4.0%	83%

Table 1.5.c. CO key source categories identified by 1990-2013 trend assessment (Emissions in Gg).

NFR14 Code	Longname	Trend	Trend contribution	Cumulative trend contribution
1A3bi	Road transport: Passenger cars	5.1%	21%	21%
1A3biv	Road transport: Mopeds & motorcycles	3.6%	15%	35%
1A2a	Stationary combustion in manufacturing industries and construction: Iron and steel	3.5%	14%	49%
1A4bi	Residential: Stationary	3.2%	13%	63%
1A3bii	Road transport: Light duty vehicles	1.9%	7.9%	71%
1A4bii	Residential: Household and gardening (mobile)	1.9%	7.7%	78%
1A2b	Stationary combustion in manufacturing industries and construction: Non-ferrous metals	1.4%	5.6%	84%

Table 1.6.a. PM_{10} key source categories identified by 2013 level assessment (Emissions in Gg).

NFR Code	Longname	2013	Contribution	Cumulative contribution
3B4gi	Manure mangement - Laying hens	2.9	11%	11%
2H3	Other industrial processes	2.6	10%	21%
1A4bi	Residential: Stationary	2.1	8.0%	28%
2H2	Food and beverages industry	1.7	6.3%	35%
1A3bvi	Road transport: Automobile tyre and brake wear	1.4	5.2%	40%
2B10a	Chemical industry: Other	1.3	5.0%	45%
3B4gii	Manure mangement - Broilers	1.3	4.9%	50%
2C1	Iron and steel production	1.2	4.7%	55%
3B3	Manure management - Swine	1.2	4.5%	59%
2D3i	Other solvent use	1.2	4.4%	64%
1A3bi	Road transport: Passenger cars	1.2	4.3%	68%
1A3bvii	Road transport: Automobile road abrasion	1.1	4.2%	72%
2A6	Other mineral products	1.1	4.0%	76%
1A3bii	Road transport: Light duty vehicles	1.0	3.9%	80%
3Dc	Farm-level agricultural operations including storage, handling and transport of agricultural products	0.6	2.3%	82%

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	13%	13%
1A1b	Petroleum refining	6.5	9.3%	22%
1A3bi	Road transport: Passenger cars	5.6	8.1%	30%
2H3	Other industrial processes	5.4	7.8%	38%
1A3biii	Road transport: Heavy duty vehicles and buses	5.0	7.2%	45%
2H2	Food and beverages industry	4.3	6.2%	52%
2B10a	Chemical industry: Other	4.1	5.9%	58%
1A3bii	Road transport: Light duty vehicles	3.7	5.3%	63%
1A4bi	Residential: Stationary	2.5	3.6%	66%
1A1a	Public electricity and heat production	2.2	3.2%	70%
2A6	Other mineral products	2.0	2.9%	73%
1A2gvii	Mobile Combustion in manufacturing industries and construction:	1.9	2.7%	75%
2D3i	Other solvent use	1.9	2.7%	78%
3B3	Manure management - Swine	1.7	2.4%	80%

Table 1.6.c. PM_{10} key source categories identified by 1990-2013 trend assessment (Emissions in Gg).

NFR14 Code	Longname	Trend	Trend contribution	Cumulative trend contribution
3B4gi	Manure mangement - Laying hens	3.9%	14%	14%
2C1	Iron and steel production	3.3%	12%	26%
1A1b	Petroleum refining	3.2%	12%	37%
1A3biii	Road transport: Heavy duty vehicles and buses	2.0%	7.2%	45%
1A4bi	Residential: Stationary	1.7%	6.1%	51%
1A3bi	Road transport: Passenger cars	1.4%	5.2%	56%
1A3bvi	Road transport: Automobile tyre and brake wear	1.4%	4.9%	61%
3B4gii	Manure mangement - Broilers	1.2%	4.2%	65%
1A3bvii	Road transport: Automobile road abrasion	1.1%	4.1%	69%
3B3	Manure management - Swine	0.8%	2.9%	72%
1A1a	Public electricity and heat production	0.8%	2.9%	75%
2H3	Other industrial processes	0.8%	2.8%	78%
2D3i	Other solvent use	0.7%	2.4%	80%

Table 1.7.a. $PM_{2.5}$ key source categories identified by 2013 level assessment (Emissions in Gg).

