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

Greenhouse gas emissions
in the Netherlands 1990-2022

National Inventory Report 2024

RIVM report 2024-0017

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Synopsis

Greenhouse gas emissions in the Netherlands 1990–2022

Total greenhouse gas (GHG) emissions in the Netherlands decreased by 7.6 per cent in 2022, compared to the 2021 emissions. This decrease was mainly the result of lower natural gas consumption by industry, households, and agriculture due to higher natural gas prices. In 2022, the share of renewable energy was 15 per cent of total final energy consumption. In 2021, this share was 13 per cent.

In 2022, total GHG emissions (including indirect CO_2 emissions and including emissions from the Land use, land use change and forestry sector (LULUCF)) in the Netherlands amounted to 158.4 Tg CO_2-eq. This is approximately 30.5 per cent below the emissions in the base year 1990 (228.1 Tg CO_2-eq). Thanks to this emission reduction, the Netherlands met the Urgenda target (by which national GHG emissions must be reduced by at least 25 per cent relative to 1990).

CO_2 emissions in 2022 were 21.6 per cent below the level in the base year. The total of the emissions of methane, nitrous oxide and fluorinated gases (CH_4, N_2O and F-gases) was reduced by 55.8 per cent over this period.

This report documents the Netherlands' annual submission for 2024 of its GHG emissions inventory 1990-2022 in accordance with the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC, 2006) prescribed by the United Nations Framework Convention on Climate Change (UNFCCC) and the Paris Agreement (PA). The report contributes to fulfilling the reporting requirements under the Governance Regulation of the Energy Union (EU 2018/1999) and implementing regulations.

This report includes explanations of observed trends in emissions, an assessment of the sources with the highest contribution to total national emissions (key sources) and a description of the uncertainty in the emissions estimates. Estimation methods, data sources and emission factors (EFs) are described for each source category, and there is also a description of the quality assurance system and the verification activities performed on the data. The report also describes changes in methodologies since the previous submission (NIR 2023), the results of recalculations and planned improvements.

Keywords: greenhouse gases, emissions, trends, methodology, climate

Publiekssamenvatting

Emissies van broeikasgassen tussen 1990 en 2022

In 2022 zijn in Nederland in totaal 7,6 procent minder broeikasgassen naar de lucht uitgestoten dan in 2021. Deze daling komt vooral doordat industrie, huishoudens en landbouw minder aardgas hebben verbruikt vanwege de hogere aardgasprijzen. In 2022 steeg ook het aandeel 'onuitputtelijke' energiebronnen, zoals zonne- en windenergie. In totaal is dit 15 procent van het energieverbruik in Nederland. In 2021 was dit 13 procent.

De totale hoeveelheid uitgestoten broeikasgassen wordt uitgedrukt in CO_2-equivalenten en bedroeg in 2022 158,4 miljard kilogram. De uitstoot wordt vergeleken met het basisjaar 1990. Ten opzichte van het basisjaar is de uitstoot gedaald met 30,5 procent. In 1990 was de uitstoot 228,1 miljard kilogram CO_2-equivalenten. Hiermee is het zogeheten Urgenda-doel (een minimale afname van 25 procent ten opzichte van 1990) ruim gehaald.

De uitstoot van het broeikasgas CO_2 is 21,6 procent lager dan die in het basisjaar. De uitstoot van de andere broeikasgassen (methaan, distikstofoxide en gefluoreerde gassen) is sinds 1990 met 55,8 procent gedaald.

Dit blijkt uit de definitieve inventarisatie van broeikasgasemissies in 2022 die het RIVM elk jaar op verzoek van het ministerie van Economische Zaken en Klimaat (EZK) maakt. Hiermee voldoet Nederland aan de nationale rapportageverplichtingen voor 2024 van het Klimaatverdrag van de Verenigde Naties (UNFCCC), van het Akkoord van Parijs en van het Bewakingsmechanisme Broeikasgassen van de Europese Unie. De voorlopige emissiecijfers over 2022 zijn in het najaar van 2023 gepubliceerd.

In de inventarisatie staan ook analyses van ontwikkelingen in de uitstoot van broeikasgassen tussen 1990 en 2022. Ook bevat het een analyse van de belangrijkste bronnen die broeikasgassen uitstoten ('sleutelbronnen'), net als de onzekerheid in de berekening van deze uitstoot. Daarnaast zijn de gebruikte berekeningsmethoden en databronnen beschreven. Ten slotte bevat het een overzicht van het kwaliteitssysteem en de manier waarop de Nederlandse Emissieregistratie de berekeningen controleert.

Kernwoorden: broeikasgassen, emissies, trends, methodiek, klimaat, hernieuwbare energiebronnen, internationaal

Contents

Executive summary

ES1 Background information on greenhouse gas (GHG) inventories and climate change

This report documents the Netherlands' annual submission of its greenhouse gas (GHG) emissions inventory for 2024, in line with the annual reporting requirements under the United Nations Framework Convention on Climate Change (UNFCCC) and the Paris Agreement (PA). It contributes to fulfilling the reporting requirements under the Governance Regulation of the Energy Union (EU 2018/1999) and implementing regulations.
The report has been prepared in line with the reporting guidelines provided in Decisions by the UNFCCC Conference of the Parties (COP) and the Conference of the Parties serving as the meeting of the Parties to the Paris Agreement (CMA).

This report is structured as follows:

- Chapter 1 documents the National System as approved by the UNFCCC review in 2007 (and reconfirmed in 2017).
- Chapter 2 summarises the emissions trends, which are further described and documented in the subsequent chapters.
- Chapters 3–8 document emissions and trends for the following sectors:
    - Energy (sector 1);
    - Industrial processes and product use (IPPU, sector 2);
    - Agriculture (sector 3);
    - Land use, land use change and forestry (LULUCF, sector 4);
    - Waste (sector 5);
    - Other (sector 6).
- Chapter 9 describes indirect CO_2 emissions.
- Chapter 10 documents recalculations and improvements since the previous report (NIR 2023).

Note that this report provides no specific information on government policies for reducing GHG emissions. Such information can be found, for example, in the Netherlands State of the Environment Report 2023 (PBL, 2023) (biennial edition; in Dutch: *Balans van de Leefomgeving*) prepared by the Netherlands Environmental Assessment Agency (PBL), in the 8th National Communication under the UNFCCC (EZK, 2022), in the Climate and Energy Outlook 2023 (PBL, TNO, Statistics Netherlands and RIVM, 2023) and in the draft updated National Energy and Climate Plan 2021-2030 (EZK, 2023).

The Common Reporting Format (CRF) files, containing data on emissions, activity data and implied emission factors (IEFs), accompany this report. The complete set of CRF tables, as well as the NIR 2024 in PDF format, are also available on http://english.rvo.nl/nie.

Please note that a detailed description of calculation methods for the various CRF sectors can be found in the corresponding methodology reports. In these methodology reports, the calculation methods are described, adjusted and updated every year according to the most recent scientific insights. Although these are separate documents containing detailed information, both the CRF and the methodology reports form an integral part of the inventory.

Institutional arrangements for inventory preparation

The GHG emissions inventory process of the Netherlands is an integral part of the national Pollutant Release and Transfer Register (NL-PRTR). Figure ES.1 shows the structure of the inventory process and the bodies responsible for each stage.

The Ministry of Infrastructure and Water Management and the Ministry of Economic Affairs and Climate Policy (EZK) have contracted the National Institute for Public Health and the Environment (RIVM) to compile and maintain the PRTR and to coordinate the annual preparation of the NIR and the completion of the CRF tables.

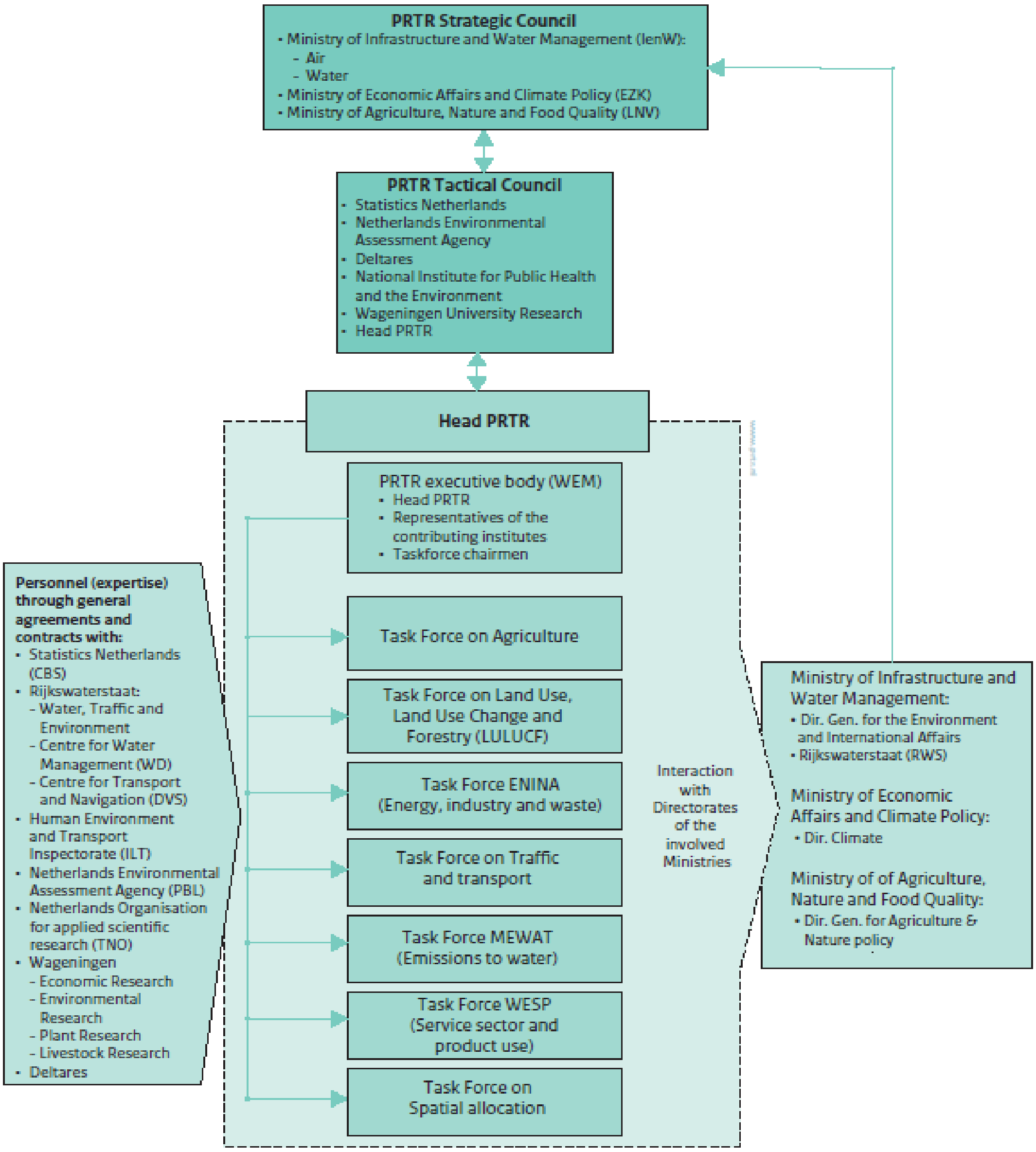


Figure ES.1 Main elements in the GHG emissions inventory compilation process

Methodology reports

Emissions data is reported in accordance with the 2006 IPCC Guidelines (IPCC, 2006) and for a significant part (where indicated), the 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories Methodologies are described in methodology reports. The present CRF/NIR is based on these methodology reports, which are part of the National System.

Note that the methodology reports are also part of the national GHG submission. References are included in Annex 7 and are also available at http://english.rvo.nl/nie. The methodology reports, and any changes in them, have been prepared and approved under the lead of the Chair of the respective PRTR Task Force. Moreover, the methodology reports are reviewed and approved by the National Inventory Entity (NIE).

Base year

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

Key categories

The IPCC Approach 1 method consists of ranking the list of source category/gas combinations according to their contribution to annual national total emissions and to the national total trend (for details of the Approach 1 analysis see the corresponding methodology reports).
The key categories are those whose emissions add up to 95% of the national total (including LULUCF): 39 categories for annual level assessment (emissions in 2022) and 47 categories for the trend assessment. In total the Netherlands reports 124 source categories.

The IPCC Approach 2 method for the identification of key categories requires the incorporation of the uncertainty in each of these source categories before ordering the list of shares. This has been carried out using the uncertainty estimates presented in Annex 2. Here, a total contribution of up to 90% to the overall uncertainty has been used to avoid the inclusion of too many small sources. The results of the Approach 1 and Approach 2 level and trend assessments are summarised in Annex 1. A combination of Approach 1 and 2 and level and trend assessments yields a total of 65 key categories including LULUCF.

ES2 Summary of trends in national emissions and removals

Total GHG emissions (including indirect CO_2 emissions and emissions from LULUCF) in the Netherlands in 2022 were estimated at 158.4 Tg (Teragram or Megaton) CO_2 equivalents (CO_2-eq). This is approximately 30.5% below total emissions in the base year (228.1 Tg CO_2-eq).

CO_2 emissions (including indirect CO_2 emissions and emissions from LULUCF) in 2022 were about 21.6% lower than in 1990. CH_4 emissions in 2022 were 49.0% below 1990 levels, mainly due to decreases in emissions from the Waste sector and the Agricultural sector. N_2O emissions decreased by 58.7% in 2022 compared to 1990, mainly due to decreases in emissions from Agriculture and from Industrial Processes and Product Use (IPPU).
By contrast, CH_4 and N_2O emissions from fossil fuel combustion increased.
Compared to the base year, the emissions of F-gases (HFCs, PFCs and SF_6) decreased by 77.9%, 97.8% and 41.1%, respectively (see Table ES.1). Total emissions of all F-gases were 83.4% lower than in 1990, partly as a result of the Netherlands' programme for reducing emissions of non-CO_2 greenhouse gases (ROB). Figure ES.2 shows a graphical representation of these trends.

Table ES.1 Summary of emissions trends per gas (Tg CO_2 equivalents, including LULUCF and indirect CO_2 emissions), 1990–2022 (differences due to rounding)

	CO_2 incl. indirect and LULUCF	CH_4 incl. LULUCF	N_2O incl. LULUCF	HFCs	PFCs	SF_6	Total (incl. LULUCF)
1990	168.4	36.3	16.1	4.7	2.4	0.2	228.1
1995	178.4	33.8	16.2	6.3	2.1	0.3	237.1
2000	177.2	27.7	14.3	4.0	1.7	0.2	225.2
2005	183.2	22.8	12.9	1.3	0.3	0.2	220.6
2010	187.5	22.2	7.8	2.0	0.3	0.1	219.9
2015	169.7	20.8	8.0	1.7	0.1	0.1	200.4
2021	143.9	19.1	7.1	1.2	0.1	0.1	171.5
2022	132.1	18.5	6.6	1.0	0.1	0.1	158.4

Compared to 2021, overall 2022 GHG emissions decreased by 7.6%. The changes for the specific gases were as follows (please note that differences compared to table ES.1 are due to rounding):

- CO_2 emissions (including LULUCF) decreased by 8.2% (-11.8 Tg CO_2) – mainly in the categories 1A1 Energy industries (-2.0 Tg CO_2), 1A2 Manufacturing industries and construction (-2.0 Tg CO_2) and 1A4 Other Sectors (-6.8 Tg CO_2) – due to a decrease in natural gas consumption as a result of a higher natural gas price in 2022 compared to 2021. The road transport emissions of CO_2 decreased by 0.2 Tg in 2022. The amount of energy from renewables and waste in the Netherlands increased from 13% in 2021 to 15% of final energy consumption in the Netherlands in 2022.
- CH_4 emissions decreased by 3.1% (-0.6 Tg CO_2-eq), mainly in category 1A4 Other sectors.
- N_2O emissions decreased by 6.6% (-0.5 Tg CO_2-eq), mainly due to a small decrease in emissions in 2B4 (Caprolactam production).
- F-gas emissions decreased by 10.4% (-0.15 Tg CO2-eq). Emissions of both HFCs and PFCs decreased (HFC emissions decreased by 10.6% or 0.12 Tg CO_2-eq, and PFC emissions by 27.6% or 0.02 Tg CO_2-eq), SF_6 emissions showed a small increase. Fluctuations in F-gas emissions over the past few years are mainly due to market circumstances. The main decrease for both HFCs and PFCs in 2022 stemmed from category 2B9 (fluorochemical production).

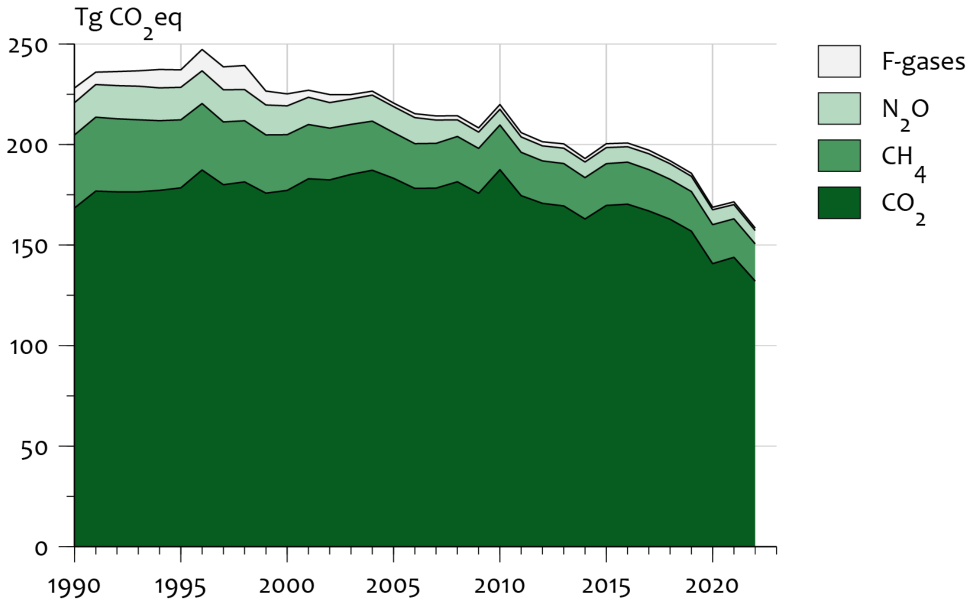


Figure ES.2 Overview of trends in GHG emissions (including LULUCF), 1990–2022

ES3 Overview of source and sink category emissions estimates and trends

Table ES.2 and Figure ES.3 provide an overview of the emissions trends (in CO_2-eq) per IPCC sector. The Energy sector is by far the largest contributor to national total GHG emissions. In 2022, emissions from this sector were about 23.3% lower than in 1990. Emissions from all sectors were lower than in the base year, the largest decreases being in Waste and IPPU.

In this inventory, all major source categories show a decrease in CO_2 equivalent emissions compared to 1990. Only a few relatively minor source categories show an increase in emissions since 1990, e.g. category 1A1c Manufacturing of solid fuels and other energy industries (+0.3 Tg CO_2-eq), 2B8 Petrochemical and carbon black production (+0.3 Tg), 2B10 Other chemical industry (+0.9 Tg), 2D Non-energy products from fuels and solvent use (+0.2 Tg CO_2-eq), 2F Product uses as substitutes for ODS (+0.9 Tg CO_2-eq), 3H Urea application (+0.1 Tg CO_2-eq), 4A Forest land (+ 0.7 Tg CO_2-eq), 4E Settlements (+0.2 Tg CO_2-eq), 4F Other land (+0.1 Tg CO_2-eq), 4G Harvested wood products (+0.2 Tg CO_2-eq) and 5B Biological treatment of solid waste (+0.2 Tg CO_2-eq).

Table ES.2 Summary of emissions trends per sector (Tg CO_2 equivalents, including indirect CO_2 emissions), 1990–2022

	1. Energy	2. IPPU	3. Agri-culture	4. LULUCF	5. Waste	Total (incl.) LULUCF
1990	154.1	27.0	25.2	5.4	16.3	228.1
1995	167.0	26.3	24.3	5.2	14.4	237.1
2000	163.8	24.0	20.7	5.4	11.3	225.2
2005	168.5	20.8	18.4	5.5	7.4	220.6
2010	171.9	18.8	18.3	5.4	5.4	219.9
2015	154.5	16.5	19.1	6.2	4.1	200.4
2021	129.8	16.1	18.0	4.4	3.1	171.5
2022	118.2	14.3	18.0	5.1	2.9	158.4

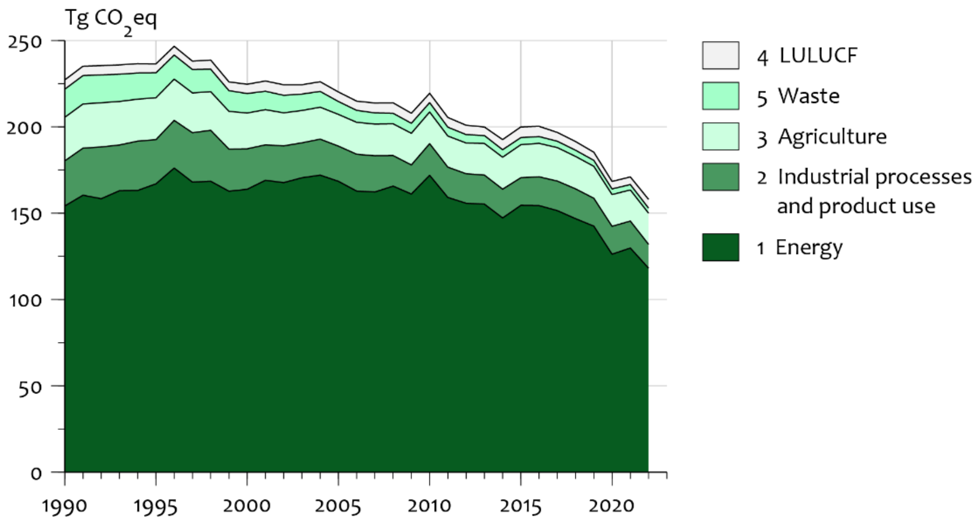


Figure ES.3 Overview of trends in GHG emissions per sector (incl. LULUCF), 1990–2022

ES4 Other information

General uncertainty evaluation

The results of the uncertainty estimation 2 are summarised in Annex 2 of this report.

The ***level*** uncertainty in total CO_2 equivalent emissions (including LULUCF) in 2022 is ±3%. This means that, with a confidence level of 95%, total emissions of greenhouse gases in the Netherlands range between 162.7 and 153.3 Tg CO_2-eq. Per individual gas, the level uncertainties in emissions of CO_2, CH_4, N_2O and the total group of F-gases have been calculated at ±3%, ±8%, ±29% and ±25%, respectively.
The ***trend*** uncertainty in total CO_2-eq emissions (including LULUCF) for 1990–2022 is ±1.4%. This means that the trend in total CO_2-eq emissions between 1990 and 2022 (including LULUCF), which is calculated to be a 30.7% decrease, will range from a 29.3% to a 32.1% decrease.
The uncertainties in the trends for the individual gases are ±1.2%, ±4.5%, ±5% and ±5%, respectively. Annex 2 provides details of the uncertainties not only in 2022, but also in the base year 1990.

Completeness of the national inventory
The Netherlands' GHG inventory includes almost all sources that, according to the 2006 IPCC Guidelines, should be included in the inventory. The following very minor sources are not included:

- CO_2 from Asphalt roofing (2A4d), due to negligible amounts (below threshold);
- CO_2 from Road paving (2A4d), due to negligible amounts (below threshold);
- CH_4 emissions from Other livestock (alpacas) (3A1), due to negligible amounts (below threshold);
- CH_4 and N_2O emissions from the decomposition of manure from other livestock (alpacas) (3A2), due to negligible amounts (below threshold);
- Part of CH_4 from Industrial wastewater (5D2 sludge), due to negligible amounts;
- Precursor emissions (carbon monoxide (CO), nitrogen oxide (NO_x), non-methane volatile organic compounds (NMVOC) and sulphur dioxide (SO_2)) from memo item 'International bunkers' (international transport), as these emissions are not included in national total emissions;
- Indirect CO_2 emissions from CO process emission, due to negligible amounts.

Methodological changes, recalculations and improvements
Since the NIR 2023 (Van der Net et al., 2023), some improvements to the inventory (including recalculations) have been implemented, and these are documented in this NIR 2024. The rationale behind the recalculations is documented in Chapters 3–9 and their impacts on the inventory are summarised in Chapter 10. Table ES.3 presents the results of these recalculations in the NIR 2024 compared to the figures reported in the NIR 2023.

*Table ES.3 Differences between the NIR 2023 and NIR 2024 for the 1990–2021 period due to recalculations (Units: **Tg CO_2-eq;** for F-gases: **Gg CO_2-eq**)*

Gas	Source	1990	2000	2010	2020	2021
CO_2 [Tg]	NIR 2024	167.5	176.6	187.0	140.3	143.4
	NIR 2023	168.5	177.3	187.1	140.5	143.9
	Difference	*-0.6%*	*-0.4%*	*-0.1%*	*-0.1%*	*-0.3%*
CH_4 [Tg]	NIR 2024	36.3	27.7	22.2	19.4	19.1
	NIR 2023	36.0	27.4	21.9	19.2	19.0
	Difference	*0.8%*	*1.2%*	*1.3%*	*1.0%*	*0.8%*
N_2O [Tg]	NIR 2024	16.1	14.3	7.8	7.4	7.1
	NIR 2023	16.2	14.4	7.9	7.5	7.2
	Difference	*-0.7%*	*-0.6%*	*-1.1%*	*-1.9%*	*-2.0%*
PFCs [Gg]	NIR 2024	2,396.6	1,715.2	290.5	61.8	72.4
	NIR 2023	2,397.3	1,723.2	299.9	65.3	79.5
	Difference	*0.0%*	*-0.5%*	*-3.1%*	*-5.4%*	*-8.9%*
HFCs [Gg]	NIR 2024	4,697.2	4,029.3	1,978.0	1,043.3	1,159.1
	NIR 2023	4,697.2	4,029.0	1,977.9	1,056.6	1,172.5
	Difference	*0.0%*	*0.0%*	*0.0%*	*-1.3%*	*-1.1%*
SF_6 [Gg]	NIR 2024	213.1	234.6	108.1	128.4	123.9
	NIR 2023	213.1	234.6	108.1	128.4	123.9
	Difference	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*
Total [Tg CO_2-eq]	NIR 2024	228.1	225.2	219.9	168.8	171.5
	NIR 2023	228.9	225.7	219.8	168.9	172.0
	Difference	*-0.4%*	*-0.2%*	*0.0%*	*-0.1%*	*-0.3%*

Improving the QA/QC system
The QA/QC (quality assurance/quality control) programme is up to date and all procedures and processes meet the National System requirements (as part of the annual activity programme of the Netherlands' PRTR). QA/QC activities undertaken as part of the National System are described in Chapter 1.

Emissions trends for indirect GHGs and SO_2
Compared to 1990, CO and NMVOC emissions were reduced in 2022 by 66.0% and 60.1%, respectively. For SO_2, the reduction was 90.1%; for NO_x, the 2022 emissions were 71.4% below the 1990 level. Table ES.4 provides trend data. Further documentation on these gases can be found in the annual Informative Inventory Report (IIR, Wever et al., 2024).

Table ES.4 Emissions trends for indirect GHGs and SO_2 (in Gg)

	1990	1995	2000	2005	2010	2015	2019	2020	2021	2022
Total NO_x	681	581	494	431	343	273	240	212	206	195
Total CO	1,172	936	753	708	651	518	482	422	414	398
Total NMVOC	606	436	337	270	274	258	247	250	244	242
Total SO_2	198	136	79	68	36	31	23	20	21	20

1 Introduction

1.1 Background information on greenhouse gas inventories and climate change

This report documents the Netherlands' annual submission of its greenhouse gas (GHG) emissions inventory for 2024, in line with the United Nations Framework Convention on Climate Change (UNFCCC) and the annual reporting requirements under the Paris Agreement. The report is also in line with reporting requirements under the Governance Regulation of the Energy Union (EU 2018/1999) and implementing regulations. Chapter 1 provides accompanying information to the national greenhouse gas inventory, including a description of the National System, QA/QC procedures, key categories, uncertainties, and a general description of data sources.

1.1.1 Background information on climate change reporting

Climate Convention, Kyoto Protocol and Paris Agreement

The United Nations Framework Convention on Climate Change (UNFCCC) was ratified for the European part of the Netherlands in 1994 and took effect in March 1994. In 2005, the convention's Kyoto Protocol (KP) came into force. Rules for Monitoring, Reporting and Verification (MRV), initially agreed under the Convention itself, were further extended in the KP under Articles 5, 7 and 8, and implemented successively. The National System for the Netherlands under Article 5.1 of the KP was reviewed (Article 8 of the KP) and accepted in 2007. The greenhouse gas (GHG) inventory is prepared annually under this National System. The UNFCCC review of the inventory in October 2022 confirmed that the Netherlands' inventory and inventory process continues to be in line with the requirements for National Systems.

Following the replacement of the Kyoto Protocol by the Paris Agreement, the national arrangements for the preparation of the inventory (including quality assurance and control procedures) must still be implemented and maintained, similar to the previous requirements.

This National Inventory Report (NIR) 2024, accompanied by the Common Reporting Format (CRF), reports on the Netherlands' national GHG emissions. The methodologies applied for calculating the emissions are in accordance with the 2006 IPCC Guidelines, as well as the 2019 Refinement to the 2006 IPCC Guidelines, where relevant, and can be found in this report and the methodology reports.

The structure of this report complies with the format required by the UNFCCC (FCCC/SBSTA/2004/8).

Geographical coverage

The reported emissions are those that derive from the legal territory of the Netherlands. This includes inland water bodies and coastal waters in a zone stretching 12 miles from the coastline. It excludes the constituent countries of the Kingdom of the Netherlands: Aruba, Curaçao and Sint Maarten. It also excludes Bonaire, Saba and Sint

Eustatius, which have been public bodies (*openbare lichamen*) since 10 October 2010 with their own legislation, which is not applicable to the European part of the Netherlands.
Emissions from offshore oil and gas production on the Dutch part of the continental shelf are included.

1.1.2 *Background information on the GHG emissions inventory*

The NIR (and CRF) cover the seven direct GHGs: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulphur hexafluoride (SF_6) and nitrogen trifluoride (NF_3) (the last four are termed the 'F-gases'). For reasons of data confidentiality, NF_3 emissions cannot be reported separately; therefore, they are included in the PFC emissions.
The Netherlands reports total GHG emissions including indirect CO_2 emissions (originating from the use and/or evaporation of NMVOC). The following *indirect* GHG emissions are also reported: nitrogen oxides (NO_x); carbon monoxide (CO); non-methane volatile organic compounds (NMVOC); and sulphur oxides (SO_x).

This report provides explanations for the trends in GHG emissions per gas and per sector for the 1990–2022 period. Moreover, it summarises the methods and data sources used for the assessments of the uncertainty in annual emissions and in emissions trends, as well as for the Key Category Assessment following Approach 1 and 2 of the 2006 IPCC Guidelines.

This inventory report does not include detailed assessments of the extent to which changes in emissions are due to the implementation of policy measures. This information can be found in, among others, the 8th Netherlands National Communication under the United Nations Framework Convention on Climate Change (NC8: EZK, 2022), and the Climate and Energy Outlook 2023 (PBL, TNO, Statistics Netherlands, RIVM 2023).

The Netherlands also reports emissions under other international agreements. All emissions estimates are adopted from the Netherlands' Pollutant Release and Transfer Register (PRTR), which is compiled by various cooperating organisations, described in Box 1. One unique database is used to ensure consistency regarding all internationally reported data.

In line with the requirements of the national arrangements for the preparation of the inventory, the methodologies for calculating GHG emissions in the Netherlands are updated on an annual basis.
Since 2015, emissions data has been calculated according to the 2006 IPCC Guidelines (IPCC, 2006) and, for a significant part (where indicated), according to the 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories.
The methodologies applied in the NIR 2024 are documented in five methodology reports. The methodology reports are an integral part of this submission (see Annex 7) and are available on the website: http://english.rvo.nl/nie. The methodology reports are prepared and approved under the lead of the PRTR Task Force Chair. Any changes in methodologies are also reviewed by the National Inventory Entity (NIE).

Changes in methodologies are described in the relevant chapters. Chapter 10 documents the recalculations and improvements made following the recommendations of the latest reviews.

In this report, GHG emissions are given in gigagrams (Gg) and teragrams (Tg). 1 gigagram is equal to 1 kiloton (kt); 1 teragram (Tg) is equal to 1 megaton (Mt).
Global warming potential (GWP)-weighted emissions of the GHGs are also provided (in CO_2 equivalents), using GWP values that are based on the effects of GHGs over a 100-year horizon, in accordance with UNFCCC Decision -/CP.27 'Revision of the UNFCCC reporting guidelines on annual inventories for Parties included in Annex I to the Convention' (UNFCCC, 2022) and the 5th IPCC Assessment Report (AR5). The GWP of each individual GHG is provided in Annex 8.

The CRF spreadsheet files accompany this report as electronic annexes. The CRF tables contain detailed information on GHG emissions, activity data, and (implied) emission factors (EFs) by sector, source category, and GHG. The complete set of CRF tables and this report comprise the NIR, which is available on http://english.rvo.nl/nie.

1.2 Description of the national inventory arrangements

1.2.1 Institutional, legal and procedural arrangements

The Ministry of Economic Affairs and Climate Policy (EZK) has overall responsibility for climate change policy issues, including the preparation of the National GHG Emissions Inventory.

The National System was finalised and established by the end of 2005 and is described in greater detail in the Eighth Netherlands National Communication under the United Nations Framework Convention on Climate Change (NC8: EZK, 2022).

As part of this system, the Act on the Monitoring of Greenhouse Gases also took effect in December 2005. This Act required the establishment of the National System for the monitoring of GHGs and empowered the Minister of Economic Affairs and Climate Policy (EZK) to appoint an authority responsible for the National System and the National GHG Emissions Inventory. In a subsequent regulation, the Minister appointed the Rijksdienst voor Ondernemend Nederland (RVO) as the NIE, the single national entity required under the Kyoto Protocol. Following the replacement of the Kyoto Protocol by the Paris Agreement, national arrangements for the preparation of the inventory still have to be maintained, similar to the previous requirements.

In addition to coordinating the establishment and maintenance of a National System, RVO was tasked with the coordination of improved QA/QC activities as part of the National System, as well as the coordination of support/response to the UNFCCC review process.
EZK assigned the National Institute for Public Health and the Environment (RIVM) as the institute responsible for coordinating the compilation and maintenance of the pollutants emission register/inventory (PRTR system), which includes GHGs. The main purpose of the PRTR project is the production of an annual set of

unequivocal emissions data that is up-to-date, complete, transparent, comparable, consistent, and accurate. The PRTR project system is used as the basis for the GHG emissions documented in this NIR and for the completion of the CRF tables. RIVM also coordinates the annual compilation of the NIR.

1.2.2 *Overview of inventory planning, preparation and management*

The Dutch PRTR system has been in operation in the Netherlands since 1974. This system encompasses data collection, data processing, and registering and reporting emissions data for approximately 375 policy-relevant compounds and compound groups present in air, water and soil. The emissions data is produced in an annual (project) cycle (RIVM, 2022).

In addition to RIVM, various external agencies contribute to the PRTR by performing calculations or submitting activity data (see Box 1).

Box 1: Pollutant Release and Transfer Register (PRTR) project

Responsibilities for coordination of the PRTR project
Major decisions on tasks and priorities are taken by the Steering Committee ER (SCER) by approving the Annual Work Plan. This committee consists of representatives of the commissioning ministries, regional governments, RIVM, Statistics Netherlands (CBS) and the Netherlands Environmental Assessment Agency (PBL).

As per September 2020, the SCER was split into a Strategic Board, consisting of representatives of the commissioning ministries (Ministries of Infrastructure and Water Management; Economic Affairs and Climate policy; Agriculture, Nature and Food security), and a Tactical Board, consisting of representatives of the various external agencies and RIVM (see Figure 1.3). The Strategic Board formally approves the Annual Work Plan.

The PRTR project leader at RIVM acts as Head of the PRTR and is responsible for the PRTR process; the outcomes of that process are the responsibility of the bodies involved. The collaboration of the various bodies is ensured by means of contracts, covenants or other agreements.

Task Forces
Emissions experts from the participating organisations take part in the Task Forces that calculate national emissions from ~500 relevant emission sources. After intensive checking, national emissions figures are accepted by the PRTR project leader and the dataset is stored in the Central Database.

The ~500 relevant emissions sources are logically divided into 48 work packages. An emissions expert is responsible for one or more work packages, for data collection, and for emissions' calculation. The experts are also closely involved in developing the methodologies for calculating the emissions. Work packages are assigned to the seven Task Forces described below.

Task Force on Energy, Industry and Waste Management (ENINA)
Covers emissions to air from the Industry, Energy production, Refineries and Waste management sectors. ENINA includes emissions experts from the following organisations: RIVM, TNO, Statistics Netherlands, Rijkswaterstaat Environment (Waste Management Department).

Task Force on Transportation
Covers emissions to soil and air from the Transportation sector (aviation, shipping, rail and road transport). PBL, Rijkswaterstaat, Statistics Netherlands, RIVM, and TNO participate in this task force.

Task Force on Agriculture
Covers the calculation of emissions to soil and air from Agriculture. Participating organisations include RIVM, PBL, Wageningen Environmental Research (WenR), Wageningen University Research (WUR) and Statistics Netherlands.

Task Force on Water (MEWAT)
Covers the calculation of emissions from all sectors to water. MEWAT includes experts from Rijkswaterstaat, Deltares, RIVM, Statistics Netherlands and TNO.

Task Force on Consumers and Other Sources of Emissions (WESP)
Covers emissions caused by consumers, trade and services. The members are emissions experts from RIVM and TNO.

Task force on Land Use, Land Use Change and Forestry (LULUCF)
Covers the calculation of sources and sinks of CO_2 from Land use, land use-change and forestry. The LULUCF task force includes emission experts from the following organisations: Wageningen University Research (WUR), PBL and RIVM.

Task force on spatial allocation
This task force does not calculate emissions, but geographically distributes the emissions throughout the Netherlands. The task force includes emission experts from Wageningen University Research (WUR), TNO, Deltares and RIVM.

1.2.2.1 Responsibility for reporting

RIVM is responsible for the preparation of the NIR with input from the relevant PRTR Task Forces and from RVO in its role as the NIE.
RVO is responsible for submission to the UNFCCC in its role as the NIE, following approval by EZK.

1.2.2.2 Overview of inventory preparation and management under Article 7 of the Kyoto Protocol

Since the second commitment period of the Kyoto Protocol ended in 2020, this information is no longer included in this NIR.

1.2.3 Reporting, QA/QC, archiving and overall coordination

The preparation of the NIR includes the documentation and archiving of statistical data for the estimates and QA/QC activities. RVO is responsible for coordinating QA/QC and responses to the EU, as well as for providing additional information requested by the UNFCCC once the NIR and the CRF have been submitted. RVO is also responsible for coordinating the submission of supporting data for the UNFCCC review process. EZK formally approves the NIR prior to submission; in some cases, approval follows consultation with other ministries.

1.2.3.1 Information on the QA/QC plan

As part of its National System, the Netherlands has developed and implemented a QA/QC programme. This programme is assessed annually and updated as necessary. The key elements of the current programme (RVO, 2023) are summarised in this chapter, notably those relating to the NIR. For more detailed information the QA/QC programme, please see Quality assurance and quality control (rvo.nl).

1.2.3.2 QA/QC procedures for the CRF/NIR 2024

The system of methodology reports was developed and implemented in order to increase the inventory's transparency, including methodologies, procedures, tasks, roles and responsibilities. Transparent descriptions of all these are included in the methodology reports for each gas and sector and in process descriptions for other relevant tasks in the National System. The methodology reports are assessed annually and updated when necessary.

The generic annual data and QC process is as follows. The responsible experts (in Dutch: 'werkveldtrekkers') within the respective PRTR Task Forces fill in a standard-format database with emissions data for the time series – this year, that relates to 1990–2022 (with the exception of the LULUCF data, which is delivered via a separate submission). This standard format database is uploaded to and stored in the national emissions database. Following a first check of the data by RIVM for completeness, the (corrected) data is made available to the relevant Task Forces for consistency checks and trend analyses (comparability, accuracy).
Several weeks before the dataset was fixed, a trend verification workshop was organised by RIVM (7 December 2023). The verification process is described in more detail in section 1.2.3.3. The workshop's conclusions, including with respect to how the experts should resolve issues for improvement identified during the workshop, were

documented and collected by RIVM. Further improvements to the dataset were then implemented by the Task Forces.

QA for the current NIR 2024 also includes the following activities:

- Take remaining issues from former UNFCCC reviews and ESD reviews into account and make the requested improvements (summarised in Annex 10).
- A peer and public review on the basis of the final submission of the previous NIR in Q2, and from August through October 2023, respectively. Results of these reviews are summarised in Chapter 10. Identified issues will be addressed in upcoming NIRs.
- In order to identify and detect possible errors, the following tools are also used:
    - A list that links NL PRTR database entries to CRF entries was shared with the responsible experts. The aim is to give the experts insights into the link between the NL PRTR database and the CRF;
    - An Excel tool used by the NIC to prepare tables and figures for the NIR was made available for experts. This tool also permits checking trends at a sub-category level;
    - An Excel overview including IEFs per (sub)category was extracted from the CRF. This overview permits checking dips and jumps across the time series.

The QA/QC system must operate within the available resources (both capacity and finance). Within these limitations, QA/QC activities focus on:

- *The QA/QC programme* (RVO, 2023), which has been developed and implemented as part of the national arrangements. This programme includes quality objectives, the QA/QC plan and a general schedule for the implementation of the activities. The programme is reviewed annually and updated when necessary (the full description of the QA/QC programme can also be found here: Quality assurance and quality control (rvo.nl)).
  Figure 1.1 summarises the main elements of the annual QA/QC cycle. To ensure high-quality and continuous improvement, the annual inventory process is implemented as a cyclical project, on the basis of the iterative Deming cycle of Plan–Do–Check–Act. QA/QC procedures for basic LULUCF data are different from QA/QC procedures for other sectors, and have been elaborated and documented in the description of QA/QC of the external agencies (Wanders et al., 2021).

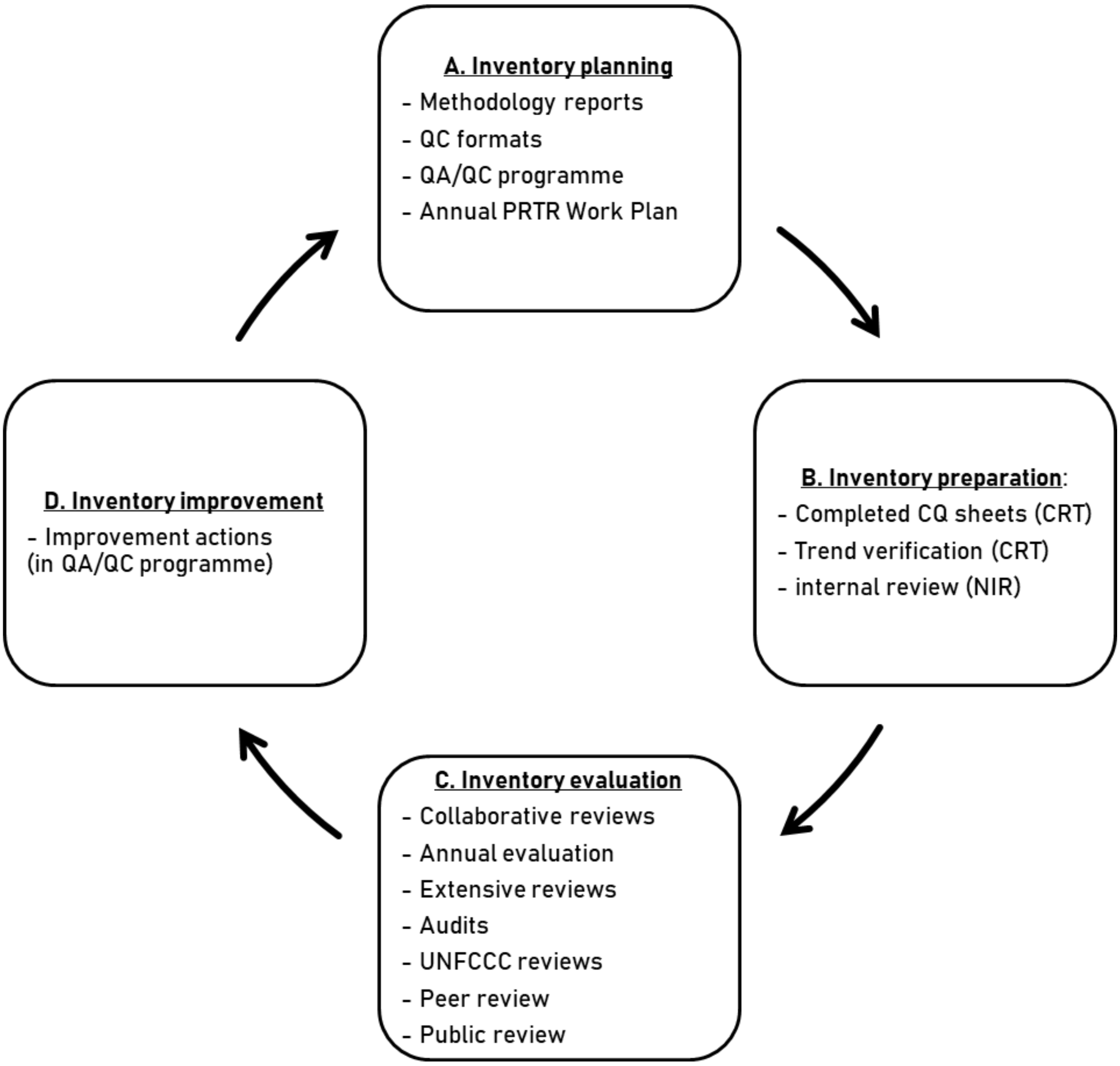


Figure 1.1 QA/QC management cycle (RVO, 2023)

- *The annual RIVM Work Plan* (RIVM, 2023). The Work Plan describes the tasks and responsibilities of the parties involved in the PRTR process, such as products to be delivered, scheduling (planning), and emissions estimation (including the methodology reports on GHGs), as well as those of the members of the Task Forces. The annual Work Plan also describes the general QC activities to be performed by the Task Forces before the annual PRTR database is fixed (see section 1.6.2).
- *European Emission Trading Scheme (EU-ETS).* Selected companies (large emitters) are part of the EU-ETS. They are obliged to report their CO_2 emissions in accordance with monitoring procedures which include strict QA/QC. The reported emissions are checked and approved by the Dutch Emissions Authority (NEa) and used in the inventory for QC and to calculate specific EFs.
- *Agreements/covenants* between RIVM and other institutes involved in the annual PRTR process. The general agreement is that, by accepting the annual Work Plan, the institutes involved commit to delivering capacity for the work/products specified in

that Work Plan. The role and responsibilities of each institute have been described (and agreed) within the framework of the PRTR Work Plan.
- *Specific procedures* established to fulfil the QA/QC requirements. General agreements on these procedures are described in the QA/QC programme as part of the National System. The following specific procedures and agreements have been described in the QA/QC plan and the annual PRTR Work Plan:
  - QC on data input and data processing as part of the annual trend analysis and consolidation of the database following approval of the institutions involved.
  - Documentation of the consistency, completeness and correctness of the CRF data (see also section 1.6.2). According to the 2006 IPCC Guidelines (Volume 1, chapter 6), the emission estimates for all source categories or sub-source categories that show a greater than 10% change in the last year compared to the previous year have to be checked. The Netherlands has chosen for a lower limiting value: 5% changes at target group level, and 0.5% at levels concerning the national total. In these cases, the work package leaders give explanations for the identified changes. The work package leaders send these explanations to the secretary of the PRTR project, who archives them centrally.
  - A peer and public review based on the final submission of the previous NIR. Results of this review are summarised in Chapter 10 and in the QA/QC sections of the specific chapters. Identified issues will be addressed in upcoming NIRs.
  - Audits: In the context of the annual Work Plan, it has been agreed that the institutions involved in the PRTR will inform RIVM about forthcoming internal audits. Furthermore, RVO is assigned the task of organising audits, if needed, of relevant processes or organisational issues within the National System.
  - Archiving and documentation: Internal procedures have been agreed (in the PRTR annual Work Plan) for general data collection and the storage of fixed datasets in the RIVM database, including the documentation/archiving of QC checks. To improve transparency, the implemented QC checklists have also been documented and archived, as part of the QA/QC plan. Since 2012, the RIVM database has reserved space where the Task Forces can store data needed for their emissions calculations. The use of this storage space is optional, as the storage of essential data is also guaranteed by the external agencies’ quality systems.
  - Methodology reports: These have been updated and documented and are an integral part of this submission (see Annex 7).
  - RVO (as the NIE) maintains a website (www.rvo.nl/nie) and a central archive of relevant documents.
- *Annual inventory improvement*: Within the inventory project, resources are made available to keep the total inventory up to the latest standards. In an annual cycle, Task Forces are invited to draft proposals for improving their emissions estimates. The proposals are prioritised in a consensus process and budgets are

made available for the selected improvements. Proposals for improvements that contribute to a reduction in uncertainty of emissions estimates are given priority over others. All planned improvements are documented in the annual Work Plan.

- *Evaluation*: Once a year, those involved in the annual inventory tasks are invited to participate in an evaluation of the process. The results form input into the annual review of the QA/QC programme and the annual Work Plan.
- *General QC checks:* A checklist was developed and implemented to facilitate general QC checks. A number of general QC checks have been added to the annual PRTR Work Plan and are mentioned in the methodology reports. The general QC for the present inventory was largely performed at the institutes involved as an integral part of their PRTR work (Wanders et al, 2021).
- *Category-specific QC*: The comparison of emissions data with data from independent sources was one of the actions proposed in the inventory improvement programme. However, because it did not seem possible to substantially reduce uncertainties through independent verification (measurements) – at least not on a national scale – this issue has received low priority in recent years. Nonetheless, Dutch experts are engaged in several (EU) projects that aim at improving QC by independent verification. The Netherlands would welcome any operational tools for independent verification that might help to further improve the inventory.