NFR14 Code	Longname	2013	Contribution	Cumulative contribution
1A4bi	Residential: Stationary	2.0	16%	16%
2D3i	Other solvent use	1.2	9.3%	25%
1A3bi	Road transport: Passenger cars	1.2	9.0%	34%
1A3bii	Road transport: Light duty vehicles	1.0	8.1%	42%
2C1	Iron and steel production	0.8	6.2%	49%
2B10a	Chemical industry: Other	0.7	5.9%	55%
2H3	Other industrial processes	0.7	5.2%	60%
1A3biii	Road transport: Heavy duty vehicles and buses	0.5	4.2%	64%
1A3di(ii)	International inland waterways	0.5	3.8%	68%
1A2gvii	Mobile Combustion in manufacturing industries and construction:	0.4	3.1%	71%
1A4cii	Agriculture/Forestry/Fishing: Off-road vehicles and other machinery	0.4	3.0%	74%
1A3dii	National navigation (shipping)	0.4	2.8%	77%
2A6	Other mineral products	0.4	2.8%	79%
2H2	Food and beverages industry	0.3	2.1%	81%

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
2C1	Iron and steel production	5.9	13%	13%
1A3bi	Road transport: Passenger cars	5.6	12%	25%
1A1b	Petroleum refining	5.5	12%	37%
1A3biii	Road transport: Heavy duty vehicles and buses	5.0	11%	47%
1A3bii	Road transport: Light duty vehicles	3.7	7.9%	55%
1A4bi	Residential: Stationary	2.4	5.2%	60%
2B10a	Chemical industry: Other	2.1	4.6%	65%
2D3i	Other solvent use	1.9	4.0%	69%
1A1a	Public electricity and heat production	1.9	4.0%	73%
1A2gvii	Mobile Combustion in manufacturing industries and construction	1.8	3.9%	77%
2H3	Other industrial processes	1.6	3.5%	80%

Table 1.7.c. $PM_{2.5}$ key source categories identified by 1990-2013 trend assessment (Emissions in Gg).

NFR14 Code	Longname	Trend	Trend contribution	Cumulative trend contribution
1A4bi	Residential: Stationary	3.0%	16%	16%
1A1b	Petroleum refining	2.9%	16%	32%
1A3biii	Road transport: Heavy duty vehicles and buses	1.8%	9.8%	41%
2C1	Iron and steel production	1.8%	10%	51%
2D3i	Other solvent use	1.4%	7.8%	59%
1A3bi	Road transport: Passenger cars	0.8%	4.6%	63%
1A1a	Public electricity and heat production	0.7%	3.7%	67%
1A3dii	National navigation (shipping)	0.6%	3.1%	70%
1A3di(ii)	International inland waterways	0.5%	2.8%	73%
2H3	Other industrial processes	0.5%	2.5%	75%
1A3bvi	Road transport: Automobile tyre and brake wear	0.4%	2.3%	78%
2C3	Aluminium production	0.4%	2.3%	80%
2B10a	Chemical industry: Other	0.4%	1.9%	82%

Table 1.8.a. Pb key source categories identified by 2013 level assessment (Emissions in Mg).

NFR14 Code	Longname	2013	Contribution	Cumulative contribution
2C1	Iron and steel production	9.5	67%	67%
1A3ai(i)	International aviation LTO (civil)	1.6	12%	79%
2A3	Glass production	0.9	6.2%	85%

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	68%	68%
2C1	Iron and steel production	56	17%	85%

Table 1.8.c. Pb key source categories identified by 1990-2013 trend assessment (Emissions in Mg).

NFR14 Code	Longname	Trend	Trend contribution	Cumulative trend contribution
1A3bi	Road transport: Passenger cars	2.84%	45%	45%
2C1	Iron and steel production	2.12%	33.6%	79%
1A3ai(i)	International aviation LTO (civil)	0.45%	7.2%	86%

Table 1.9.a. Hg key source categories identified by 2013 level assessment (Emissions in Mg).