1.2.3.3 Verification activities for the CRF/NIR 2024

Two weeks prior to the trend analysis meeting, RIVM made availabel a snapshot of the database in a web-based application (Emission Explorer, EmEx), allowing checks by the institutes and experts involved (PRTR Task Forces). This enabled the Task Forces to check for level errors and inconsistencies in the algorithms/methods used for calculations throughout the time series. The Task Forces performed checks for all gases and sectors. The sector totals were compared to the previous year’s dataset. Where significant differences were found, the Task Forces evaluated the emissions data in greater detail. The results of these checks were used as input for discussions at the trend analysis workshop and were subsequently documented.
During the trend analysis, the GHG emissions for all years between 1990 and 2022 were checked in two ways:

1. The datasets from previous years’ submissions were compared to the current submission; regarding all emissions for which no methodological changes have been announced, emissions from 1990 to 2021 should be identical to those reported last year.
2. The data for 2022 was compared to the trend development for each gas since 1990. Checks of outliers were carried out at a more detailed level for the sub-sources of all sector background tables. Experts specifically checked:
   - annual changes in emissions of all GHGs;
   - annual changes in activity data;
   - annual changes in IEFs;
   - level values of IEFs.

Data checks were performed by sector experts and others involved in preparing the emissions database and the inventory. This resulted in a checklist of actions to be taken. This checklist was used as input for the trend analysis meeting and supplemented with the actions agreed at this meeting. This action list is shared with all work package leaders and Task Force Chairs. Table 1.1 presents the key verification actions for the CRF tables/NIR 2024.

The completion of an action was reported on the checklist. On the basis of the completed checklist and the documentation of trends, Chairs of the Task Forces approved the dataset of their respective Task Force. The dataset was then fixed by the Head of the PRTR (RIVM project leader) and formally agreed to by the principal institutes: RIVM, PBL Statistics Netherlands, Deltares and WUR.

The internal versions of the CRF and NIR and all documentation (emails, data sheets and checklists) used in the preparation of the NIR are stored electronically on a server at RIVM.

Table 1.1 Key actions for the NIR 2024

Item	Date	Who	Result	Documentation
Automated initial check on internal and external data consistency	During each upload	Data Exchange Module (DEX)	Acceptance or rejection of uploaded sector data	Result logging in the PRTR database
Input of outstanding issues for this inventory	25-07-2023	RIVM-PRTR	List of remaining issues/actions from last inventory	Actiepunten Voorlopige cijfers 1990-2022 03-07-2023.xlsx
Sheets for comparing final data 2021 and 2022	4-12-2023	RIVM	Input for trend analysis	Actiepunten Definitieve cijfers 1990-2022_4-12-2023.xlsx
Trend analysis	7-12-2023	Task Forces	Updated action list	Actiepunten Definitieve cijfers 1990-2022_4-12-2023.xlsx
Resolving the issues on the action list	18-12-2023	Task Forces RIVM/ TNO National Inventory Compiler (NIC)	Final dataset	Actiepunten Definitieve cijfers 1990-2022_18-12-2023.xlsx
Comparison of data in CRF tables and E-PRTR database	Until 9-2-2024	NIC/TNO	First draft CRF sent to EU Final CRF to EU	15-01-2024 15-03-2024
Writing and checks of NIR	Until 15-3-2024	Task Forces/ NIC/TNO/NIE	Draft texts	R:\.\NI National Inventory Report\NIR 2024\NIR redactie
Generation of tables for NIR from CRF tables	Until 15-3-2024	NIC/TNO	Final text and tables NIR	R:\....\NIR 2024\CRF….\Tables and Figures v15.xlsx

1.2.3.4 Treatment of confidentiality issues

Some of the data used in the compilation of the inventory is confidential and cannot be published in print or electronic format. The Netherlands uses the code 'C' in the CRF for these data items. All confidential data can be made available to the official UNFCCC review process.

1.3 Inventory preparation: data collection, processing and storage

1.3.1 GHG inventory

The primary process for preparing the GHG emissions inventory in the Netherlands is summarised in Figure 1.2. This process comprises several major steps that are described in greater detail in the following sections.

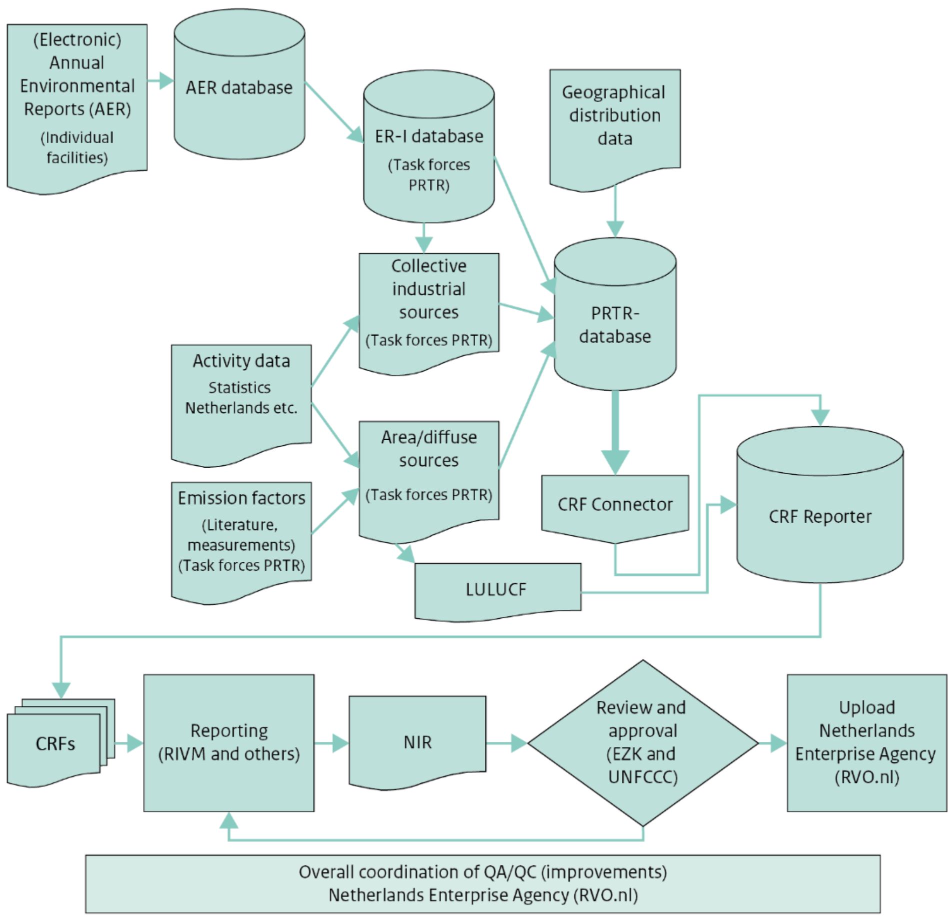


Figure 1.2 Main elements in the GHG emissions inventory process

1.3.2 Data collection

Various data suppliers provide the basic input data for emissions estimates. The principal data sources for GHG emissions are:

Statistical data

Statistical data is provided under various (not specifically GHG-related) obligations and legal arrangements. These include national statistics from Statistics Netherlands and various other sources of data on sinks, water, and waste. The provision of relevant data for GHGs is guaranteed through covenants and an Order in Decree prepared by EZK. For GHGs, agreements with Statistics Netherlands and Rijkswaterstaat Environment with respect to waste management are in place.

Data from individual companies
Data from individual companies are provided in the form of electronic annual environmental reports (e-AERs). A large number of companies have a legal obligation to submit an e-AER that includes – in addition to other environment-related information – emissions data validated by the competent authorities (usually regional implementing agencies and occasionally local authorities) that also issue environmental permits to these companies.

Any industrial activity in the Netherlands requires an environmental permit. As part of the permit application, the operator has to submit a documented account of the emissions and the production capacity. On the basis of this data, the competent authority will set (emissions) limits in the environmental permit. The determination of the applicable (emissions) limits is based on national policies and the specific expertise of the competent authorities. This expertise is also used in the annual verification of the emissions in the environmental reports. The national inventory relies on this verification and only performs sample checks on the data. This procedure is only possible due to the country-specific situation in the Netherlands, where industry is fully aware of the need for emissions reductions that are required by legislation. This results in an open and constructive communication between plant operators and competent authorities on activity levels and emissions. For this reason, the inventory team can limit the verification of the emissions data from individual companies to a minimum.

Some companies provide data voluntarily within the framework of environmental covenants. Large companies are also obliged to participate in the European Emission Trading System (EU-ETS). They have to report their CO_2 emissions in specific annual ETS emissions reports.
When these major industry reports contain plant-specific activity data and EFs of sufficient quality and transparency, these are used to calculate CO_2 emissions estimates for specific sectors.
The AERs from individual companies also provide information that is essential to calculating the emissions of substances other than CO_2. The calculations of industrial process emissions of non-CO_2 GHGs (e.g. N_2O, HFC-23 and PFCs released as by-products) are mainly based on information from these AERs, as are emissions figures for precursor gases (CO, NO_x, NMVOC and SO_2). Only those AERs with high-quality and transparent data are used as a basis for calculating total source emissions in the Netherlands.

Many Dutch industrial (sub)sectors consist of a single company. This is the reason why the Netherlands cannot report activity data (confidential business information) in the NIR or CRF at the most detailed level. Although this may hamper the review process, all confidential data can and will be made available to the EU and UNFCCC review teams on request.

Additional GHG-related data
Additional GHG-related data is provided by other institutes and consultants specifically contracted to provide information on sectors not sufficiently covered by the above-mentioned data sources. For example, RIVM has contracts and financial arrangements with various agricultural institutes and TNO.
In 2004, the Ministry of Agriculture, Nature and Food Quality (LNV) contracted a number of agricultural institutes to develop a monitoring system and methodology description for the LULUCF dataset. In accordance with a written agreement between the Ministry of Economic Affairs and Climate Policy (EZK) and RIVM, these activities also form part of the PRTR.

1.3.3 Data processing and storage

Data processing and storage are coordinated by RIVM. These processes consist notably of the elaboration of emissions estimates and data preparation in the PRTR database. The emissions data is stored in a central database, thus efficiently and effectively satisfying national and international criteria for emissions reporting. Using a custom-made programme (CRF Connector), all relevant emissions and activity data is extracted from the PRTR database and included in the CRF Reporter, thus ensuring the highest level of consistency. Data from the CRF Reporter is used in the compilation of the NIR.

The emissions calculations and estimates made using the input data are performed by five Task Forces, as described in section 1.2.
These Task Forces are responsible for assessing emissions estimates on the basis of the input data and EFs provided. RIVM commissioned TNO to assist in the compilation of the CRF tables (see Figure 1.3).

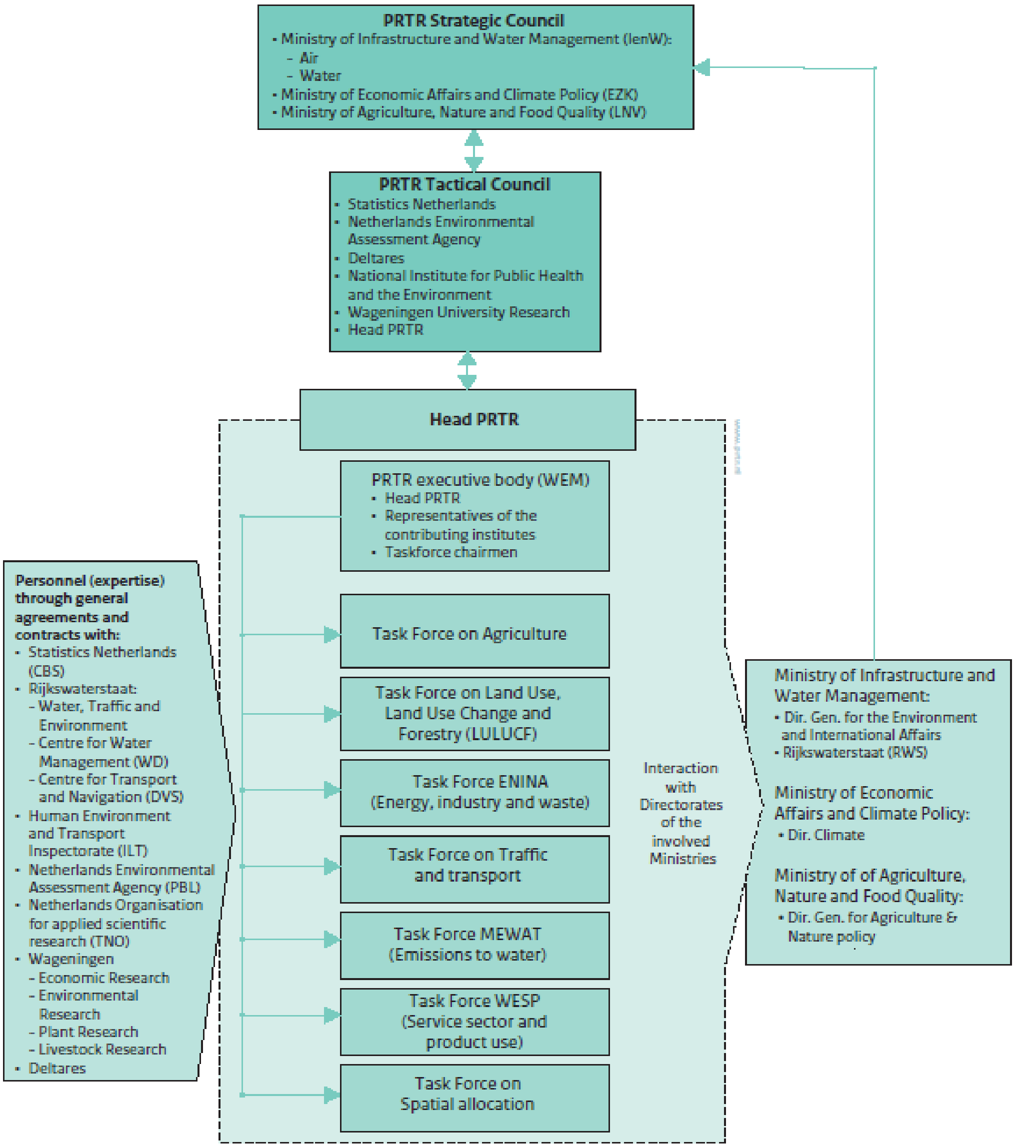


Figure 1.3 Organisational arrangements for PRTR project

1.4 General description of methodologies (including tiers) and data sources used

1.4.1 GHG emissions inventory

Methodologies

Table 1.2 provides an overview of the methods used to estimate GHG emissions. Methodology reports documenting the methodologies, data sources, and QA/QC procedures used in the GHG emissions inventory of the Netherlands, as well as other key documents, are listed in Annex 3.

The sector-specific chapters of this report provide a brief description of the methodologies applied for estimating the emissions from each key source.

Table 1.2 CRF Summary Table 3 with methods and EFs applied

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	**CO_2**		**CH_4**		**N_2O**	
	Method applied	**Emission factor**	**Method applied**	**Emission factor**	**Method applied**	**Emission factor**
1. Energy	CS,T1,T2,T3	CS,D,PS	OTH,T1,T1b,T2,T3	CS,D,OTH,PS	D,T1,T2	CS,D
A. Fuel combustion	CS,T1,T2	CS,D	T1,T2,T3	CS,D	D,T1,T2	CS,D
1. Energy industries	CS,T2	CS,D	T1,T2	CS,D	D,T1	D
2. Manufacturing industries and construction	T2	CS,D	T1,T2	CS,D	T1,T2	D
3. Transport	T1,T2	CS,D	T1,T2,T3	CS,D	T1,T2	CS,D
4. Other sectors	T1,T2	CS,D	T1,T2	CS,D	T1,T2	CS,D
5. Other	T2	CS	T2	CS	T2	CS
B. Fugitive emissions from fuels	CS,T1,T2,T3	CS,D,PS	OTH,T1,T1b,T2,T3	CS,D,OTH,PS		
1. Solid fuels	T2	CS	OTH	OTH		
2. Oil and natural gas	CS,T1,T2,T3	CS,D,PS	T1,T1b,T2,T3	CS,D,PS		
C. CO_2 transport and storage						
2. Industrial processes	CS,T1,T1a,T2,T3	CS,D,PS	CS,T1	CS,D	CS,T1,T2	CS,PS
A. Mineral industry	CS,T1,T2,T3	D,PS				
B. Chemical industry	CS,T1,T3	CS,D	CS	CS	T1,T2	CS,PS
C. Metal industry	T1a,T2	D,PS				
D. Non-energy products from fuels and solvent use	T1,T3	CS,D	T1	D		
E. Electronic industry						
F. Product uses as ODS substitutes						
G. Other product manufacture and use	CS	CS	CS	CS	CS	CS
H. Other	T1	CS				
3. Agriculture	T1	D	T1,T2,T3	CS,D	T1,T1b,T2	CS,D
A. Enteric fermentation			T1,T2,T3	CS,D		
B. Manure management			T1,T2	CS,D	T1	CS

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO_2		CH_4		N_2O	
	Method applied	Emission factor	Method applied	Emission factor	Method applied	Emission factor
C. Rice cultivation						
D. Agricultural soils					T1,T1b,T2	CS,D
E. Prescribed burning of savannas						
F. Field burning of agricultural residues						
G. Liming	T1	D				
H. Urea application	T1	D				
I. Other carbon-containing fertilisers						
J. Other						
4. Land use, land use change and forestry	CS,T1,T2,T3	CS,D	CS,T1	CS,D	CS,T1,T2	CS,D
A. Forest land	T1,T2	CS,D	T1	CS,D	T1	CS,D
B. Cropland	CS,T1,T3	CS,D	T1	CS	T2	CS,D
C. Grassland	CS,T1,T2	CS,D	CS,T1	CS,D	CS,T2	CS,D
D. Wetlands	T1,T2	CS,D	T1	D	T2	CS,D
E. Settlements	CS,T1,T2	CS,D			T2	CS,D
F. Other land	CS,T1,T2	CS,D			T1,T2	CS,D
G. Harvested wood products	T1	D				
H. Other						
5. Waste			T1,T2	CS,D	T1,T2	CS,D
A. Solid waste disposal			T2	CS		
B. Biological treatment of solid waste			T1	CS	T1	CS
C. Incineration and open burning of waste						
D. Waste water treatment and discharge			T1,T2	CS,D	T2	D
E. Other						
6. Other *(as specified in summary 1.A)*						

	HFCs		PFCs		SF_6		Unspecified mix of HFCs and PFCs	
	Method applied	**Emission factor**	**Method applied**	**Emission factor**	**Method applied**	**Emission factor**	**Method applied**	**Emission factor**
2. Industrial processes	T2	CS	T2	CS			T2	CS
A. Mineral industry								
B. Chemical industry	T2	CS	T2	CS				
C. Metal industry			T2	CS				
D. Non-energy products from fuels and solvent use								
E. Electronic industry			T2	CS				
F. Product uses as ODS substitutes	T2	CS					T2	CS
G. Other product manufacture and use								
H. Other								

1.4.2 *Data sources*

The methodology reports provide detailed information on the activity data used for the inventory. In general, the following primary data sources supply the annual activity data used in the emissions calculations:

- Fossil fuel data: (1) Statistics Netherlands national energy statistics (Energy Balance); (2) natural gas and diesel consumption in the agricultural sector (Wageningen Economic Research (WecR); (3) (residential) biofuel data: Statistics Netherlands national renewable energy statistics (Renewable Energy).
- Transport statistics: (1) monthly statistics for traffic and transport; (2) Statistics Netherlands national renewable energy statistics (Renewable Energy).
- Industrial production statistics: (1) individual company AERs; (2) national statistics; ETS reports as a data source and for QA/QC reasons.
- Confidential data obtained directly from firms: production data and N_2O emissions data from the Chemelot site; as it had a site permit for the AERs, no N_2O emissions data is available at company level.
- Consumption/emissions of PFCs and SF_6: reported by individual firms.
- Refrigerant use data from inspection authorities: data about filling, reusing, dismantling and retrofitting stationary cooling installations, for calculating HFC emissions from stationary cooling.
- Anaesthetic gas: data provided by the three suppliers in the Netherlands. Should not all suppliers provide their data, gap-filling is performed on the basis of market shares.
- Spray cans containing N_2O: the Dutch Association of Aerosol Producers (Nederlandse Aerosol Vereniging, NAV).
- Animal numbers and Manure production and handling: Statistics Netherlands /WecR agricultural database, data from the annual agricultural census and the I&R system of RVO.
- Fertiliser statistics and distribution: WecR agricultural statistics and the INITIATOR model from WenR.
- Forest and wood statistics:
  - stem volume, annual growth, carbon balance: data from four National Forest Inventories: HOSP (1988–1992), 5th National Forest Inventory (NFI-5, 2001–2005), 6th National Forest Inventory (NFI-6 2012–2013) and 7th National Forest Inventory (NFI-7 2017-2021);
  - EFISCEN-space forest model, Wageningen Environmental Research (WenR);
  - harvest data: wood balance data from the National Forest Inventories NFI-5, NFI-6 and NFI-7, in combination with FAO harvest statistics;
  - FAO data on imports, exports, and production of sawnwood, wood panels and paper and paperboard from 1961 onwards.
- Land use and land use change: based on digitised and digital topographical maps of 1990 (Kramer and van Dorland, 2009), 2004 (Kramer et al., 2007), 2009 (Kramer and Clement, 2016), 2013 (Kramer and Clement, 2015), 2017 (Kramer, 2019) and 2021 (Kramer and Los, 2022).

- Soil maps: De Vries et al. (2003) and 2014 update (De Vries et al., 2014) and projected map 2040 (Erkens et al., 2021).
- Soil information system: information on soil profiles, soil organic matter, bulk density (Finke et al., 2001; Kuikman et al., 2003; De Groot et al., 2005; Lesschen et al., 2012).
- RothC and Miterra models for calculating carbon stock changes in managed mineral soils under agricultural use.
- Waste treatment in incineration plants, composting and digestion of organic waste, amount landfilled, and CH_4 recovery from landfills: Working Group on Waste Registration (WAR), Rijkswaterstaat Environment and Statistics Netherlands.
- Wastewater data: national statistics from Statistics Netherlands, individual company AERs.

Many recent statistics are available on the Statistics Netherlands' statistical website StatLine, and from the Statistics Netherlands /PBL/RIVM Environmental Data Compendium. It should be noted, however, that the units and definitions used for domestic purposes on these websites can differ from those used in this report (for instance: temperature-corrected CO_2 emissions versus actual emissions in this report; in other cases, emissions are presented with or without the inclusion of organic CO_2 and with or without LULUCF sinks and sources).

1.5 Brief description of key categories

The analysis of key categories is performed in accordance with the 2006 IPCC Guidelines. To facilitate identification of key categories, the contribution made by categories to emissions is classified per gas according to the IPCC potential key category list, as presented in volume 1, chapter 4, Table 4.1 of the 2006 IPCC Guidelines. An extensive overview of the results of the key category analysis (KCA) is provided in Annex 1 of this report. The key categories are also listed per section in each of Chapters 3 to 9. Please note that the Netherlands uses a country-specific aggregation. The KCA is used for the prioritisation of possible inventory improvement actions.

Two approaches for performing the KCA have been used. In approach 1, key categories are identified using a pre-determined cumulative emission threshold. Key categories are those that, when listed in descending order of magnitude, add up to 95% of the total national inventory level. In approach 2, uncertainties are included for activity data, emission factors and total emissions. Here, key categories are those that, together, are responsible for 90% of the uncertainty at the total national inventory level. The method of error propagation is used to calculate the total uncertainty per category resulting from the uncertainties in activity data and emission factors. Apart from the level assessment, a trend assessment is performed. The level assessment looks at the contribution made by each source or sink category to the total national inventory level. The trend assessment identifies those categories that may not be large enough to be identified by means of the level assessment, but whose trend is significantly different from the trend of the overall inventory, and should therefore receive particular attention. As with the level assessment, the trend assessment is performed with and without the incorporation of uncertainty data, the latter being based on error propagation.

The IPCC Approach 1 method (without uncertainties) has 39 categories for annual level assessment (emissions in 2022) and 47 categories for the trend assessment out of a total of 124 source categories. A combination of Approach 1 and 2 (the last one including uncertainties), level and trend assessments amounts to a total of 65 key categories including LULUCF.

1.6 General uncertainty evaluation, including data on the overall uncertainty of the inventory totals

An IPCC Approach 2 methodology for estimating uncertainty in annual emissions has been applied to all of the emission categories, in order to compare the results with the Approach 1 methodology (without uncertainties). In the approach 2 method applied here, propagation of error is used to calculate total uncertainties on the basis of data for emission factors and activities (see Annex 1).

On the national level, a Monte Carlo assessment was also performed. These results have been compared to the results of the error propagation method.

1.6.1 GHG emissions inventory

Uncertainty estimates – propagation of error

The following information sources were used for estimating the uncertainty in activity data and EFs:

- default uncertainty estimates provided in the 2019 IPCC Guidelines;
- sections on uncertainties included in the methodology reports. See Annex 7 for references.

These data sources were supplemented with expert judgements by RIVM, PBL, WUR and Statistics Netherlands emissions experts. Uncertainty estimates were prepared independently, and their views were discussed to reach consensus.

This was followed by an estimation of the uncertainty in the emissions in 1990 and 2022 according to the IPCC Approach 1 methodology for both annual emissions and the emissions trend for the Netherlands. Uncertainties are presented here as half the 95% confidence interval. The reason for halving the 95% confidence interval is that the value then corresponds to the familiar plus or minus value when uncertainties are loosely quoted as 'plus or minus x%'. In cases where asymmetric uncertainty ranges were assumed, the larger percentage was used in the calculation.

The results of the uncertainty calculation are summarised in Annex 2 of this report. The calculation of annual uncertainty in CO_2 equivalent emissions gives an overall uncertainty of approximately 3% in 2022, based on calculated uncertainties of 3%, 8%, 29% and 26% for CO_2 (including LULUCF), CH_4, N_2O and F-gases, respectively.

However, these figures do not include the correlation between source categories (e.g. cattle numbers for enteric fermentation and animal manure production), nor do they include a correction for non-reported sources. The correlation between source categories is included in a Monte Carlo uncertainty assessment.

Monte Carlo analysis
A Monte Carlo analysis has been implemented in the Dutch emissions inventory and its results are used for comparison with the Approach 2 error propagation results.

Where possible, correlations between activity data and emission factors have been included in the Monte Carlo analysis.
Activity data:

- The energy statistics are more accurate on an aggregated level (e.g. for Industry) than on a detailed level (e.g. for each individual industry sector). This type of correlation also occurs in several Transport subsectors, such as road transport, shipping, and aviation.
- The same data source is used to calculate different emissions. This type of correlation occurs where the identifier of the activity (e.g. animal number or inhabitants) must be equal in different source/pollutant combinations.

Emission factors:

- The uncertainty of an EF for a specific fuel from stationary combustion is assumed to be equal for all the sources using this fuel in the stationary combustion sector. This type of correlation is also used in several Transport subsectors such as shipping and aviation.
- The EFs for the various types of cattle (cattle for meat production or dairy cattle) are assumed to be correlated. The same goes for the EFs for poultry, and for horses, mules and asses.

The results of the Approach 2 uncertainty analysis are presented in Table 1.3.

Table 1.3 Level uncertainties for 2022 (95% confidence ranges) based on Monte Carlo analysis, including LULUCF

CRF category	CO_2	CH_4	N_2O	F-gases	Total (CO_2-eq)
1	4%	35%	29%		4%
2	16%	63%	35%	26%	14%
3	18%	9%	38%		12%
4	32%	78%	99%		29%
5	27%	21%	22%		17%
Total	**4%**	**9%**	**28%**	**26%**	**4%**

Table 1.4 Level uncertainties for 2022 (95% confidence ranges) based on standard error propagation including LULUCF

CRF category	CO_2	CH_4	N_2O	F-gases	Total (CO_2-eq)
1	2%	26%	30%		2%
2	19%	62%	35%	26%	16%
3	18%	9%	40%		13%
4	30%	65%	230%		29%
5		21%	28%		18%
Total	**3%**	**8%**	**29%**	**26%**	**3%**

The differences between error propagation and the Monte Carlo analysis can be explained as follows:

- For N_2O in LULUCF, there is a triangular distribution in the Monte Carlo analysis (e.g. -80% and +400%). In the Monte Carlo analysis, both values are used, while in the KCA calculation, only the + value (or 400%) is used. As a result, the uncertainty according to the KCA is higher than the uncertainty according to the Monte Carlo analysis.
- For CH_4 in CRF 1 and in LULUCF, the incorporation of correlations in the Monte Carlo analysis result in a higher uncertainty compared with the error propagation method.

Table 1.5 and 1.6 present the uncertainties based on error propagation in the trend between 1990 and 2022 for CRF categories (including LULUCF) and the various greenhouse gases.

Table 1.5 Trend uncertainties (95%-confidence ranges) of CRF categories including LULUCF based on standard error propagation

CRF category	Trend compared to base year (%)	Uncertainty in trend (%)
1	-23.4	1.2
2	-47.2	5.5
3	-28.5	5.5
4	-19.9	3.8
5	-82	1.7
Total	**-30.7**	**1.4**

Table 1.6 Trend uncertainties (95%-confidence ranges) of individual gases based on standard error propagation

Greenhouse gas	Trend compared to base year (%)	Uncertainty in trend (%)
CO_2	-21.9	1.2
CH_4	-49.6	4.5
N_2O	-58.7	4.8
F gases	-83.4	4.7
Total	**-30.7**	**1.4**

More details on the level and trend uncertainty assessments can be found in Annex 2. In the analyses described above (and in more detail in Annex 2), only random errors were estimated, on the assumption that the methodology used for the calculations did not include any systematic errors that can occur in practice.

Base year (1990) uncertainties
Table 1.7 presents the uncertainties in the base year (Approach 2, including uncertainties using error propagation), which are based on expert judgement in 2000 (Van Amstel et al., 2000) as well as on the 2020 methodology (Ruyssenaars et al., 2020). Please note that these uncertainties were calculated excluding LULUCF.

Table 1.7 Assessment of uncertainties in 1990 emissions (without LULUCF)

Greenhouse gas	2000 methodology	2020 methodology
CO_2	3%	3%
CH_4	17%	21%
N_2O	34%	70%
HFC/SF_6 PFC	41% 100%	 70%
F-gases	100%	70%
Total	**4.4%**	**4.3%**

1.7 General assessment of completeness

1.7.1 GHG emissions inventory

DNV GL (2020) was commissioned by the NIE to investigate the completeness of the Netherlands Greenhouse Gas Inventory. As a result, the conclusions from the former assessment of completeness still stand. The Netherlands' GHG inventory includes almost all sources that, according to the 2006 IPCC Guidelines, should be included in the inventory. The following minor sources are not included:

- CO_2 from Asphalt roofing (2A4d), due to negligible amounts (below threshold);
- CO_2 from Road paving (2A4d), due to negligible amounts (below threshold);
- CH_4 emissions from Other livestock (alpacas) (3A1), due to negligible amounts (below threshold);
- CH_4 and N_2O emissions from the decomposition of manure from other livestock (alpacas) (3A2), due to negligible amounts (below threshold);
- Part of CH_4 from Industrial wastewater (5D2 sludge), due to negligible amounts;
- Precursor emissions (carbon monoxide (CO), nitrogen oxide (NO_x), non-methane volatile organic compounds (NMVOC) and sulphur dioxide (SO_2)) from memo item 'International bunkers' (international transport), as these emissions are not included in national total emissions;
- Indirect CO_2 emissions from CO process emission, due to negligible amounts.

A number of recommendations by DNV GL relating to the 2019 refinement of the IPCC Guidelines are implemented, and other recommendations will be further explored. During the COP26, it was

decided that the implementation of these guidelines will be voluntary as of the NIR 2023.
Annex 6 presents the assessment of completeness and sources, potential sources and sinks for this submission of the NIR 2024 and the CRF tables.

2 Trends in greenhouse gas emissions and removals

2.1 Description of emissions and removal trends for aggregated GHG emissions and removals

This chapter summarises the trends in GHG emissions for the 1990–2022 period by GHG and by sector. More sectoral details are provided in Chapters 3–8.

Table 2.1 presents all GHG emissions by gas and by sector in 2022. Also, the relative shares of the sectors are provided. CO_2 is the main GHG emission in the Netherlands, followed by CH_4, N_2O and F-gases.

Table 2.1 The Netherlands' GHG emissions in CO_2 equivalents (kt) by gas and sector in 2022

Sector	CO_2	CH_4	N_2O	HFCs	PFCs	SF_6	Unspeci-fied mix of HFCs and PFCs	NF_3	Total	Share
1. Energy	115,637.42	1,990.13	533.50						118,161.04	75%
2. Industrial processes and product use	115,14.35	416.57	639.52	1,036.33	52.40	125.49	NO,IE	NO,IE	13,784.65	9%
3. Agriculture	89.23	13,148.80	4,801.50						18,039.53	11%
4. Land use, land use change and forestry	4,382.25	593.33	84.78						5,060.35	3%
5. Waste	NO,IE,NA	2,372.72	568.69						2,941.40	2%
6. Other *(as specified in summary 1.A)*	NO	NO	NO	NO	NO	NO	NO	NO	NO	
Indirect CO_2	457.46								457.46	0%
Total CO_2 equivalent emissions, including indirect CO_2, with land use, land use change and forestry									**158,444.44**	**100%**
International bunkers	45,182.79	148.82	326.34						45,657.96	
Aviation	9,542.91	1.87	70.74						9,615.51	
Navigation	35,639.89	146.95	255.61						36,042.45	

The energy sector is by far the largest contributor to the inventory, followed by Agriculture, IPPU, LULUCF and Waste.

Figure 2.1 presents the contributions made by the individual sectors (including LULUCF) to the total emissions of the various GHGs.

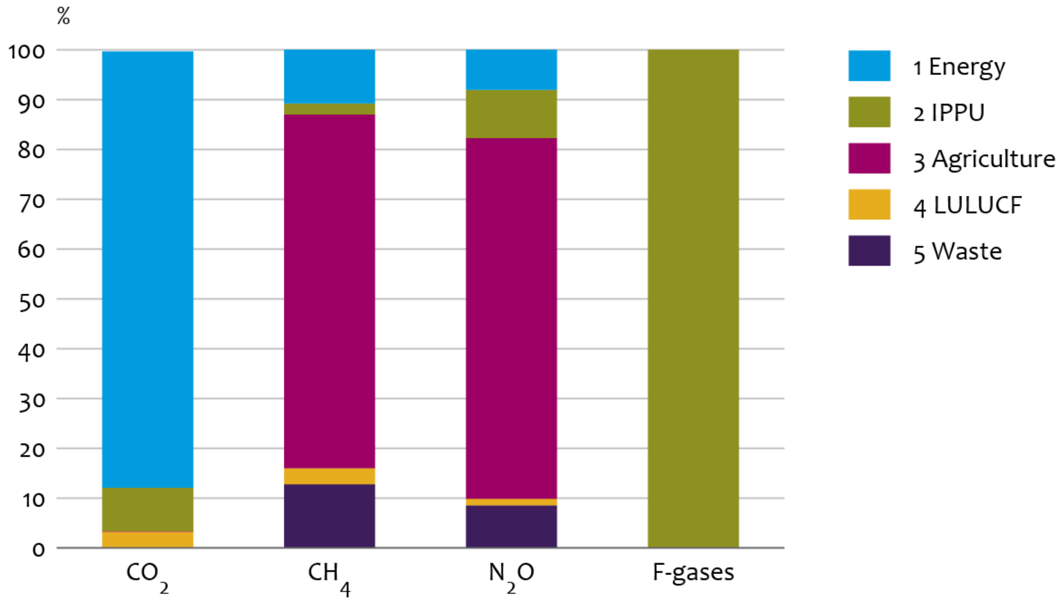


Figure 2.1 Relative contributions of the individual sectors (including LULUCF) to GHG emissions in 2022

The dominance of the Energy sector regarding CO_2 emissions is clearly visible. The agricultural sector is the main contributor of CH_4 and N_2O emissions. All F-gases originate from the IPPU sector.

Figure 2.2 shows the index of economic development (GDP) of the Netherlands since 1990, compared with the development in GHG emissions for the 1990–2022 period.

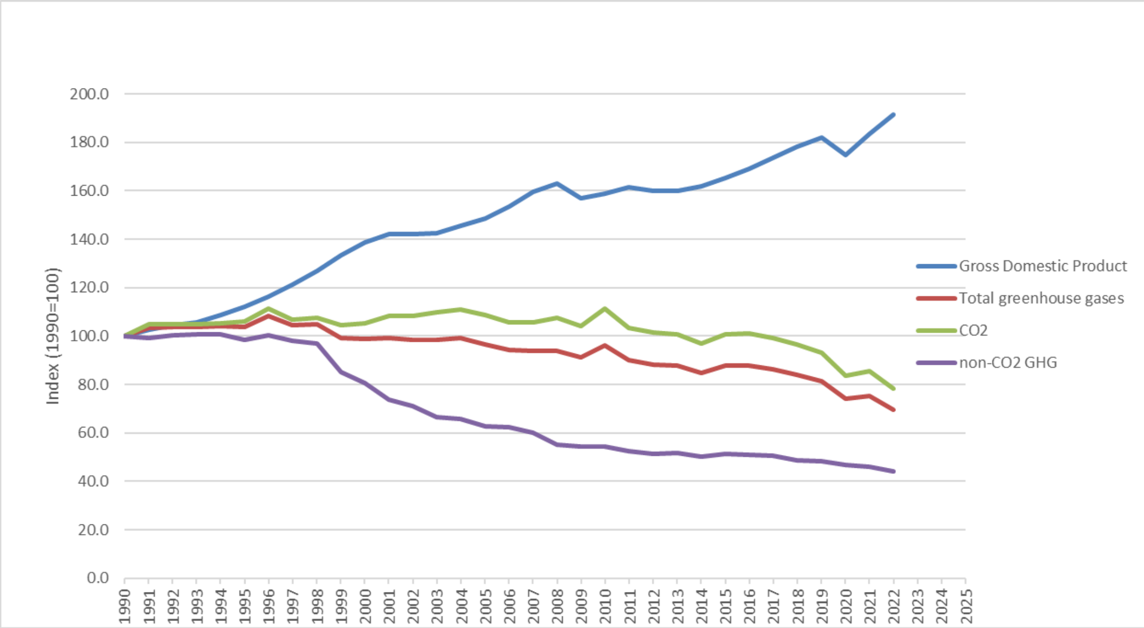


Figure 2.2 Development of greenhouse gas emissions compared with GDP (Gross Domestic Product), for the 1990–2022 period

In 2022, total GHG emissions (including indirect CO_2 emissions and including emissions from LULUCF) in the Netherlands were estimated at 158.4 Tg CO_2-eq. This is 30.5% lower than the 228.1 Tg CO_2-eq reported for the base year (1990), while the economy increased by more than 90% in the same period. The trend in total GHG emissions was largely determined by the emission reductions achieved in non-CO_2 gases (55.8% reduction in 2022 compared to 1990; over the same period, CO_2 emissions declined by 21.6%).

Renewable energy

Figure 2.3 shows the mix of renewable energy sources in the Netherlands and the trend. Renewables accounted for 277 PJ in 2022 (15.0% of total energy use in the Netherlands), a 6% increase compared to 2021[1].

[1] Renewable energy share rose to 15 percent in 2022 | CBS (consulted 29 February 2024)

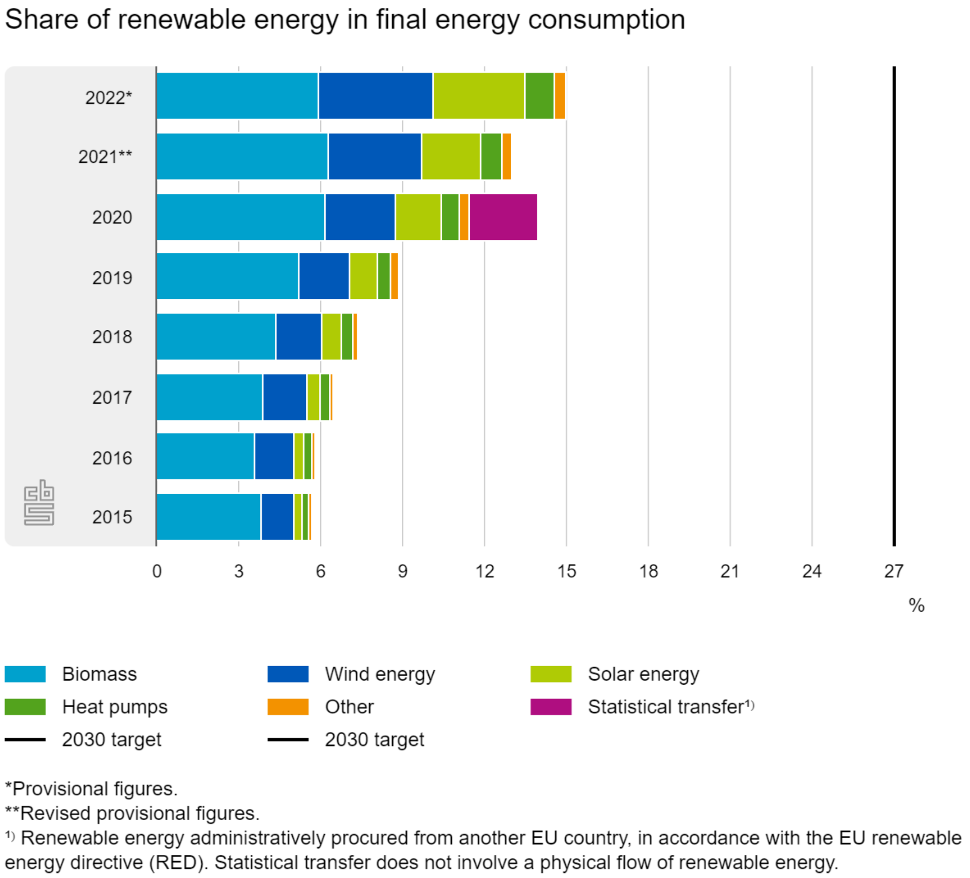


Figure 2.3 Development of renewable energy sources as a percentage of total energy demand in the Netherlands, 1990–2022 (Statistics Netherlands, 2024)[2]

Energy efficiency

The efficiency of total final energy consumption can be expressed by the so-called technical ODEX as defined by the Odyssee-Mure project[3]. The dimension of the ODEX is final energy used divided by a measure of energy consuming activities, which means that a lower value of the ODEX represents an increase in energy efficiency. The technical ODEX measures the energy efficiency progress by sector (industry, transport, households, services) and for the economy as a whole (all final consumers). For each sector, the index is calculated as a weighted average of sub-sectoral indices of energy efficiency progress; sub-sectors being industrial branches, services sector branches, end-uses for households and transport modes.

[2] Renewable energy share rose to 15 percent in 2022 | CBS
[3] https://www.indicators.odyssee-mure.eu/odex-indicators-database-definition.pdf

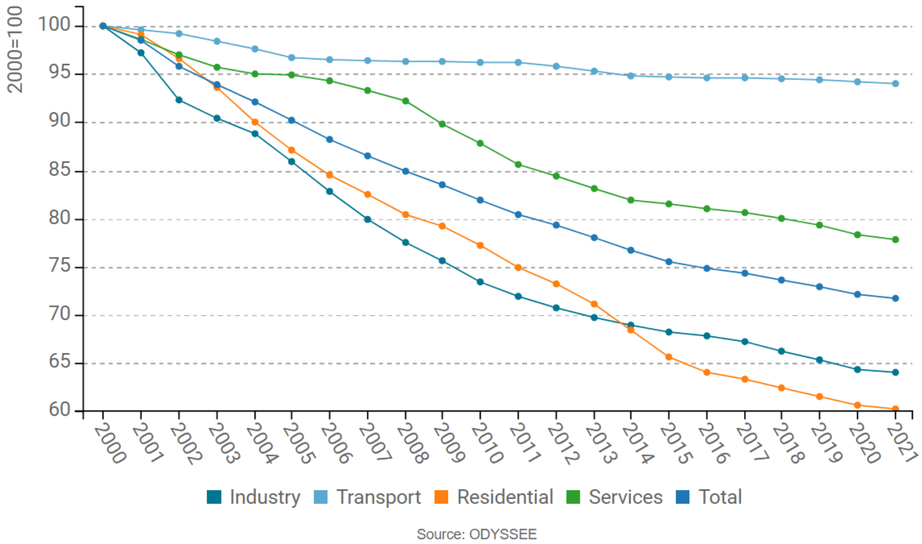


Figure 2.4 Technical ODEX for the Netherlands, 2000-2021[4]

Efficiency for total final energy consumption, as measured by the technical ODEX, has improved by around 1.6% per year since 2000[5]. Smaller than average gains have been registered in transport (0.3% per year) and services (1.2% per year). Larger gains of 2.4% per year occurred in the residential sector and in industry, where efficiency improved by 2.1% per year. The slowdown of efficiency improvements from 2008 until 2016 in industry may have been due to lower investments in new equipment since the 2007-2008 banking crisis and due to a lower utilisation rate of production capacity. A speed-up in efficiency in industry is visible after 2016.

2.2 Description of emissions and removal trends by gas

Figure 2.5 shows the emissions trends for the various gases and aggregated national total GHGs.

[4] One negative point in this figure (-1) represents a 1% increase in efficiency for final energy consumption compared to reference year 2000.
[5] https://www.odyssee-mure.eu/publications/efficiency-trends-policies-profiles/netherlands.html

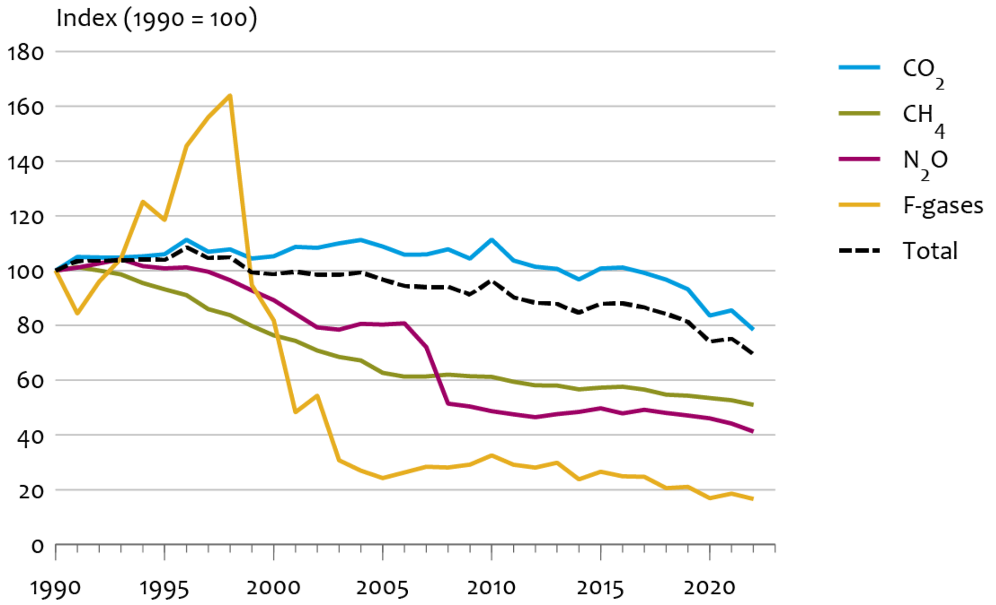


Figure 2.5 Relative emissions trends of the individual GHGs (including LULUCF) in the Netherlands, 1990-2022. The base year 1990 is set at 100

In the 1990-2022 period, emissions of total GHG (including LULUCF) decreased by 30.5 %. Emissions of carbon dioxide (CO_2) decreased by 21.6 %. Emissions of the non-CO_2 GHGs methane (CH_4), nitrous oxide (N_2O) and F-gases decreased by 49.0%, 58.7% and 83.4%, respectively.

2.2.1 *Carbon dioxide*

Figure 2.6 shows the CO_2 emissions trends for the individual sectors.

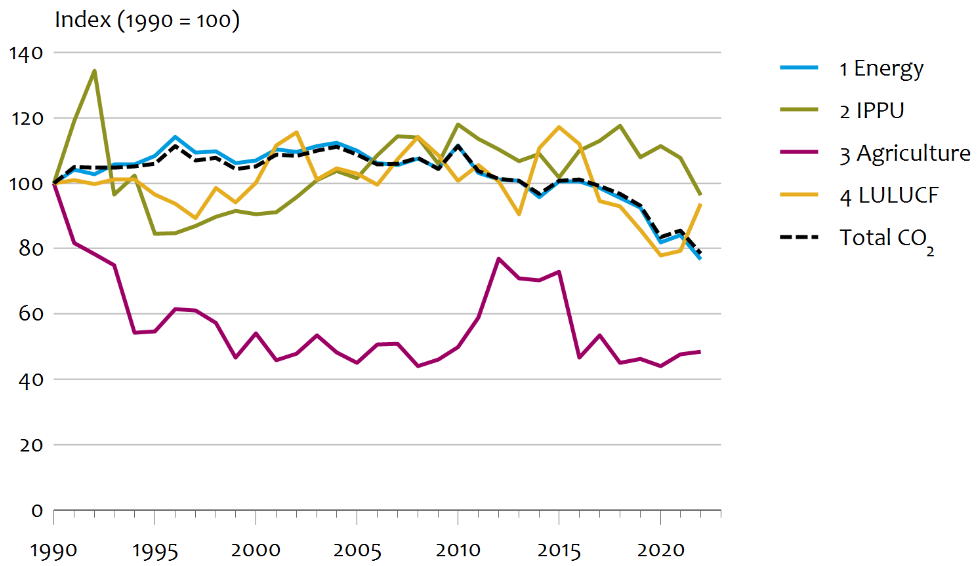


Figure 2.6 Relative emissions trends of CO_2 in the Netherlands, 1990-2022. The base year 1990 is set at 100

In the 1990–2022 period, national CO_2 emissions (including indirect CO_2 emissions from LULUCF) decreased by 21.6% (from 168.4 Tg CO_2-eq to 132.1 Tg CO_2-eq).

With regard to CO_2 emissions, the Energy sector is the primary sector in the Dutch GHG emissions inventory and is responsible for 88% of the total CO_2 emissions in the country (Figure 2.1). In the 1990-2022 period, CO_2 emissions from the Energy sector decreased by 23.2%. Note that in Figure 2.6, the CO_2 emissions trend for the Energy sector almost completely overlaps with that of total CO_2 emissions.