NFR14 Code	Longname	2013	Contribution	Cumulative contribution
2C1	Iron and steel production	0.17	33%	33%
1A1a	Public electricity and heat production	0.17	33%	66%
1A2gviii	Stationary combustion in manufacturing industries and construction: Other	0.06	11%	78%
1A4bi	Residential: Stationary	0.03	6.5%	84%

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	55%	55%
2B10a	Chemical industry: Other	0.7	20%	75%
2C1	Iron and steel production	0.4	11%	86%

Table 1.9.c. Hg key source categories identified by 1990-2013 trend assessment (Emissions in Mg).

NFR14 Code	Longname	Trend	Trend contribution	Cumulative trend contribution
2C1	Iron and steel production	3.3%	25%	25%
1A1a	Public electricity and heat production	3.2%	24%	49%
2B10a	Chemical industry: Other	3.0%	22%	71%
1A2gviii	Stationary combustion in manufacturing industries and construction: Other	1.7%	12%	84%

Table 1.10.a. Cd key source categories identified by 2013 trend level assessment (Emissions in Mg).

NFR14 Code	Longname	2013	Contribution	Cumulative contribution
2C1	Iron and steel production	0.35	57%	57%
2B10a	Chemical industry: Other	0.09	14%	71%
1A4bi	Residential: Stationary	0.06	9.2%	80%

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	45%	45%
2C1	Iron and steel production	0.7	33%	78%
1A1b	Petroleum refining	0.11	5.3%	84%

Table 1.10.c. Cd key source categories identified by 1990-2013 trend assessment (Emissions in Mg).

NFR14 Code	Longname	Trend	Trend contribution	Cumulative trend contribution
1A1a	Public electricity and heat production	12%	42%	42%
2C1	Iron and steel production	7%	26%	69%
2B10a	Chemical industry: Other	4.2%	15%	84%

Table 1.11.a. Dioxine key source categories identified by 2013 level assessment (Emissions in g I-Teq).

NFR14 Code	Longname	2013	Contribution	Cumulative contribution
2D3i	Other solvent use	14	54%	54%
1A4bi	Residential: Stationary	6.8	27%	82%

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 1990-2013 trend assessment (Emissions in g I-Teq).

NFR14 Code	Longname	Trend	Trend contribution	Cumulative trend contribution
1A1a	Public electricity and heat production	2.4%	42%	42%
2D3i	Other solvent use	1.7%	29%	71%
1A4bi	Residential: Stationary	0.9%	15%	86%

Table 1.12.a. PAH key source categories identified by 2013 level assessment (Emissions in Mg).

NFR14 Code	Longname	2013	Contribution	Cumulative contribution
1A4bi	Residential: Stationary	4.06	87.0%	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	34%	34%
1A4bi	Residential: Stationary	3.8	19%	53%
2D3d	Coating applications	2.4	12%	64%
2C1	Iron and steel production	1.6	8.1%	73%
2H3	Other industrial processes	1.4	6.8%	79%
1A3bi	Road transport: Passenger cars	0.8	4.0%	83%

Table 1.12.c. PAH key source categories identified by 1990-2013 trend assessment (Emissions in Mg).

NFR14 Code	Longname	Trend	Trend contribution	Cumulative trend contribution
1A4bi	Residential: Stationary	16%	58%	58%
2C3	Aluminium production	8%	29%	87%

B.A. Jimmink et al.

RIVM Report 2014-0166

Better information on ammonia emissions
Calculated ammonia emissions in the Netherlands are still declining over time. However as a result of new research ammonia emissions can be calculated more accurate. This shows that over the whole period 1990-2013 these emissions are higher than previously assumed. Emissions of nitrogen oxides, sulphur dioxides and non-methane volatile organic compounds continue to decrease slightly.

RIVM collects together with partner institutes these data within the Dutch Pollutant Release and Transfer Register (PRTR).

New research results
Based on new research specific emission factors for ammonia could be calculated more precisely. For example, it is determined that the ammonia emission per pig is higher than previously known. Manure that is applied contains more nitrogen, resulting in higher ammonia emissions. Furthermore, road traffic emissions are considered to be higher than previously assumed.

This is a publication of:

National Institute for Public Health and the Environment
P.O. Box 1 | 3720 BA Bilthoven
The Netherlands
www.rivm.com

march 2015

Committed to
health and sustainability

007939