Within the Energy sector, an increasing trend in electric power production until 2005 corresponds to a substantial increase in CO_2 emissions from fossil fuel combustion by power plants. Also, the diesel fuel consumption increased by 60% between 1990 and 2008, resulting in increased emissions in this sector. The decreasing trend of CO_2 between 2016 and 2022 is the result of a decline in coal combustion caused by the closure of coal-fired power plants, and an increase in renewable energy. Apart from these overall trends, some substantial interannual fluctuations are visible. These peaks and dips are mostly due to weather conditions. More gas is used during cold winters (1996 and 2010) while less is used in warm winters (2014 and 2020). The dip in the graph in 2020 is amplified by a decrease in liquid fuel combustion for vehicle use during the COVID-19 pandemic. In 2021, CO_2 emissions show a peak as a result of a cold winter. The large decrease in CO_2 emissions in 2022 compared to 2021 is mainly caused by a decrease in gaseous fuel consumption due to high prices of natural gas in 2022. For more details about the emissions in the subsectors Energy, see section 2.3.

Compared with the Energy sector, other sectors contribute much less to CO_2 emissions (Figure 2.1). The IPPU sector is responsible for 8.7% of the total CO_2 emissions in the Netherlands). CO_2 emissions from the Agriculture and LULUCF sectors amount to 0.1% and 3.3% of total CO_2 emissions in 2022.

The trend of CO_2 emissions from Agriculture is explained by fluctuations in the application of liming products and urea (see Chapter 5).

2.2.2 *Methane*

Figure 2.7 shows the CH_4 emissions trends of all individual sectors over time.

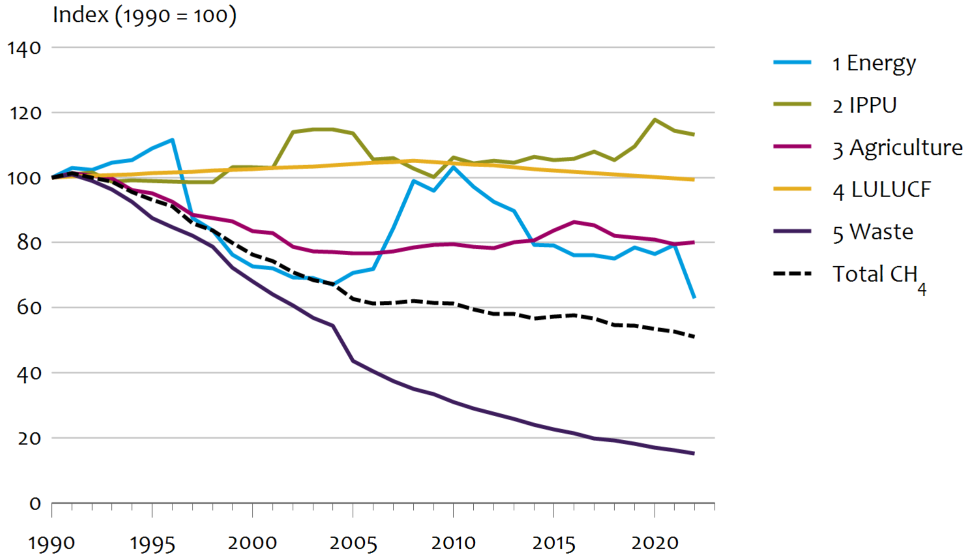


Figure 2.7 Relative emissions trends for CH_4 in the Netherlands, 1990-2022. The base year 1990 is set at 100

Between 1990 and 2022, national CH_4 emissions decreased by 49.0%, from 36.3 Tg to 18.5 Tg CO_2-eq.

The trend of total CH_4 emissions shows a relatively strong reduction between 1990 and 2005. After 2005, emissions declined further, but at a slower pace.

The Agriculture sector was the largest contributor to total methane emissions in 2022 (71.0%) (Figure 2.1). Between 1990 and 2022, CH_4 emissions from Agriculture declined by 20%.

The trend in methane emission from the Agriculture sector is mainly explained by changes in the number of mature dairy cattle and pigs (Chapter 5). The number of dairy cattle has decreased since the 1990s due to higher production rates per animal and production quotas. Between 2012 and 2016, the number of cattle increased as dairy farmers anticipated the abolition of milk production quotas. However, this resulted in exceeding the European phosphate production ceiling. The Dutch government implemented new policies in accordance with the phosphate production ceiling: the phosphate reduction scheme followed by the phosphate quota that were introduced in 2018 (MLNV, 2017). These policies resulted in a decrease in cattle (all categories) that can be kept in the Netherlands and resulted in a decrease in cattle numbers between 2017 and 2022.

CH_4 emission from the Waste sector was 12.8 % of total CH_4 emissions in 2022 (Figure 2.1). In the 1990-2022 period, methane emission from the Waste sector decreased by 85 %, mainly due to an 87% reduction in CH_4 from Managed waste disposal on land (5A1).

The Energy sector contributed 10.7% to total CH_4 emissions in the Netherlands in 2022 (Figure 2.1). In the 1990-2022 period, CH_4 emissions from Energy declined by 37%, mainly in the category Fugitive emissions (1B).

2.2.3 *Nitrous oxide*

Figure 2.8 shows the N_2O emissions trends of all individual sectors over time.

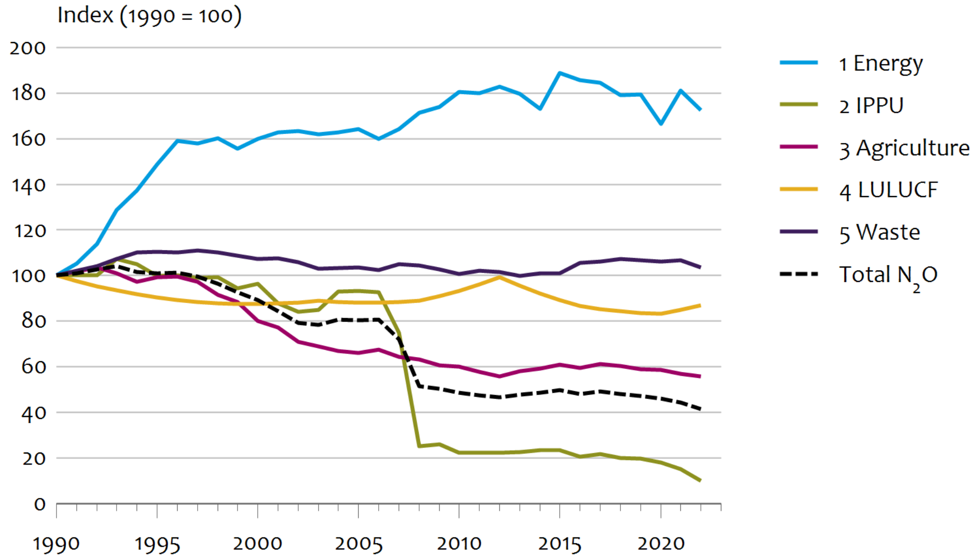


Figure 2.8 Relative emissions trends for N_2O in the Netherlands, 1990-2022. The base year 1990 is set at 100

The national total inventory of N_2O emissions decreased by 58.7%, from 16.1 Tg CO_2-eq in 1990 to 6.6 Tg CO_2-eq in 2022.

The Agriculture sector was the largest contributor to the total nitrous oxide emissions in 2022 (72.4%) (Figure 2.1). N_2O emissions from Agriculture declined by 44% between 1990 and 2022.

The decreasing trend of N_2O emission in the agricultural sector is a result of a decrease in organic and inorganic N fertiliser application, a decrease in animal numbers and a decrease in grazing in the agricultural sector from 1990 to 2012.

In 2022, the IPPU, Waste and Energy sectors contributed 9.6%, 8.6% and 8.0%, respectively, to total N_2O emissions in the Netherlands (Figure 2.1). In the 1990-2022 period, emissions from the IPPU sector decreased by 90%. N_2O emissions within the IPPU show a sharp decrease after 2006. This is a result of a change in the process of nitric acid production (2B2) under EU-ETS regulation. Emissions from Waste and Energy increased by 4% and 72%, respectively, in the 1990-2022 period. In the Energy sector, the increase in N_2O emissions mostly took place in the category Fuel combustion (1A).

2.2.4 *Fluorinated gases*

Fluorinated gases are only emitted in the IPPU sector (Figure 2.1). Within the IPPU sector, there are several F-gas emissions. Figure 2.9 shows the F-gas emissions trends over the 1990-2022 period.

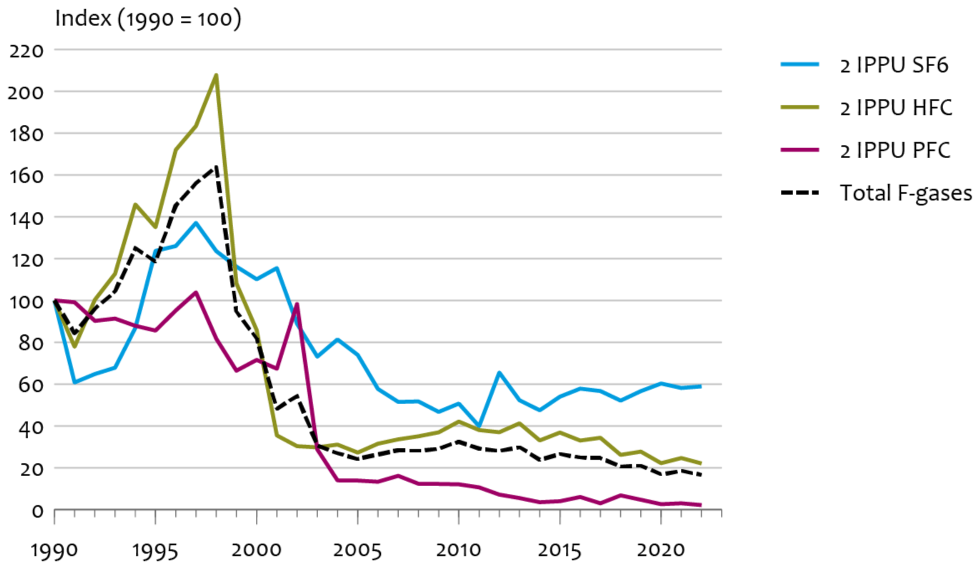


Figure 2.9 Relative emissions trends of fluorinated gases in the Netherlands, 1990-2022. The base year 1990 is set at 100

Total emissions of F-gases have decreased by 83.4%, from 7.3 Tg CO_2-eq in 1990 to 1.2 Tg CO_2-eq in 2022, partly as a result of the Netherlands' programme for reducing emissions of non-CO_2 greenhouse gases (ROB).

Within the fluorinated gases, emissions of hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs) decreased by 77.9% and 97.8%, respectively, during the 1990-2022 period, while sulphur hexafluoride (SF_6) emissions decreased by 41.1%.

It should be noted that, because there is no separate registration of NF_3 in the Netherlands, emissions of NF_3 are included in PFC emissions.

The increase in emissions between 1995 and 1998 is mainly due to a 35% increase in the HFC-23 emission as a result of increased production of HCFC-22. The sharp decrease in emissions in the 1998–2000 period is the result of a 69% decrease in HFC-23 emissions following the installation of a thermal converter (TC) at the plant.

Since 1990, there has been a substantial increase in HFC use as a substitute for (H)CFC use (category 2F). In 2022, this category accounts for 86.1% of national total HFC emissions (0.89 Tg CO_2-eq).

2.3 Description of emission and removal trends by sector

Table 2.2 and Figure 2.10 provide an overview of emissions trends for each CRF category in Tg CO_2 equivalents.

Table 2.2 Summary of emissions trends per sector (Tg CO_2 equivalents, including indirect CO_2 emissions), 1990–2022

	1. Energy	2. IPPU	3. Agri-culture	4. LULUCF	5. Waste	Total (incl.) LULUCF
1990	154.1	27.0	25.2	5.4	16.3	228.1
1995	167.0	26.3	24.3	5.2	14.4	237.1
2000	163.8	24.0	20.7	5.4	11.3	225.2
2005	168.5	20.8	18.4	5.5	7.4	220.6
2010	171.9	18.8	18.3	5.4	5.4	219.9
2015	154.5	16.5	19.1	6.2	4.1	200.4
2021	129.8	16.1	18.0	4.4	3.1	171.5
2022	118.2	14.3	18.0	5.1	2.9	158.4

The Energy sector is by far the largest contributor to national total GHG emissions (contributing 67.6% in the base year and 74.6% in 2022).

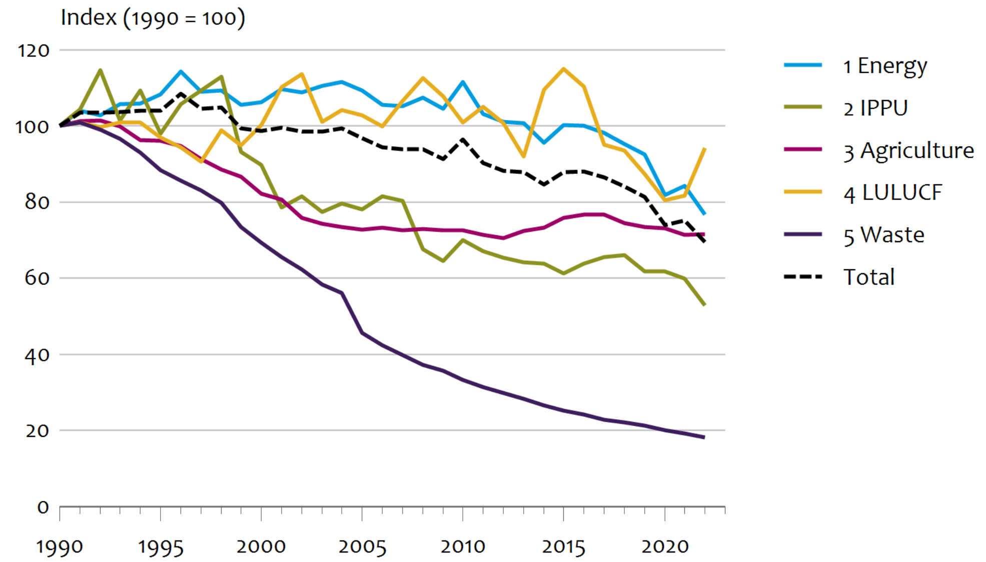


Figure 2.10 Relative GHG emissions trends (including LULUCF) of the individual sectors in the Netherlands, 1990-2022. The base year 1990 is set at 100

The emissions of the Energy sector decreased by 23.3% in the 1990–2022 period.

In 2022, total GHG emissions of all other sectors (IPPU, Agriculture, LULUCF and Waste) decreased by 47.2%, 28.5%, 5.8% and 82.0%, respectively, compared to the base year.

2.3.1 *Energy*

Figure 2.11 shows the relative trend in total GHG emissions from the Energy sector and individual subsectors.

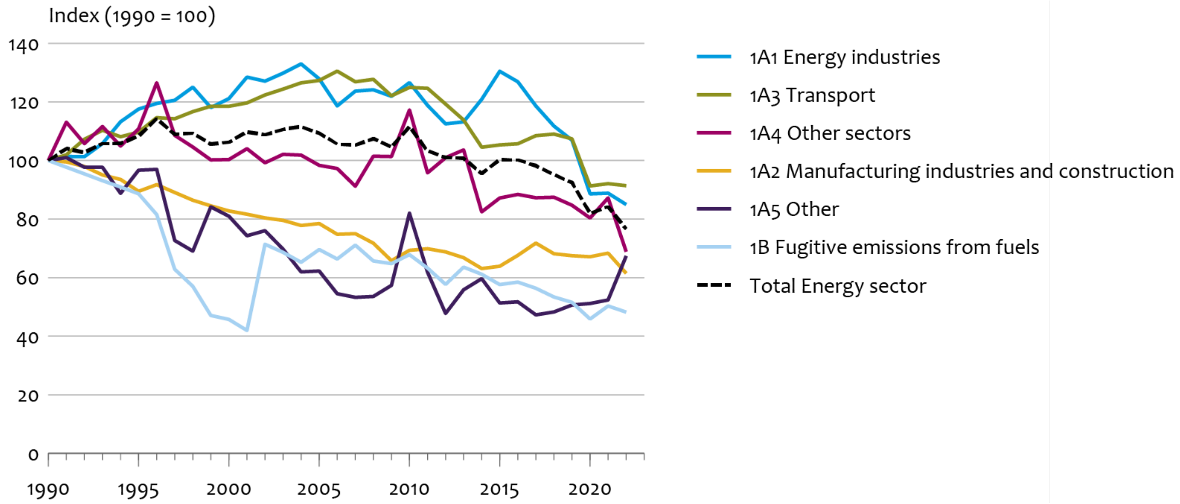


Figure 2.11 Relative emissions trends for the Energy sector and subsectors, 1990-2022. The base year 1990 is set at 100

Between 1990 and 2022, total fossil fuel combustion decreased by 15.5%, due to a 36.9% decrease in solid fuel consumption, a 24.0% decrease in gaseous fuel consumption, and a 1.7% decrease in liquid fuel consumption (see Chapter 3).

The main fluctuations in GHG emissions in this sector can be explained as follows:

- Weather conditions: Natural gas is the main source of energy used in the Netherlands for space heating. The peaks in Figure 2.11 are cold winters in 1996 and 2010, while the dip in 2014 is the result of a relatively warm winter.
- COVID-19: In 2020, there was a dip in total GHG emissions, mainly due to a decrease in liquid fuel combustion for vehicle use during the COVID-19 pandemic;
- The decreasing trend between 2016 and 2020 in total GHG emissions in the Energy sector is the result of a decline in coal combustion caused by the closure of coal-fired power plants, and an increase in renewable energy.
- In 2021 CO_2 emission show a peak as a result of a cold winter.
- The large decrease in CO_2 emissions in 2022 compared to 2021 is mainly caused by a decrease in gaseous fuel consumption due to high prices of natural gas in 2022.

As the Energy sector is the largest contributor to national total GHG emissions, more details about the emissions trends for the individual subsectors in the Energy sector are provided in the paragraphs below.

2.3.1.1 Energy industries (1A1)

The main fluctuations in GHG emissions in this sector (1A1) can be explained as follows:

- an increase in natural gas combustion due to a change in ownership structures of CHP (Combined Heat and Power) plants which resulted in a shift of natural gas combustion from 1A2 to 1A1a in 1990-1998;
- new, large coal-fired power plants commencing operations in 2015 and 2016, resulting in a shift from natural gas to coal;

- closure of old coal-fired power plants in 2015–2019, resulting in a decrease in coal consumption from 2017 onwards;
- in some years, the import of electricity was higher (e.g. in 1999–2008, 2012–2014) than in other years;
- total CO_2 emissions from the five large refineries in the Netherlands fluctuated between 10 and 13 Tg CO_2;
- combustion of natural gas by the oil and gas production industry for heating purposes increased from 2008 until 2013. Between 2013 and 2021, the production of natural gas was reduced by more than 75%, which also resulted in a decrease in the amount of natural gas combusted in this sector;
- high natural gas prices in 2022 resulted in a decrease in natural gas consumption and an increase in coal consumption compared to 2021.

2.3.1.2 Manufacturing industries and construction (1A2)

The main fluctuations in GHG emission in this sector (1A2) can be explained as follows:

- decreasing emissions between 1990 and 2000 were mainly due to a decrease in cogeneration facilities in the industrial sector (category 1A2c Chemicals);
- emissions in the category 1A2 generally follow production in the manufacturing industries. The effect of the economic crisis in 2008 is clearly visible. In 2016 and 2017, emissions increased because of growing economic activities;
- the decrease in GHG emissions in 2018 and 2019 was a result of less natural and residual gas combustion (category 1A2c Chemicals);
- the increase in gaseous and liquid fuel consumption in 2019 and 2020 is because one power plant (using natural gas and chemical waste gas) is now part of a chemical plant. The emissions of this power plant are therefore allocated to 1A1a in the period up to 2019 and to 1A2c in 2020;
- in 2022, there was a large decrease in natural gas consumption compared to 2021, caused by the high prices of natural gas in 2022.

2.3.1.3 Road transport (1A3)

The main fluctuations in GHG emissions in this sector (1A3) can be explained as follows:

- an increase in diesel fuel consumption between 1990 and 2006 resulted in increased emissions in category 1A3b (Road vehicles);
- since 2006, GHG emissions from transport have decreased, while from 2014 till 2020, they have slightly increased again; this is explained by an improving economy with more transport in the 2014-2019 period;
- in 2020, a dip in GHG emissions in the transport sector is clearly visible. This is due to measures taken during the COVID-19 pandemic, resulting in much less road traffic;
- despite the increase in road traffic in 2022, GHG emissions have decreased slightly in 2022 compared to 2021.

2.3.1.4 Other sectors (1A4)

The main fluctuations in GHG emission in this sector (1A4) can be explained as follows:

- substantial interannual fluctuations in emissions are a result of fluctuations in temperature. More natural gas is used during cold winters (e.g. 1996 and 2010) and less in warm winters (e.g. 2014 and 2020).
- In the residential category (1A4b), CO_2 emissions decreased between 1990 and 2020, while the number of households has increased. This is mainly due to improved insulation and increased use of high-efficiency boilers for central heating. In 2022, a large decrease in GHG emissions became evident, which was caused by a decrease in gaseous fuel consumption due to the high natural gas prices (resulting in less heating by households).

2.3.2 Industrial processes and product use

In 2022, IPPU contributed 8.7% to national total GHG emissions (including LULUCF) compared to 11.8% in 1990. The sector is a major source of N_2O emissions, accounting for 9.6% of national total N_2O emissions in 2022.

The main fluctuations in GHG emissions as shown in Figure 2.10 can be explained as follows:

- Category 2B: an increase in emissions of fluorinated gases until 1998, mainly due to increased production of HCFC-22;
- category 2B: a major decrease in emissions of fluorinated gases from 1999 onwards, due to a reduction in HFC-23 emissions from HCFC-22 production;
- category 2B: a decrease in N_2O emissions as a result of the production of nitric acid under EU-ETS regulations.

2.3.3 Agriculture

In 2022, agriculture contributed 11.4% of the national GHG emissions compared to 11.0% in 1990. This sector is a major contributor to national total CH_4 and N_2O emissions; in 2022, agriculture accounted for 71.0% of the total CH_4 emissions and for 72.4% of the total N_2O emissions.

The main fluctuations in GHG emissions in the Agriculture sector as shown in Figure 2.10 can be explained as follows:

- category 3A: Emissions decreased slightly, mainly due to a decrease in CH_4 emissions from cattle;
- category 3D: N_2O emissions have decreased from 1990 onwards, caused by a relatively large decrease in N inputs into soil.

2.3.4 LULUCF

The total net emissions in the LULUCF sector decreased from 5.4 Tg CO_2-eq in 1990 to 5.1 Tg CO_2-eq in 2022. The sector accounts for 3.2% of national total CO_2 equivalent emissions in 2022.

Decreases in CO_2 equivalent emissions in the 1990-2022 period mainly occurred in categories 4B (Cropland) and 4C (Grassland).

Compared to 2021 emissions in the LULUCF sector increased from 4.4 to 5.1 Tg CO_2-eq. This is explained by a sharp decrease in the net CO_2 sink, which is the result of a change in methodology but also due to the real observed decrease in forest carbon sink, based on the latest National Forest Inventory (NFI) data (see Chapter 6).

2.3.5 *Waste*

Between 1990 and 2022, emissions from the Waste sector decreased by 82.0% (from 16.3 Tg CO_2-eq in 1990 to 2.9 Tg CO_2-eq in 2022). This decrease is mainly due to an 86.8% reduction in CH_4 from landfills.

2.3.6 *Precursor gases*

The emissions of carbon monoxide (CO), nitrogen oxides (NO_x), non-methane volatile organic compounds (NMVOC), and sulphur dioxide (SO_2) are also reported in the greenhouse gas inventory as requested by the UNFCCC guidelines. Although these gases are not included in the GWP weighted GHG emission totals, they affect the overall radiative balance of the atmosphere and thus contribute to climate change. Nitrogen oxides, carbon monoxide and NMVOCs can result in an increase in tropospheric ozone concentration, increasing radiative forcing. Sulphur oxides are included because they contribute to sulphate aerosol formation, which has a cooling effect.

The calculation methodologies regarding these emissions are explained in detail in the Netherlands' Informative Inventory Report (Wever et al, 2024), in line with the EMEP guidebook. Figure 2.12 shows the relative emissions trends for carbon monoxide (CO), nitrogen oxides (NO_x), non-methane volatile organic compounds (NMVOC), and sulphur dioxide (SO_2). Table 2.3 provides trend data.

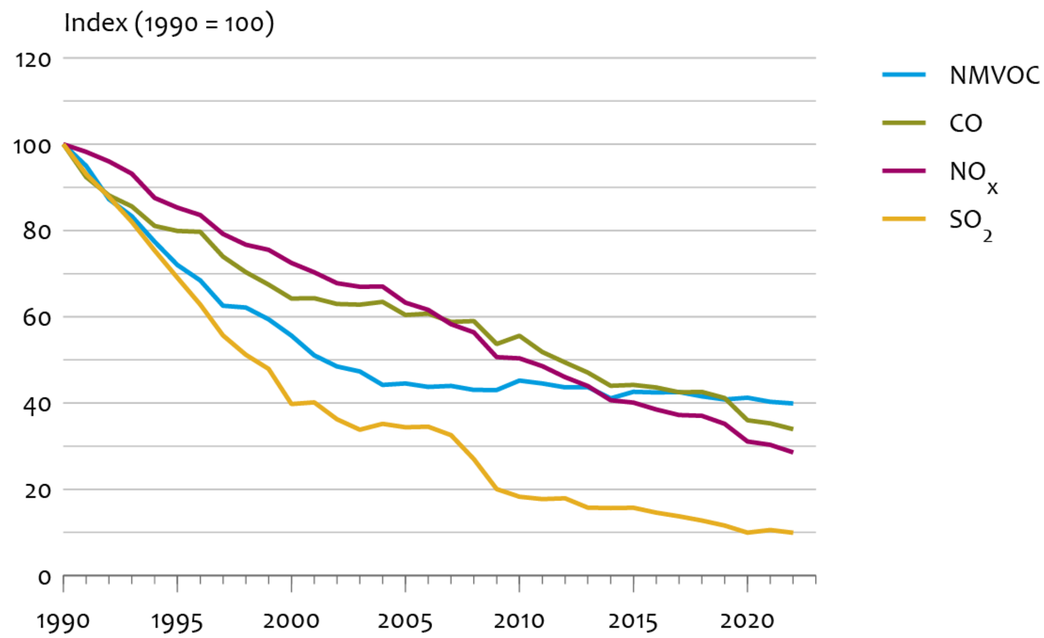


Figure 2.12 Relative emissions trends for NO_x, CO, NMVOC and SO_2 in the Netherlands, 1990-2022. The base year 1990 is set at 100

Table 2.3 Emission trends for indirect GHGs and SO_2 (in Gg)

	1990	1995	2000	2005	2010	2015	2019	2020	2021	2022
Total NO_x	681	581	494	431	343	273	240	212	206	195
Total CO	1,172	936	753	708	651	518	482	422	414	398
Total NMVOC	606	436	337	270	274	258	247	250	244	242
Total SO_2	198	136	79	68	36	31	23	20	21	20

In the 1990-2022 period, emissions of CO, NO_x, NMVOC and SO_2 were reduced by 66%, 71%, 60% and 90%, respectively. With the exception of NMVOC, most of the emissions stem from fuel combustion.

3 Energy (CRF sector 1)

Major changes in the Energy sector compared to the National Inventory Report 2023	
Emissions:	In 2022, GHG emissions related to the Energy sector decreased by 9.0% compared to 2021. The decrease mainly occurred in the other sectors and manufacturing industry due to a decrease in natural gas combustion, as the natural gas prices were much higher in 2022 than in 2021.
New key categories:	1A1a Public Electricity and Heat Production: liquids CO_2
Activity data:	Energy statistics have been updated/improved for the years 2015-2021
other changes:	In response to review recommendation (E.2, 2022) and in line with the IPCC 2006 Guidelines (vol. 3, Chapter 1, box 1.1 and vol. 3, Chapter 3.9.4.2), the emissions from combustion of waste gas by the chemical industry have been reallocated from 1A2c to 2B10.

3.1 Overview of the sector

3.1.1 Energy supply and energy demand

The energy system in the Netherlands is largely driven by the combustion of fossil fuels (Figure 3.1). Natural gas is used most, followed by liquid fuels, except in 2022 when high prices of natural gas resulted in a reduction of the natural gas consumption. In the most recent years, the share of biogenic fuels has been higher than the share of solid fuels. The contribution made by other fuels (waste & nuclear) is relatively small (2-3%).

Part of the supply of fossil fuels is not used for energy purposes but for feed stocks in the (petro-)chemical or fertiliser industries. Emissions from fuel combustion (as reported for the Sectoral Approach in CRF 1A) are consistent with national energy statistics (available via: https://opendata.cbs.nl/statline/#/CBS/en/dataset/83140ENG/table?dl=9F451).

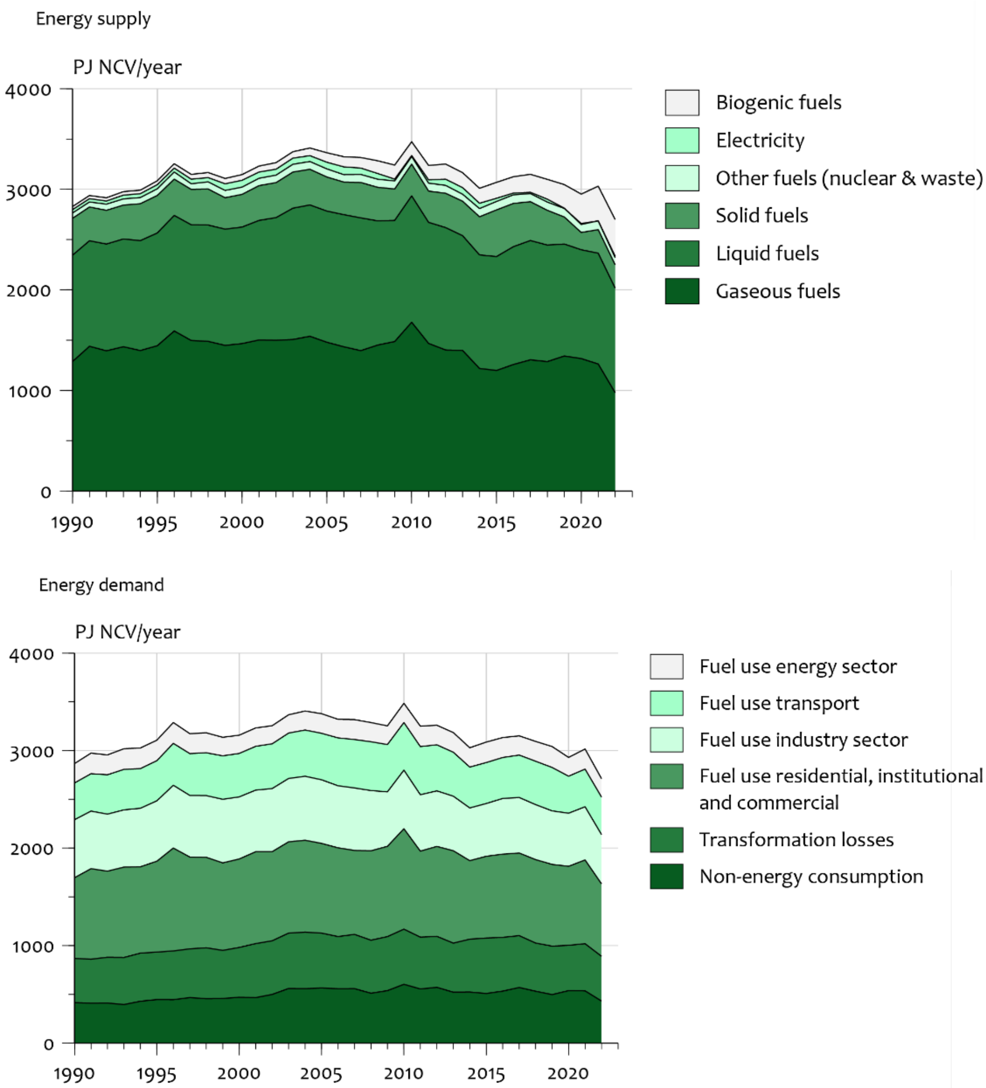


Figure 3.1 Overview of energy supply and energy demand in the Netherlands, 1990–2022, as published by Statistics Netherlands ('Electricity' refers to imported electricity only)

3.1.2 *Trends in fossil fuel use and fuel mix*

Natural gas represents a majority share (>50%) of national energy consumption in all non-transport subsectors: Energy industries, Manufacturing industries and construction and Other sectors (mainly for space heating). Oil products are primarily combusted in transport, refineries and the petrochemical industry, while the use of coal is limited to power generation and steel production.

Between 1990 and 2022, total fossil fuel combustion decreased by 15.5%, due to a 36.9% decrease in solid fuel consumption, a 24.0% decrease in gaseous fuel consumption, and a 1.7% decrease in liquid fuel consumption.
Total fossil fuel consumption for combustion decreased by about 13.1% between 2021 and 2022, due to a decrease by 5.6% for solid fuel combustion, a decrease by 5.6% for liquid fuel combustion, and a decrease by 22.5% for gaseous fuel combustion. The large decrease in

gaseous fuel consumption in 2022 is mainly caused by high prices of natural gas in 2022.
Note that solid fuel consumption showed an increase in 2015 and 2016 caused by three new coal-fired power plants. The decrease in solid fuel consumption between 2016–2020 was due to the closure of old coal-fired power plants. The combustion of solid fuels has increased again in 2021, as a result of the high prices of natural gas.
Winter temperatures have a large influence on gas consumption, as natural gas is used for space heating in most buildings in the Netherlands. 1996 and 2010 both had a cold winter compared to other years, causing an increase in the use of gaseous fuel for space heating. 2014 had a warm winter compared to other years resulting in a decline in the use of gaseous fuel for space heating.

3.1.3 *GHG emissions from the Energy sector*

Table 3.1 shows the emissions in the main categories in the Energy sector. The Energy sector is the prime sector in the Dutch GHG emissions inventory and is responsible for 88% of the total CO_2 emissions in the country, resulting primarily from combustion with a relatively limited amount from fugitive emissions.

Table 3.1 Overview of emissions in the Energy sector in the base year and the last two years of the inventory

Sector/category	Gas	1990	2021	2022	2022 vs 1990	Contribution to total in 2022 (%) by		
		Emissions in Tg CO_2-eq			%	sector	total gas	total CO_2-eq
1 Energy	CO_2	150.7	126.7	115.6	-23.2%	97.9%	87.6%	73.0%
	CH_4	3.2	2.5	2.0	-37.1%	1.7%	10.7%	1.3%
	N_2O	0.3	0.56	0.53	72.4%	0.5%	8.0%	0.3%
	all	154.1	129.8	118.2	-23.3%	100.0%		74.6%
1A Fuel combustion	CO_2	149.8	125.6	114.5	-23.5%	96.9%	86.7%	72.3%
	CH_4	1.0	2.1	1.6	62.9%	1.4%	8.7%	1.0%
	N_2O	0.3	0.6	0.5	72.4%	0.5%	8.0%	0.3%
	all	151.1	128.3	116.7	-22.8%	98.8%		73.6%
1B Fugitive emissions	CO_2	0.9	1.1	1.1	23.8%	0.9%	0.8%	0.7%
	CH_4	2.2	0.4	0.4	-82.5%	0.3%	2.1%	0.2%
	all	3.1	1.5	1.5	-51.8%	1.2%		0.9%
Total national emissions (incl. LULUCF)	CO_2	168.4	143.9	132.1	-21.6%			
	CH_4	36.3	19.1	18.5	-49.0%			
	N_2O	16.1	7.1	6.6	-58.7%			
	Total*	228.1	171.5	158.4	-30.5%			

** including f-gases*

The Energy sector includes:
- use of fuels in stationary and mobile applications;
- conversion of primary energy sources into more usable energy forms in refineries and power plants;
- exploration and exploitation of primary energy sources;
- distribution of fuels.

Key categories are indicated throughout the chapter on (sub)category level.

3.1.4 *Overview of shares and trends in emissions*

Figure 3.2 show the contributions of the subcategories and emissions trends in the Energy sector. Most of the emissions from the energy sector stem from the Energy industries sector (1A1), followed by the Other sectors (1A4).

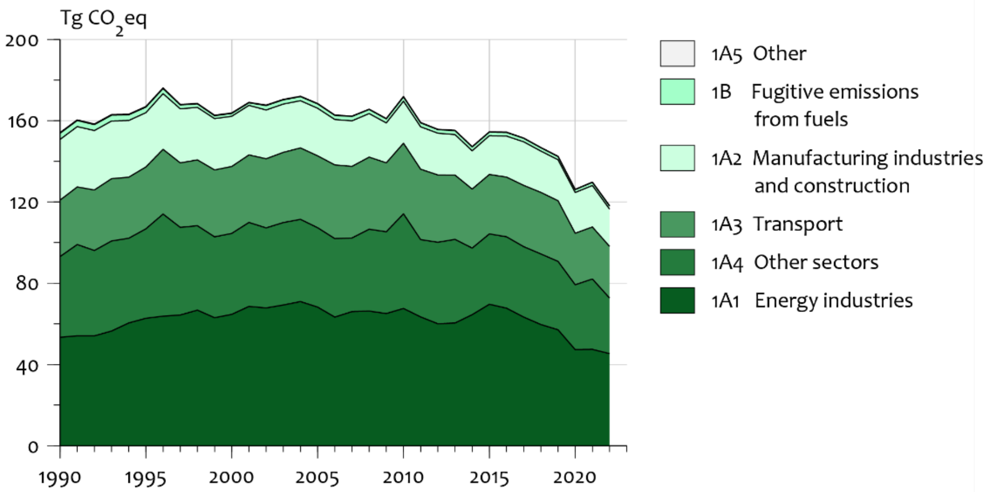


Figure 3.2 Sector 1 Energy – trend and emissions levels of total greenhouse gas emissions per source category, 1990–2022

3.2 Fuel combustion (1A)

Table 3.2 presents the source categories and trend in emissions under category 1A in the Energy sector.

Table 3.2 Overview of emissions in the Fuel combustion sector (1A) in the base year and the last two years of the inventory

Sector/category	Gas	1990	2021	2022	2022 vs 1990	Contribution to total in 2022 (%) by		
		Emissions in Tg CO_2-eq			%	sector	total gas	total CO_2-eq
1A Fuel combustion	CO_2	149.8	125.6	114.5	-23.5%	96.9%	86.7%	72.3%
	CH_4	1.0	2.1	1.6	62.9%	1.4%	8.7%	1.0%
	N_2O	0.3	0.6	0.5	72.4%	0.5%	8.0%	0.3%
	All	151.1	128.3	116.7	-22.8%	98.8%		73.6%
1A1 Energy Industries	CO_2	53.1	47.0	45.0	-15.4%	38.0%	34.0%	28.4%
	CH_4	0.1	0.1	0.1	61.4%	0.1%	0.7%	0.1%
	N_2O	0.1	0.3	0.2	89.5%	0.2%	3.8%	0.2%
	All	53.4	47.4	45.3	-15.0%	38.4%		28.6%
1A2 Manufacturing industries and construction	CO_2	29.8	20.3	18.3	-38.6%	15.5%	13.8%	11.5%
	CH_4	0.1	0.1	0.1	-8.0%	0.1%	0.3%	0.0%
	N_2O	0.0	0.0	0.0	34.5%	0.0%	0.7%	0.0%
	All	29.9	20.4	18.4	-38.5%	15.5%		11.6%
1A3. Transport	CO_2	27.5	25.3	25.2	-8.5%	21.3%	19.0%	15.9%
	CH_4	0.2	0.1	0.1	-68.7%	0.1%	0.3%	0.0%
	N_2O	0.1	0.2	0.2	95.0%	0.2%	2.8%	0.1%
	All	27.8	25.6	25.4	-8.6%	21.5%		16.0%
1A4. Other sectors	CO_2	39.1	32.8	26.0	-33.5%	22.0%	19.7%	16.4%
	CH_4	0.6	1.8	1.4	113.2%	1.1%	7.3%	0.9%
	N_2O	0.0	0.1	0.1	14.1%	0.0%	0.8%	0.0%
	All	39.7	34.7	27.4	-31.1%	23.2%		17.3%
1A5 Other	CO_2	0.3	0.2	0.2	-32.6%	0.2%	0.2%	0.1%
	CH_4	0.0	0.0	0.0	-44.1%	0.0%	0.0%	0.0%
	N_2O	0.0	0.0	0.0	-42.9%	0.0%	0.0%	0.0%
	All	0.3	0.2	0.2	-32.8%	0.2%		0.1%

3.2.1 Comparison of the Sectoral Approach with the Reference Approach

Emissions from fuel combustion are estimated by multiplying fuel quantities combusted through specific energy processes by fuel-specific emission factors (EFs) and, in the case of non-CO_2 GHGs, source category-dependent EFs. This Sectoral Approach (SA) is based on actual fuel demand statistics. The IPCC Guidelines also require – as a quality control activity – the estimation of CO_2 emissions from fuel combustion on the basis of a national carbon balance derived from fuel supply statistics. This is the Reference Approach (RA). This section gives a detailed comparison of the SA with the RA.

Energy supply balance

Table 3.3 presents the energy supply balance of fossil fuels for the Netherlands in 1990 and 2022 at a relatively high aggregation level. The Netherlands used to produce large amounts of natural gas, both onshore (Groningen gas) and offshore. A large share of the gas produced was exported. Due to earthquakes in Groningen caused by natural gas extraction, the production has been reduced since 2014. More natural gas has been imported. Natural gas represents a major share of the national energy supply.

Table 3.3 Energy supply balance for the Netherlands (PJ NCV/year) as reported in CRF table 1.A(b)

Year	Role	Indicator name	Solid fuels	Liquid fuels	Gaseous fuels
1990	Supply	Primary production	0	170	2,283
		Total imports	390	3,811	85
		Stock change	2	13	-0
		Total exports	-25	-2,422	-1,081
		Bunkers	0	-530	0
	Consumption	Gross inland consumption	-367	-1,043	-1,287
		whereof: Final non-energy consumption	-11	-324	-95
2022	Supply	Primary production	0	20	539
		Total imports	241	6,288	1,170
		Stock change	-5	-168	-193
		Total exports	-5	-4,529	-535
		Bunkers	0	-595	0
	Consumption	Gross inland consumption	-231	-1,016	-981
		whereof: Final non-energy consumption	1	-362	-68

Comparison of CO_2 emissions
The IPCC Reference Approach (RA) uses apparent consumption data (gross inland consumption) per fuel type to estimate CO_2 emissions from fossil fuel use. This approach is used as a means of verifying the sectoral total CO_2 emissions from fuel combustion (IPCC, 2006). The RA uses Eurostat energy statistics (production, imports, exports, stock changes and bunkers) to determine apparent fuel consumption, which is then combined with carbon EFs to calculate carbon content of the fuels. Non-combusted carbon used as feedstock, as a reductant, or for other non-energy purposes is then deducted.
The Eurostat energy statistics for the Netherlands are based on the national energy statistics as provided by Statistics Netherlands, but the level of aggregation is sometimes different. The fuels from the Eurostat energy statistics are allocated to the fuels in the RA, as presented in Table 3.4. National default, partly country-specific, CO_2 EFs are adopted from Zijlema (2024) (see Annex 5).

Table 3.4 Relation between fuel types in RA and in Dutch energy statistics

Fuel types in the Reference Approach			**Fuel types in the Eurostat energy statistics**
Liquid fossil	Primary fuels	Crude oil	Crude oil
		Orimulsion	NO [1)]
		Natural gas liquids	Natural gas liquids
	Secondary fuels	Gasoline	Additives and oxygenates (excluding biofuel portion) Gasoline-type jet fuel Motor gasoline (excluding biofuel portion) Aviation gasoline
		Jet kerosene	Kerosine-type jet fuel (excluding biofuel portion)
		Other kerosene	Other kerosene
		Shale oil	NO [1)]
		Gas/diesel oil	Gas oil and diesel oil (excluding biofuel portion)
		Residual fuel oil	Fuel oil
		Liquefied petroleum gases (LPG)	Liquified petroleum gases
		Ethane	IE [3)]
		Naphtha	Naphtha
		Bitumen	Bitumen
		Lubricants	Lubricants
		Petroleum coke	Petroleum coke
		Refinery feedstocks	Refinery feedstocks
		Other oil	Paraffin waxes Other oil products n.e.c Refinery gas White spirit and special boiling point industrial spirit
Solid fossil	Primary fuels	Anthracite	Anthracite
		Coking coal	Coking coal
		Other bituminous coal	Other bituminous coal
		Sub-bituminous coal	IE [2)]
		Lignite	Lignite
		Oil shale and tar sand	NO [1)]

Fuel types in the Reference Approach			**Fuel types in the Eurostat energy statistics**
	Secondary fuels	BKB and patent fuel	Brown coal briquettes Patent fuel
		Coke oven/gas coke	Coke oven coke Gas coke
		Coal tar	Coal tar
Gaseous fossil		Natural gas (dry)	Natural gas
Waste (non-biomass fraction)		Other	Non-renewable municipal waste Industrial waste (non-renewable)
Peat			NO [1)]
Biomass total		Solid biomass	Primary solid biofuels Charcoal
		Liquid biomass	Pure biogasoline Blended biogasoline Pure biodiesels Blended biodiesels Pure bio jet kerosene Blended bio jet kerosene Other liquid biofuels
		Gas biomass	Biogases
		Other non-fossil fuels (biogenic waste)	Renewable municipal waste

Notes:
1. NO = Not occurring; orimulsion, shale oil, oil shale and tar sand and peat are not used in the Netherlands.
2. IE = included elsewhere; sub-bituminous coal is included in other bituminous coal.
3. IE = included elsewhere; ethane is included in LPG.

Table 3.5 presents the results of the RA calculations for the 1990-2022 period, compared with the official national total emissions reported as fuel combustion (SA, source category 1A). The annual difference calculated from the direct comparison ranges between -0.6% and +7.9%.

Table 3.5 Comparison of CO_2 emissions: RA versus SA (in Tg)

	1990	1995	2000	2005	2010	2015	2020	2021	2022
Reference Approach									
Liquid fuels	49.2	52.4	52.7	54.9	53.1	47.4	42.7	45.8	45.7
Solid fuels	33.4	34.2	30.1	31.4	29.4	43.6	15.9	21.7	21.5
Gaseous fuels	67.7	76.3	77.5	78.6	87.5	62.1	68.7	65.2	51.6
Other fuels	0.6	0.9	1.5	2.2	2.5	2.8	2.7	2.8	2.6
Total RA	150.9	163.8	161.8	167.1	172.6	155.9	130.0	135.6	121.4
	1990	**1995**	**2000**	**2005**	**2010**	**2015**	**2020**	**2021**	**2022**
Sectoral Approach									
Liquid fuels	45.7	50.1	51.9	51.6	46.4	41.2	35.8	36.5	37.8
Solid fuels	33.6	34.2	29.9	31.7	29.9	42.9	16.2	21.9	21.5
Gaseous fuels	69.9	77.4	77.3	79.2	88.2	63.4	67.6	64.5	52.5
Other fuels	0.6	0.8	1.6	2.1	2.5	2.9	2.8	2.7	2.7
Total SA	149.8	162.5	160.7	164.5	167.0	150.4	122.3	125.6	114.5
	1990	**1995**	**2000**	**2005**	**2010**	**2015**	**2020**	**2021**	**2022**
Difference (%)									
Liquid fuels	7.7%	4.6%	1.7%	6.5%	14.5%	14.9%	19.2%	25.6%	20.8%
Solid fuels	-0.4%	-0.1%	0.7%	-1.1%	-1.8%	1.6%	-1.5%	-0.8%	-0.1%
Gaseous fuels	-3.2%	-1.4%	0.2%	-0.7%	-0.7%	-2.0%	1.6%	1.1%	-1.7%
Other fuels	1.3%	5.6%	-5.7%	4.5%	0.6%	-2.7%	-2.5%	4.4%	-2.4%
Total	0.8%	0.8%	0.7%	1.5%	3.3%	3.6%	6.3%	7.9%	6.0%

Differences between the RA and the SA are due to four factors:

- In response to review recommendation (E.2 2022) and in line with the IPCC 2006 Guidelines (vol. 3, chapter 1, box 1.1 and vol. 3, chapter 3.9.4.2), the emissions from combustion of chemical waste gas in the chemistry sector have been reallocated from 1A2c to 2B10. However, these emissions actually result from the combustion of fuels, and are also included in the energy statistics as fuel combustion. Chemical waste gas combustion is responsible for 4.0 – 7.9 Mton CO_2, which is now included in CRF 2B10. If the emissions of chemical waste gas would be included in the energy sector, the Sectoral Approach emissions would be 4.0 – 7.9 Mton CO_2 higher, and the difference between the sectoral approach and the reference approach would range between -1.9% and +1.9% for the years from 1995 onwards. For the 1990-1994 period, the difference would be higher (between -2.9% and -6.0%).
- There is a 'statistical difference' in the energy statistics, responsible for approximately 1-2% of the RA total in 1990-1994 and 1996-1997, and 0-1% for 1995 and again from 1998 onwards. The difference between RA and SA in 1990 (following correction for chemical waste gas allocation) is for a large part

due to the statistical difference, which is -3.0% for gaseous fuels and -1.3% for liquid fuels.

- In the SA, company-specific EFs are used, while country-specific EFs are used in the RA.
- The energy statistics contain production data for chemical waste gas and additives. This data cannot be included in the RA tables and is therefore excluded from the RA (while combustion of these fuels is included in the SA). As a result, the CO_2 emissions from liquid fuels in the RA are slightly underestimated.

3.2.2 International bunker fuels (1D)

3.2.2.1 Source category description

Figure 3.3. shows that jet kerosene consumption (used in international aviation) more than doubled between 1990 and 1999, and increased slowly between 2000 and 2019 (with the exception of the 2008-2012 period, when the economic crisis resulted in a decrease in fuel deliveries). In 2020 and 2021, the jet kerosene consumption decreased as a result of measures taken during the COVID-19 pandemic.
No deliveries of aviation gasoline or biogenic fuels for international aviation are reported in the Energy Balance.

Fuel deliveries for international navigation (residual fuel oil, gas/diesel oil, LNG and biodiesel) increased by 57% between 1990 and 2007, but then decreased by 30% to 479 PJ in 2022. In the 2008–2012 period, this decrease can mainly be attributed to the economic crisis. Fuel deliveries have, however, continued to decrease in recent years, even though the economy and transport volumes have grown. The continued decrease can be attributed partially to more fuel-efficient shipping (resulting, for instance, from lower sailing speed, as shown by Marin, 2019) and partially to the decreased share of Dutch ports in the Northwest European bunker market.
Deliveries of diesel oil for international maritime navigation almost doubled between 2014 and 2015, which can be attributed to more stringent regulation on sulphur oxide emissions from ships in the North Sea.

Deliveries of lubricants for international navigation increased from 3.8 PJ in 1990 to 7.1 PJ in 2001, followed by a decrease to 3.2 PJ in 2009 (economic crisis), followed by an increase to 4.7 PJ in 2022.

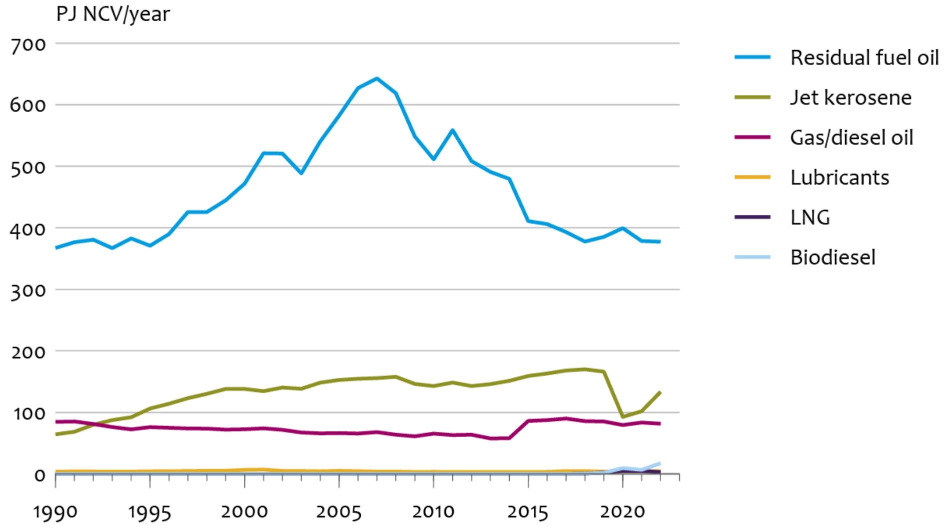


Figure 3.3 Marine and aviation bunker fuels, 1990–2022, as reported in CRF table 1.D (from Statistics Netherlands)

3.2.2.2 Methodological issues

As described in Geilenkirchen et al. (2024), CO_2 emissions from bunker fuels are calculated using a Tier 1 and 2 approach. Default IPCC heating values and CO_2 EFs are used for heavy fuel oil, jet kerosene, and lubricants, whereas country-specific heating values and CO_2 EFs are used for diesel oil derived from the Netherlands' list of fuels (Zijlema, 2024). CH_4 and N_2O emissions resulting from the use of bunker fuels are calculated by means of a Tier 1 approach, using default IPCC EFs for both substances (IPCC Guidelines, Volume 2, Chapter 3, tables 3.5.3 and 3.6.5).

3.2.2.3 Category-specific recalculations

The energy statistics have been updated for a few fuels/years:

- LNG (international navigation): The fuel consumption of LNG has been updated for 2017 and 2018, resulting in an increase in LNG consumption by 3% (5 TJ) in 2017 and a decrease by 2% (9 TJ) in 2018.
- Gas/diesel oil and biodiesel (international navigation) has been reallocated from biodiesel to gas/diesel oil: in 2020, 3% of the gas/diesel oil (2.4 PJ) and in 2021, 5% (4.2 PJ).

This updated activity data is used to calculate the emissions of CO_2, CH_4 and N_2O.

3.2.3 Feed stocks and non-energy use of fuels

Table 3.3 shows that a large share of the gross national consumption of petroleum products was due to non-energy applications. These fuels were mainly used as feedstock in the petrochemical industry (naphtha), and the carbon is stored in many products (bitumen, lubricants, etcetera). A fraction of the gross national consumption of natural gas (mainly in ammonia production) and coal (Iron and steel production, Food processing) was also used in non-energy applications, and hence this gas/coal was not directly oxidised. In many cases, these products are finally oxidised in waste incinerators or during use (e.g. lubricants in two-stroke engines). In the RA, these product flows are excluded from the calculation of CO_2 emissions.

3.2.4 Energy industries (1A1)

3.2.4.1 Category description

Table 3.6 provides an overview of the emissions in the Energy industries sector (1A1) as well as for the key categories. Figure 3.4 presents the development of total GHG emissions by sub-category of the energy industries, in the years 1990-2022.

Table 3.6 Overview of emissions in the energy industries sector (1A1) in the base year and the last two years of the inventory

Sector/category	**Gas**	**1990**	**2021**	**2022**	**2022 vs 1990**	**Contribution to total in 2022 (%) by**		
		Emissions in Tg CO_2-eq			**%**	**sector**	**total gas**	**total CO_2-eq**
1A1 Energy Industries	CO_2	53.1	47.0	45.0	-15.4%	38.0%	34.0%	28.4%
	CH_4	0.1	0.1	0.1	61.4%	0.1%	0.7%	0.1%
	N_2O	0.1	0.3	0.2	89.5%	0.2%	3.8%	0.2%
	All	53.4	47.4	45.3	-15.0%	38.4%		28.6%
1A1a Public Electricity and Heat Production, total	CO_2	40.0	35.0	33.2	-17.2%	28.1%	25.1%	20.9%
1A1a liquids	CO_2	0.2	0.3	0.5	98.2%	0.4%	0.3%	0.3%
1A1a solids	CO_2	25.9	16.7	16.5	-36.3%	13.9%	12.5%	10.4%
1A1a gas	CO_2	13.3	15.3	13.5	1.6%	11.5%	10.3%	8.5%
1A1a other fuels	CO2	0.6	2.7	2.7	343.4%	2.3%	2.0%	1.7%
1A1b. Petroleum refining, total	CO_2	11.0	9.5	9.4	-14.3%	8.0%	7.1%	6.0%
1A1b liquids	CO_2	10.0	6.9	8.3	-17.0%	7.0%	6.3%	5.2%
1a1b gases	CO_2	1.0	2.5	1.2	10.9%	1.0%	0.9%	0.7%
1A1c Manufacture of Solid Fuels and Other Energy Industries, total	CO_2	2.1	2.5	2.4	12.3%	2.0%	1.8%	1.5%
1A1c solids & liquid	CO_2	0.9	1.2	1.3	38.4%	1.1%	1.0%	0.8%
liquids	CO_2	0.0	0.0	0.0	-100.0%	0.0%	0.0%	0.0%
solids	CO_2	0.9	1.2	1.3	39.9%	1.1%	1.0%	0.8%
1A1c gases	CO_2	1.2	1.3	1.1	-8.1%	0.9%	0.8%	0.7%

In line with the IPCC Guidelines (see volume 1, Table 4.1 in IPCC, 2006), aggregated emissions by fuel type and category are used for the categorisation of key categories in 1A1 (the same approach is used for 1A2, 1A3 and 1A4). On that basis, category 1A1 comprises the following key categories:

1A1	Energy Industries: all fuels	N_2O
1A1a	Public Electricity and Heat Production: liquids	CO_2
1A1a	Public Electricity and Heat Production: solids	CO_2
1A1a	Public Electricity and Heat Production: gaseous	CO_2
1A1a	Public Electricity and Heat Production: other fuels: waste incineration	CO_2
1A1b	Petroleum Refining: liquids	CO_2
1A1b	Petroleum Refining: gaseous	CO_2
1A1c	Manufacture of Solid Fuels: solids	CO_2
1A1c	Manufacture of Solid Fuels: gaseous	CO_2

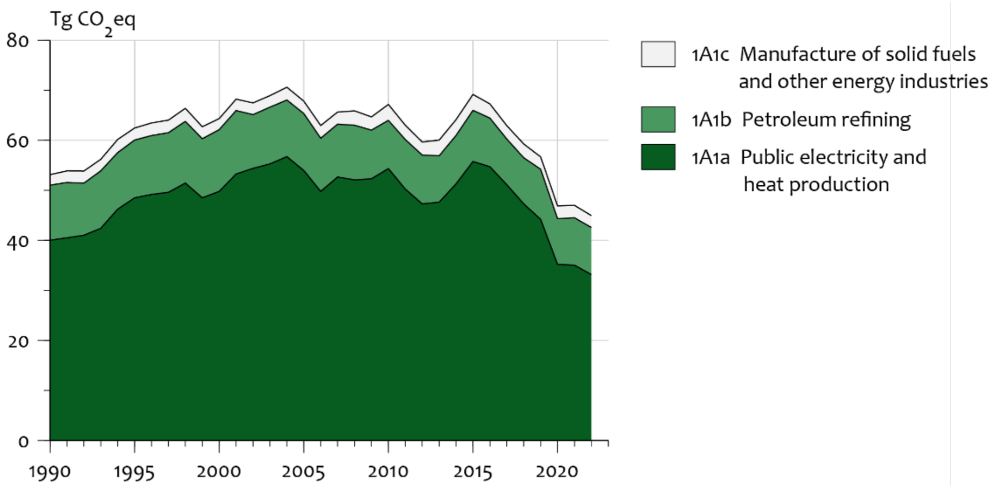


Figure 3.4 1A1 Energy industries – trend in total GHG emission by sub-category, 1990–2022

Public electricity and heat production (1A1a)
The Dutch electricity sector mainly consist of gas and coal-fired power stations and gas-fired cogeneration plants (combined heat and power, CHP). Many of the gas-fired cogeneration plants are operated as joint ventures with industries. The increasing trend in electric power production until 2005 corresponds to a substantial increase in CO_2 emissions from fossil fuel combustion by power plants (see Figure 3.4). The decreasing trend of CO_2 between 2016 and 2020 is the result of a decline in coal combustion caused by the closure of coal-fired power plants, and an increase in renewable energy.

Compared to other countries in the EU, nuclear power and renewable energy were only responsible for a small share of the electricity production in the Netherlands, but this increased to 3% and 40% respectively of the total electricity production in 2022 (as reported by Statistics Netherlands in:
https://opendata.cbs.nl/#/CBS/en/dataset/80030eng/table?dl=76A65).
The main renewable energy sources for electricity production are wind, biomass and solar.
The public electricity and heat production source sub-category also includes all emissions from large-scale waste incineration facilities. Since all these incineration facilities produce heat and/or electricity, the emissions from waste incineration are allocated in 1A1a and the waste

incinerated in these installations is allocated under other fuels (fossil part of waste) and biomass (biogenic part of waste).
In addition, a large proportion of blast furnace gas and a significant part of coke oven gas produced by the single iron and steel plant in the Netherlands is combusted in the public electricity sector (see Figure 3.5; BF/OX/CO/FO refers to blast furnace gas, oxygen furnace gas, coke oven gas, and phosphor oven gas).

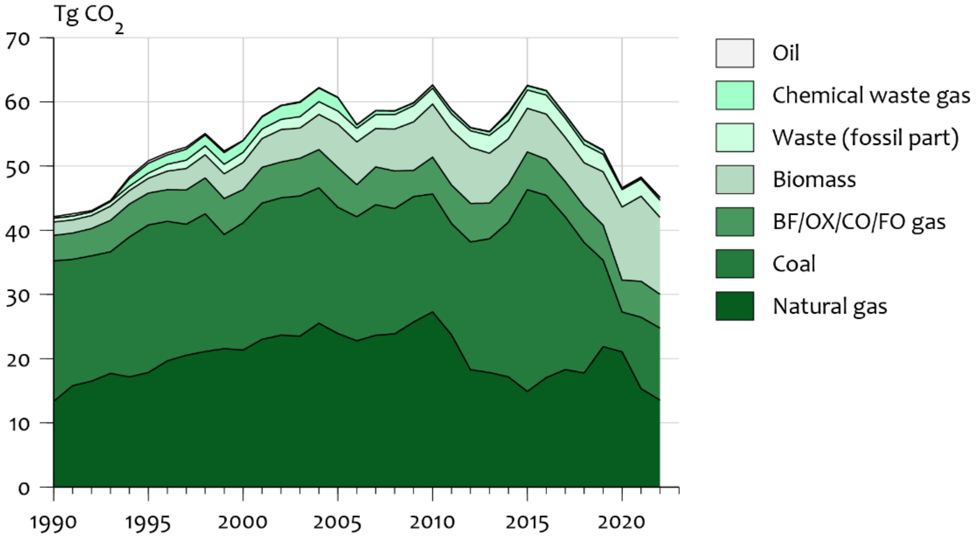


Figure 3.5 Trend in CO_2 emissions from fossil and biogenic fuel use in power plants, 1990–2022

Waste oils (waste oil, waste lubricant, waste solvent, etcetera) are collected by certified waste management companies. Until 2002, waste oils were used in the preparation of bunker fuels. Since then, this use has been prohibited for environmental reasons, and waste oils are now either exported to Germany or recycled. The recycling part of waste oils (feedstock for chemical plants, clean-up and or distillation) results in small fractions of non-useable wastes. In the past, these were incinerated in a special combustion facility in the Netherlands (at that time, they were reported under 1.A.1.a, as plant-recovered waste heat). Since the closure of this plant, which reported its emissions and activity data directly to the inventory, the residues have been exported for ecological processing, and the resulting foreign emissions are no longer included in the Dutch inventory.

Most of the biogas combustion recovered at landfill sites occurs in combined heat and power (CHP) plants operated by utilities; therefore, these emissions are also allocated to 1A1a.

CO_2 emissions from the waste incineration of fossil carbon increased from 1990 until 2017. Since then, these emissions have declined. From 1990 onwards, an increasing amount of waste has been combusted rather than deposited in landfills, the result of environmental policy aimed at reducing waste disposal in landfills as well as at the import of waste (see Chapter 7). The increase in the CO_2 EF for other fuels between 2004 and 2010 was due to the increase in the share of plastics (with a high carbon content) in combustible waste.

The decrease in the implied emission factor (IEF) for CO_2 from biomass in the 1990-2000 period is due to the increase in the share of pure biomass co-combusted with coal-firing, which has a lower EF than the organic carbon in waste combustion with energy recovery.

Between 1990 and 1998, a change in the ownership structures of plants (joint ventures) caused a shift of cogeneration plants from category 1A2 (Manufacturing industries and construction) to 1A1a (Public electricity and heat production). This shift largely explains the increase in natural gas combustion in 1A1a between 1990 and 1998. A similar shift occurred for a few large chemical waste gas-fired steam boilers. The corresponding CO_2 emissions allocated to the Energy sector increased from virtually zero in 1990 to 8.5 Tg in 1998 and to 9.1 Tg in 2005.The strong increase in liquid fuel use in 1994 and 1995 was due to the use of chemical waste gas (which is included in liquid fuels) in joint venture electricity and heat production facilities. This also explains the somewhat lower IEF for CO_2 from liquids since 1995, because the EF for chemical waste gas is lower than the EF for other liquid fuels.

Figure 3.5 shows a fluctuation in CO_2 emissions in 1A1a due to market circumstances. Other influencing factors have been:

- an increase in natural gas combustion due to a change in ownership structures of plants which resulted in a shift of natural gas combustion from 1A2 to 1A1a in 1990–1998;
- new, large coal-fired power plants commencing operations in 2015 and 2016 resulted in a shift from natural gas to coal;
- closure of old coal-fired power plants in 2015–2019 has resulted in a decrease in coal consumption from 2017 onwards;
- high natural gas prices in 2022 resulted in a decrease in natural gas consumption and an increase in coal consumption;
- In some years, the import of electricity was higher (e.g. 1999–2008, 2012–2014) than in others.

Petroleum refining (1A1b)
There are five large refineries in the Netherlands; they export a large part of their products to the European market. Consequently, the Dutch petrochemical industry is relatively large.
1A1b is the second largest emission source sub-category in category 1A1. The combustion emissions from this sub-category should be viewed in relation to the fugitive emissions reported under category 1B2. From 1990 to 2022, total CO_2 emissions from the refineries (as reported in 1A1b and1B2a-iv) fluctuated between 10 and 13 Tg CO_2.

Since 1998, one refinery has operated a Shell Gasification and Hydrogen Production (SGHP) unit, supplying all the hydrogen for a large-scale hydrocracker. The chemical processes involved in the production of hydrogen also generate CO_2 (CO_2 removal and a two-stage CO shift reaction). Refinery data specifying these fugitive CO_2 emissions is available and has been used since 2002. It is reported in the category 1B2. Combustion emissions reported in this category are calculated by subtracting the carbon for this non-combustion process from the total fuel use in this category.

The use of plant-specific EFs for refinery gas from 2002 onwards has also caused a change in the IEF for CO_2 emissions from total liquid fuel compared to the years prior to 2002. The EF for refinery gas is adjusted to ensure exact correspondence between the total CO_2 emissions calculated and the total CO_2 emissions officially reported by the refineries.
The interannual variation in the IEFs for CO_2, CH_4 and N_2O emissions from liquid fuels is explained by the high and variable proportion (between 40% and 90%) of refinery gas in total liquid fuel. Refinery gas has a low default EF compared to most other oil products and has shown variable EFs for the years from 2002 onwards.

Manufacture of solid fuels and other energy industries (1A1c)
Source sub-category 1A1c comprises:

- 1A1ci: Fuel combustion (of solid fuels) for on-site coke production by the iron and steel plant Tata Steel and fuel combustion from an independent coke production facility (Sluiskil, which ceased operations in 1999).
- 1A1cii: Combustion of 'own' fuel (natural gas) by the oil and gas production industry for heating purposes: the difference between the amounts of fuel produced and sold, minus the amounts of associated gas that are flared, vented, or lost by leakage.

Fuel combustion emissions from coke production (1A1ci) by the iron and steel plant are based on a mass balance. See section 3.2.5.1 for more information on emissions from the iron and steel sector, including emissions from coke production.

CO_2 emissions from 1A1cii increased from 2008 till 2013. The increase is mainly due to the operation of less productive sites for oil and gas production compared to those operated in the past. This explains the steady increase over time in this category with respect to gas consumption. Between 2013 and 2022, the production of natural gas declined by 79%, which also resulted in a decrease in the amount of natural gas combusted in this sector. The interannual variability in the EFs for CO_2 and CH_4 emissions from gas combustion (non-standard natural gas) is mainly due to differences in gas composition and the variable losses in the compressor stations of the gas transmission network, reported in the Annual Environmental Reports (AERs) of the gas transport company.
Liquid fuels are generally not used in 1A1c; only a small amount of liquid fuels was used until 2013. From 2014 onwards, no liquid fuel use has been registered in the energy statistics for this sub-sector.

3.2.4.2 Methodological issues

This section provides a description of the methodology to calculate emissions from stationary combustion in the energy industries. This section is split into two parts: First, a description of the stationary combustion of all sectors except waste incineration, followed by a description on the methodology for waste incineration.
Details of methodologies, data sources, and country-specific source allocation issues are provided in section 2.1 (stationary combustion excluding waste incineration) and section 2.3.2.1 (waste incineration) of the ENINA methodology report (Honig et al., 2024).

Methodology for all sectors except waste incineration
The emissions from this source category are calculated in two steps: First, emissions are calculated by multiplying fuel consumption by country-specific EFs. Second, reported emissions of a select number of companies are used to refine the emissions calculation. The following section provides a description of these two steps as well as a comparison of the country-specific EFs and the IEFs (including an explanation of the differences).

Emissions calculation step 1
The first step of the emissions calculation consists of a multiplication of fuel consumption by country-specific EFs.
Activity data is derived from the aggregated statistical data from national energy statistics published annually by Statistics Netherlands (see https://opendata.cbs.nl/statline/#/CBS/en/dataset/83140ENG/table?dl=5FD79). The aggregated statistical data is based on confidential data from individual companies. When necessary, emissions data from individual companies is also used; for example, when companies report a different EF for derived gases (see the following section, Emissions calculation step 2).
Emission factors are either IPCC default or country-specific EFs (Tier 1 and Tier 2 method for CO_2, Tier 2 method for CH_4, and Tier 1 method for N_2O). For CO_2, IPCC default EFs are used (see Annex 5) with the exception of CO_2 from natural gas, coal, cokes, waste, waste gases, gas/diesel oil, gasoline, LPG, liquid biomass, and gaseous biomass, for which country-specific EFs are used. The CH_4 EFs are adopted from Scheffer (1997), except for the use of natural gas in gas engines and for waste. See section 2.1 of the ENINA methodology report (Honig et al., 2024) for more details on the CH_4 EF for gas engines. For N_2O, IPCC default EFs are used, except for waste and for solid fuels from the combined iron and steel plant.
A complete overview of the EFs is presented in section 2.1 of the ENINA methodology report (Honig et al., 2024).

Emissions calculation step 2
In the second step, the reported emissions of selected companies are used to refine the emissions calculation. Emissions data from individual companies (as reported in the AER and/or ETS reports) is used if companies report a different CO_2 EF for derived gases or other bituminous coal. The reported emissions data is validated by the competent authority. If this data is not accepted by the competent authority, the CO_2 emissions data is not used for the emissions inventory; country-specific EFs are used instead. This has occurred only occasionally, and the emissions are recalculated when the validated data from these companies becomes available.
For each relevant company, data from the AERs and the ETS is compared (QC check) and the data that provides greater detail for the relevant fuels and installations is used. The reported CO_2 emissions of a company are combined with energy use as recorded in energy statistics for that specific company, to derive a company-specific EF. For each selected company, a different company-specific EF is derived and used to calculate the emissions.
The following company-specific EFs have been calculated:

- Natural gas: Since 2003, company-specific EFs have been derived for the combustion of 'raw' natural gas (i.e. unprocessed natural

gas). For the years prior to 2003, EFs from the Netherlands' list of fuels (Zijlema, 2024) are used.
- Refinery gas: Since 2002, company-specific EFs have been derived for all companies and are used in the emissions inventory. For the years prior to 2002, EFs from the Netherlands' list of fuels (Zijlema, 2024) are used.
- Chemical waste gas: Since 1995, company-specific EFs have been derived for a selection of companies (largest companies). For the remaining companies, the default EF is used. If data from any of the selected companies was missing, a company-specific EF for the missing company was used (derived in 1995). For the 1990–1994 period, a country-specific EF based on an average EF for four (large) companies has been used.
- Coke oven gas: Since 2007, company-specific EFs have been derived for most companies. As coke oven gas is produced only at the single iron and steel company in the Netherlands, it is assumed that all coke oven gas has the same content, and the derived EF is used for all companies that use coke oven gas. For years prior to 2007, EFs from the Netherlands' list of fuels (Zijlema, 2024) are used.
- Phosphorus gas: Since 2006, company-specific EFs have been derived for the single company and are used in the emissions inventory. For years prior to 2006, EFs from the Netherlands' list of fuels (Zijlema, 2024) are used. This fuel was only used until 2012, when the single company using this fuel has ceased operation.
- Coal: Since 2006, company-specific EFs have been derived for most companies (for the power plants that report a reliable company-specific EF), and the default EFs are used for the remaining companies. For years prior to 2006, EFs from the Netherlands list of fuels (Zijlema, 2024) are used.
- Coke oven/gas coke (cokes): Since 2006, a company-specific EF has been derived for one company. For the other companies, a country-specific EF is used. For the years prior to 2006, a country-specific EF is used for all companies.

Methodology for waste incineration
Detailed information on activity data and EFs (waste incineration in WIPs) can be found in section 2.3.2.1 in Honig et al. (2024).

The activity data for the amount of waste incinerated derives mainly from the annual survey performed by the WAR at all 14 waste incinerators in the Netherlands. Data can be found in a background document (Rijkswaterstaat, 2024). The waste incineration plants process a small portion of hazardous waste (100-150 kilotonnes). Examples are certain organic liquids from the chemical industry, cleaning cloths contaminated with oil and/or solvents and oil filters. Other hazardous waste is incinerated abroad (mainly in north-western Europe) in rotary kilns. Hospital waste is almost always incinerated in a special facility, see Appendix C-5 of the aforementioned report. This installation processes approximately 10 kilotonnes of hospital waste. Fossil-based and biogenic CO_2, CH_4 and N_2O emissions from waste incineration are country-specific (Tier 2) and are calculated from the total amount of waste incinerated by waste stream. For some waste streams, the composition is updated annually, on the basis of analyses of household residual waste. Table 3.7 presents the total amounts of waste incinerated in terms of mass, energy, the fraction of biomass in energy, and the corresponding amounts of fossil and biogenic carbon in the total waste incinerated. The variations in annual emissions arise from the variations in the composition of the various waste streams.

Table 3.7 Composition of incinerated waste

	1990	2000	2005	2010	2015	2020	2021	2022
Total waste incinerated (Gg)	2,780	4,896	5,503	6,459	7,564	7,572	7,504	7,392
Total waste incinerated (TJ)	22,746	51,904	55,058	63,818	75,299	71,742	70,605	69,762
Energy content (MJ/kg)	8.2	10.6	10.0	9.9	10.0	9.5	9.4	9.4
Fraction biomass (energy %)	58.2	50.4	47.8	53.1	54.2	53.5	53.7	53.7
Amount of fossil carbon (Gg)	164	433	561	675	780	739	728	727
Amount of biogenic carbon (Gg)	544	938	909	1,172	1,381	1,343	1,333	1,316

Fossil-based CO_2 is calculated on the basis of the fossil-based carbon content of the incinerated waste. The fossil-based carbon content is calculated on the basis of the carbon content of the various components in the various waste streams. As stated above, for some waste streams the composition is updated annually.

The capture of carbon in a product is taken into account in the CO_2 emissions of WIPs. In earlier years, the amount of carbon capture was insignificant and in 2022, this amount is still low; less than 1 kton of CO_2 (fossil and biogenic) was captured and used in the production of bicarbonate.

Several Dutch WIPs capture CO_2. There is no clear guidance from IPCC on how to account for usage of captured CO_2 in the inventory. The Netherlands deals with this in two lines of potential application of the carbon captured:

- *use as growth medium in agriculture*. As most of the CO_2 will ultimately be emitted to the atmosphere, this amount is not subtracted from the produced CO_2;
- *use as raw material in the production of bicarbonate*. The captured amount is subtracted from the produced CO_2.

The data on the amount and type of usage comes from the annual survey of WIPs (Rijkswaterstaat, 2024). Detailed information can be found in Honig et al. (2024).

On the basis of measurement data (Spoelstra, 1993), an EF of 20 g/ton waste is applied to N_2O from incineration with selective catalytic reduction (SCR). For incineration with selective non-catalytic reduction (SNCR), an EF of 100 g/ton is applied. The percentage of SCR has increased significantly since 1990.

A survey of EFs for CH_4 used in other countries and an analysis of emissions from waste incinerators in the Netherlands made it clear that the CH_4 concentration in the flue gases from waste incinerators is below the background CH_4 concentration in ambient air. Therefore, the Netherlands uses an EF of 0 g/GJ and reports no methane. That an EF of 0 g/GJ is possible is stated in the 2006 IPCC Guidelines (Vol. 5, sections 5.2.2.3 and 5.4.2. Emissions are reported in the CRF file with the code 'NO' (as the CRF cannot handle zero values)).

A more detailed description of the method and the EFs used can be found in Honig et al. (2024). A comparison between the country-specific EFs and the IPCC defaults can also be found in this report. Table 3.8 presents the emissions from the waste incineration plants. The emissions trend is directly related to the trend for the amount of waste processed.

Table 3.8 Emissions due to incinerated waste

(in Gg)	1990	2000	2005	2010	2015	2020	2021	2022
Total CO_2 emission	2,596	5,025	5,392	6,770	7,924	7,634	7,561	7,494
CO_2 captured and stored in a product	-	-	-	-	-	1	-	-
Fossil CO_2 emissions	601	1,586	2,058	2,473	2,861	2,709	2,671	2,667
Biogenic CO_2 emissions	1,995	3,439	3,334	4,296	5,063	4,925	4,889	4,827
N_2O emissions	0	0.1	0.1	0.1	0.2	0.4	0.4	0.4
Total fossil GHG emissions (Gg CO_2-eq)	620	1,647	2,129	2,562	2,975	2,821	2,782	2,776

Comparison of emission factors

For 2022, approximately 98% of fossil CO_2 emissions were calculated using either country-specific or company-specific EFs. The remaining 2% of CO_2 emissions (from petroleum cokes, other oil, and bitumen) were calculated using default IPCC EFs.

Table 3.9 provides an overview of the implied emission factors (IEFs) used for the most important fuels (up to 95% of fuel use) in the category Energy industries (1A1). Since part of the emissions data in this sector originates from individual companies, some of the values (in Table 3.9) deviate from the standard emission factors. For reasons of confidentiality, detailed data on fuel consumption and EFs per CRF category and fuel is not presented in the NIR, but it is available to reviewers on request.

Table 3.9 Overview of IEFs used for the most important fuels (up to 95% of fuel use) for the year 2022 in the category Energy industries (1A1)

Fuel	Amount of fuel used in 2022 (TJ NCV)	IEFs (g/GJ)		
		CO_2 (x1000)	N_2O	CH_4
Natural gas	278,033	56.8	0.28	7.37
Other Bituminous Coal	196,864	93.3	0.96	0.44
Waste gas	103,176	70.8	0.10	3.60
Solid biomass	63,510	109.6	4.00	30.00
Waste, biomass	37,458	128.9	6.37	0.00
Waste, fossil	32,303	82.6	5.33	0.00

Explanation of the implied EFs

Natural gas

The CO_2, CH_4 and N_2O EFs for natural gas deviate from the standard EFs (56.5 kg CO_2/GJ, 5.7 g CH_4/GJ and 0.1 g N_2O/GJ) because this category includes emissions from the combustion of crude natural gas.

Other bituminous coal

CO_2 emissions from coal are based on emissions data from the ETS, and the IEF is different from the country-specific EF. The N_2O emissions are calculated on the basis of default IPCC emission factors (for 1A1a) and a company-specific emission factor for the combined iron/steel plant (for 1A1c). The IEF for N_2O in Table 3.9 is a weighted average.

Waste gas (refinery gas)

CO_2 emissions from refinery gas occur in refineries and in the Energy sector. The CO_2 emissions are partly based on emissions data from the ETS, and therefore the IEF is different from the country-specific EF.

Waste

The EF for N_2O emissions from waste incineration (both the fossil and biomass fraction) is either with selective non-catalytic reduction (SNCR) or with selective catalytic reduction (SCR) (100 g/ton and 20 g/ton, respectively). The EF thus depends on how the incinerator is operated. The EF for CH_4 from waste incineration is 0 g/GJ, the result of a study on emissions from waste incineration (section 2.3.2.1.2 of Honig et al. (2024); DHV, (2010); and NL Agency, (2010)). This is in accordance with the 2006 IPCC Guidelines V5, sections 5.2.2.3 and 5.4.2. The emissions are therefore reported in the CRF file with the notation key NO as the CRF cannot handle zero values. The EF for CO_2 is dependent on the carbon content of the waste, which is determined annually (section 7.4 and Honig et al., 2024).

Trends in the IEF

Trends in the IEF for most sectors can be explained by the composition of fuels used in that sector. The largest fluctuations can be explained as follows:

- 1A1a solid CO_2: The trend in the CO_2 IEF for solid fuels in 1A1a ranges between 103.1 and 132.7 kg/GJ. The main fuels used are other bituminous coal (with an EF of 92.7 kg/GJ) and blast furnace gas (with a default EF of 247.4 kg/GJ). A larger share of blast furnace gas results in a higher IEF. The steep increase in IEF between 2019 and 2020 is caused by the reduction (by more than 50%) in consumption of other bituminous coal, while the consumption of blast furnace gas only changed slightly.

- 1A1c gaseous CO_2: The trend in the CO_2 IEF for gaseous fuels in 1A1c ranges between 42.6 and 70.4 kg/GJ. The main fuels used in the production of oil and natural gas are crude 'wet' natural gas (directly extracted from the wells) and regular natural gas. The EF for wet natural gas is variable and tends to be slightly higher than the EF for regular natural gas. The variation in the EF for wet natural gas causes the variation in the IEF for gaseous fuels in 1A1c.
- 1A1c solid CO_2: The trend in the CO_2 IEF for solid fuels in 1A1a ranges between 51.4 and 117.9 kg/GJ. Emissions are based on a mass balance of Tata Steel. The fuels in the mass balance are other bituminous coal (with an EF of 94.7 kg/GJ), coke oven / gas coke (with a default EF of 106.8 kg/GJ), blast furnace gas (with a default EF of 247.4 kg/GJ) and coke oven gas (with a default EF of 42.8 kg/GJ).

3.2.4.3 Uncertainty and time series consistency

Uncertainty

The uncertainty in CO_2 emissions from this category is estimated at 4% (see section 1.7/Annex 2 for details). The accuracy of data on fuel consumption in power generation and oil refineries is generally considered to be high, with an estimated uncertainty of approximately 1-5%. The high accuracy in most of this activity data is due to the limited number of utilities and refineries, their large fuel consumption, and the fact that the data recorded in national energy statistics is verified as part of the European ETS.

The consumption of gaseous fuels in the 1A1c sub-category is mainly in the oil and gas production industry, where the split into 'own use' and 'venting/flaring' has proven difficult to establish, resulting in a high uncertainty of 15%. For other fuels, a 3% uncertainty is used, which relates to the amount of fossil waste incinerated and, therefore, to the uncertainties in the total amount of waste and the fossil and biomass fractions.

For natural gas, the uncertainty in the CO_2 EF is estimated at 0.25% on the basis of the fuel quality analysis reported by Heslinga and Van Harmelen (2006) and in the methodology reports. This value is used in the uncertainty assessment in Annex 2 and the key category assessment in Annex 1.

For hard coal (bituminous coal), an analysis was made of coal used in power generation (Van Harmelen and Koch, 2002), which is accurate to within approximately 0.5% for the year 2000 (based on 1,270 samples taken in 2000). In 1990 and 1998, however, the EF varied by ±0.9 kg CO_2/GJ (see Table 4.1 in Van Harmelen and Koch, 2002); consequently, if the default EF is applied to other years, the uncertainty is greater: approximately 1%.

Analysis of the default CO_2 EFs for coke oven gas and blast furnace gas reveals uncertainties of approximately 10% and 15%, respectively (data reported by the steel plant). Since the share of BF/OX gas in total solid fuel emissions from power generation is approximately 15–20%, the overall uncertainty in the CO_2 EF for solids in power generation is estimated to be approximately 3%. The CO_2 EFs for chemical waste gas are more uncertain than those for other fuels used by utilities. So, for liquid fuels in these sectors, a higher uncertainty of 20–25% is assumed in view of the variable composition of the derived gases used in both sectors.

For natural gas in oil and gas production (1A1c), an uncertainty of 5% is assumed, which relates to the variable composition of offshore gas. For the CO_2 EFs for other fuels (fossil waste), an uncertainty of 7% is assumed, reflecting the limited accuracy in the waste composition and, therefore, the carbon fraction per waste stream.

The uncertainty in the EFs for emissions of CH_4 and N_2O from stationary combustion is estimated at 31% and 38%, respectively, an aggregate of the various sub-categories.

For waste incineration, the uncertainty in the fossil CO_2 and N_2O emissions for 2022 is estimated at 7% and 99% respectively. The main factors influencing the uncertainties are the total amount being incinerated and the fractions of various waste components used for calculating the amounts of fossil and biogenic carbon in the waste (from their fossil and biogenic carbon fraction), and the corresponding amounts of fossil and biogenic carbon in the total waste incinerated. The uncertainty for CO_2 in the amounts of incinerated fossil waste and the uncertainty in the corresponding EF are estimated at 3% and 6%, respectively. The uncertainty for N_2O in the amounts of incinerated fossil waste and the uncertainty in the corresponding EF are estimated at 0.3% and 99%, respectively. For a more detailed analysis of these uncertainties, see Rijkswaterstaat (2014).

Time series consistency
Emissions from stationary energy combustion are calculated from the energy statistics combined with country-specific EFs (at the beginning of the time series), or a combination of company-specific and country-specific EFs (at the end of the time series).

Time series consistency is ensured for EFs and activity data for most sectors as follows:

- The country-specific EFs are based on company-specific data. Multi-year company-specific data from the most relevant companies has been used to calculate an average country-specific EF. As the same information is used to calculate both the country-specific EFs and the company-specific EFs, the EFs are consistent for the complete time series.
- Energy statistics are prepared by Statistics Netherlands using the same methodology for the complete time series. In 2015 and 2016, the energy statistics from 1990 onwards were revised using the same methodology for all years. These revised energy

statistics have been used from the 2017 submission onwards. The activity data is consistent for the complete time series.

Time series consistency in other sectors
For 1A1cii, the emissions data for 1990–2001 is obtained from the annual reports by the oil and gas extraction companies as drawn up by Fugro-Ecodata; data from 2002 onwards has been reported by individual companies in their AERs. Both datasets are based on data from individual companies and are therefore consistent for the complete time series.

3.2.4.4 Category-specific QA/QC and verification

The trends in fuel combustion in public electricity and heat production (1A1a) are compared to trends in domestic electricity consumption (production plus net imports). Large annual changes were identified and explained (e.g. changes in fuel consumption by joint ventures). For oil refineries (1A1b), a carbon balance calculation was made to check completeness. The trend in total CO_2 reported as fuel combustion by refineries was also compared to trends in activity indicators, such as total crude throughput. The IEF trend tables were then checked for changes, and interannual variations were explained in this NIR. Changes in the IEF were mainly due to changes in the type of fuel used. Furthermore, the IEFs of individual fuels were also compared to the default emission factors, and deviations from the standard EFs are explained in the NIR.
CO_2 emissions reported by companies (both in their AERs and within the ETS) were validated by the competent authority and compared.
More details on the validation of energy data can be found in section 2.1 of the ENINA methodology report (Honig et al., 2024).

3.2.4.5 Category-specific recalculations

The energy statistics have improved for 2015-2021, the main improvements being seen in gas/diesel oil, other oil, solid biomass, biogas and biogenic natural gas consumption from electricity production (1A1a), in biogenic natural gas consumption from refineries (1A1b), and in other bituminous coal consumption from cokes production (1A1c). These resulted in the following changes in emissions (in Gg for fossil and biogenic emissions together):

1A1a	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
CO_2	+0.001	-0.005	-0.001	-0.142	-0.465	-0.005	-15.943
CH_4	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.004
N_2O	-0.000	-0.000	-0.000	-0.001	-0.000	-0.000	+0.000

1A1b	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
CO_2	-0.005	-0.004	-0.003	-0.003	-0.090	-0.065	+0.394
CH_4	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	+0.000
N_2O	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	+0.000

1A1c	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
CO_2	+0.000	-0.000	-0.000	-0.000	-0.007	+0.007	+0.177
CH_4	+0.000	-0.000	-0.000	-0.000	-0.000	+0.000	-0.715
N_2O	+0.000	-0.000	-0.000	-0.000	-0.000	+0.000	+0.000

Other changes:

- 1A1ci: For the CO_2 emissions from coke production (1A1c) for 2021, an error in the CO_2 emission factor of solid fuels has been corrected. This resulted in a change in CO_2 emissions of +42.06 Gg (in 2021)

3.2.4.6 Category-specific planned improvements

There are no planned improvements.

3.2.5 Manufacturing industries and construction (1A2)

3.2.5.1 Source category description

Table 3.10 provides an overview of sub-source categories and emissions in the Manufacturing industries and construction sector (1A2).

Key categories in this sector are:

1A2 Manufacturing industries and construction: liquids CO_2
1A2 Manufacturing industries and construction: solids CO_2
1A2 Manufacturing industries and construction: gaseous CO_2

Table 3.10 Overview of emissions in the Manufacturing industries and construction sector (1A2) in the base year and the last two years of the inventory

Sector/category	**Gas**	**1990**	**2021**	**2022**	**2022 vs 1990**	**Contribution to total in 2022 (%) by**		
		Emissions in Tg CO_2-eq			**%**	**sector**	**total gas**	**total CO_2-eq**
1A2 Manufacturing industries and construction	CO_2	29.8	20.3	18.3	-38.6%	15.5%	13.8%	11.5%
	CH_4	0.1	0.1	0.1	-8.0%	0.1%	0.3%	0.0%
	N_2O	0.0	0.0	0.0	34.5%	0.0%	0.7%	0.0%
	All	29.9	20.4	18.4	-38.5%	15.5%		11.6%
1A2 liquids	*CO_2*	4.1	1.8	1.9	-54.1%	1.6%	1.4%	1.2%
1A2 solids	*CO_2*	6.6	4.0	3.8	-43.1%	3.2%	2.9%	2.4%
1A2 gases	*CO_2*	19.0	14.6	12.6	-33.8%	10.7%	9.5%	8.0%
1A2a. Iron and steel	CO_2	5.6	4.4	4.1	-26.5%	3.5%	3.1%	2.6%
1A2b. Non-ferrous metals	CO_2	0.2	0.2	0.1	-37.0%	0.1%	0.1%	0.1%
1A2c. Chemicals	CO_2	11.6	7.1	6.0	-48.0%	5.1%	4.6%	3.8%
1A2d. Pulp, paper and print	CO_2	1.7	0.9	0.9	-48.7%	0.7%	0.6%	0.5%
1A2e. Food processing, beverages and tobacco	CO_2	4.0	3.5	3.3	-17.7%	2.8%	2.5%	2.1%
1A2f. Non-metallic minerals	CO_2	2.3	1.2	1.2	-49.9%	1.0%	0.9%	0.7%
1A2g. Other	CO_2	4.4	2.9	2.7	-39.1%	2.3%	2.0%	1.7%

Natural gas is mostly used in the chemical, food and drinks, and related industries (1A2c and 1A2e); solid fuels (i.e. coal and coke-derived fuels, such as blast furnace/oxygen furnace gas) are mostly used in the iron and steel industry (1A2a); and liquid fuels are mostly used in the chemicals industry (1A2c) and in other industries (1A2g) (see Table 3.11).
Within category 1A2 (Manufacturing industries and construction), sub-category 1A2c (Chemicals) is the largest fuel user (see Table 3.11). Other large fuel-using industries are included in 1A2a (Iron and steel), 1A2e (Food processing, beverages and tobacco), and 1A2g (Other).
In response to review recommendation (E.2, 2022) and in line with the IPCC 2006 Guidelines (vol. 3, chapter 1, box 1.1 and vol. 3, chapter 3.9.4.2), the combustion emissions of waste gases have been reallocated to CRF2 (in cases where the waste gases are combusted at the plant where they are produced). Therefore, part of the combustion emissions have been reallocated from 1A2a and 1A2c to 2C1a and 2B10.

The shares of CH_4 and N_2O emissions from industrial combustion are relatively small, and these are not key sources.

In the 1990–2022 period, CO_2 emissions from combustion in 1A2 decreased by 38.6% (see Table 3.10 and Figure 3.6); the chemical industry chiefly contributed to this decrease. The large decrease in natural gas consumption between 2021 and 2022 was caused by the high prices of natural gas in 2022.

Table 3.11 Fuel use in 1A2 Manufacturing industries and construction in selected years (PJ NCV/year)

Gaseous fuels

Fuel type/ Sub-category	Amount of fuel used (PJ NCV/year)								
	1990	**1995**	**2000**	**2005**	**2010**	**2015**	**2020**	**2021**	**2022**
1A2a. Iron and steel	11.7	13.0	13.7	12.5	12.0	11.1	11.0	11.9	9.2
1A2b. Non-ferrous metals	3.8	4.3	4.2	4.0	3.6	2.7	2.3	2.7	2.4
1A2c. Chemicals	170.7	138.9	115.8	103.6	96.4	93.8	124.8	124.4	102.9
1A2d. Pulp, paper and print	29.2	24.4	27.4	29.7	21.0	18.6	15.4	16.7	15.1
1A2e. Food processing, beverages and tobacco	63.7	68.4	73.7	67.1	57.0	57.9	59.8	61.1	57.7
1A2f. Non-metallic minerals	26.1	23.8	26.5	23.5	22.6	20.4	19.1	19.3	18.4
1A2g. Other	30.1	34.8	36.2	32.6	31.4	24.0	19.8	22.0	17.4

Liquid fuels

Fuel type/ Sub-category	Amount of fuel used (PJ NCV/year)								
	1990	**1995**	**2000**	**2005**	**2010**	**2015**	**2020**	**2021**	**2022**
1A2a. Iron and steel	0.3	0.3	0.1	0.1	0.1	NO	0.1	0.1	0.1
1A2b. Non-ferrous metals	NO	NO	NO	NO	NO	NO	NO	NO	NO
1A2c. Chemicals	10.7	10.3	7.7	2.9	2.6	0.6	1.4	1.8	2.8
1A2d. Pulp, paper and print	0.0	0.0	NO	NO	NO	NO	NO	NO	NO
1A2e. Food processing, beverages and tobacco	2.2	0.6	0.2	0.2	NO	NO	0.0	0.0	0.0

Fuel type/ Sub-category	Amount of fuel used (PJ NCV/year)								
	1990	1995	2000	2005	2010	2015	2020	2021	2022
1A2f. Non-metallic minerals	5.6	4.2	1.9	0.8	0.7	0.2	0.0	0.0	0.0
1A2g. Other	36.0	35.6	37.0	34.0	29.2	25.2	24.1	22.5	23.0

Solid fuels

Fuel type/ Sub-category	Amount of fuel used (PJ NCV/year)								
	1990	1995	2000	2005	2010	2015	2020	2021	2022
1A2a. Iron and steel	73.4	80.6	68.5	81.0	70.5	80.7	71.1	76.6	72.0
1A2b. Non-ferrous metals	0.0	NO	NO	NO	NO	NO	NO	NO	NO
1A2c. Chemicals	12.8	0.2	2.1	1.7	1.2	NO	NO	NO	NO
1A2d. Pulp, paper and print	0.1	NO	NO	NO	NO	NO	NO	NO	NO
1A2e. Food processing, beverages and tobacco	2.4	1.2	1.1	0.6	1.0	0.9	0.7	0.8	0.4
1A2f. Non-metallic minerals	3.3	2.1	2.3	1.5	1.5	1.4	1.0	1.0	1.0
1A2g. Other	0.4	0.2	0.3	0.5	1.6	0.7	0.5	0.4	0.3

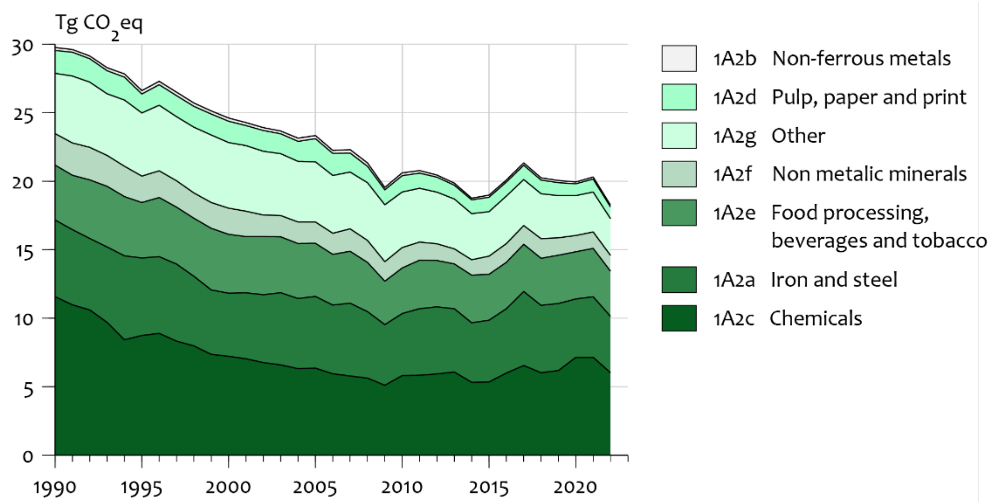


Figure 3.6 1A2 Manufacturing industries and construction – trend and emissions levels of source categories, 1990–2022.

Iron and steel (1A2a)

This sub-category refers mainly to the integrated steel plant (Tata Steel, previously known as Corus and/or Hoogovens), which produces approximately 7,000 kton of crude steel per annum. Figure 3.7 shows the production process of the Tata Steel integrated steel plant. In addition to the integrated crude steel plant, the sector comprises a (small) secondary steel-making plant which mostly uses scrap metal in an electric arc furnace to produce wire, and a number of iron foundries. The method used for calculating CO_2 emissions from Tata Steel is based on a carbon mass balance, so CO_2 emissions are not measured directly. The method allocates a quantity of C to relevant incoming and outgoing process streams (Table 3.12). As a result, CO_2 emissions can be determined at plant level only; allocation of emissions to the various sub-processes is not possible. The final difference between input and output, net C, is converted into a net CO_2 emission at plant level. For reasons of confidentiality, Table 3.12 does not include the quantities of the inputs and outputs. The figures can, however, be made available for review purposes.

Table 3.12 Input/output table for the Tata Steel integrated steel plant

Input	Output
Excipients	Produced steel
Steel scrap and raw iron	Carbonaceous products
Oil	Cokes
Pellets	BTX
Additives (limestone/dolomite)	TPA (tar, pitch and asphalt)
Iron ore	Mixed process gases: power plants
Injection coal	
Natural gas	
Coking coal	

Figure 3.7 shows the relation between the input streams from Table 3.12 (highlighted yellow) and the processes, together with the resulting emissions and the CRF categories in which the emissions were reported. Please note that the sub-flows of the gases (emissions) cannot be disaggregated in this approach; only the final flows are relevant and reported.

During the production of iron and steel, coke and coal are used as reducing agents in the blast and oxygen furnaces, resulting in blast furnace gas and oxygen furnace gas as by-products, which are used as fuel for energy purposes (see also Figure 3.7).
The Energy Balance of Statistics Netherlands distinguishes between energy figures from the Cokes Plant and the summed fuel use of the rest of processes in the integrated steel plant. Therefore, only combustion emissions from the Coke Plant and the rest of the integrated crude steel plant can be estimated. These combustion emissions (including flaring emissions) are included in 1A1ci (Manufacture of solid fuels) and 1A2a (Energy iron and steel).
Tata Steel also exports a large part of its carbon to the Energy sector in the form of mixed production gas. These emissions are included in 1A1a (Public electricity and heat production).
The relevant net process emissions are reported under sub-categories 1B1b (Solid fuel transformation), 2C1 (Iron and steel production), and 2A4d (Other process uses of carbonates).

Interannual variations in CO_2 combustion emissions from the crude steel plant can be mainly explained by the varying amounts of solid fuels used in this sector.

Combining all CO_2 emissions from the sector, total emissions closely follow the interannual variation in crude steel production (see Figure 3.8). Even though production of crude steel has increased over time, total CO_2 emissions from crude steel production have not increased. This indicates a substantial energy efficiency improvement in the sector.

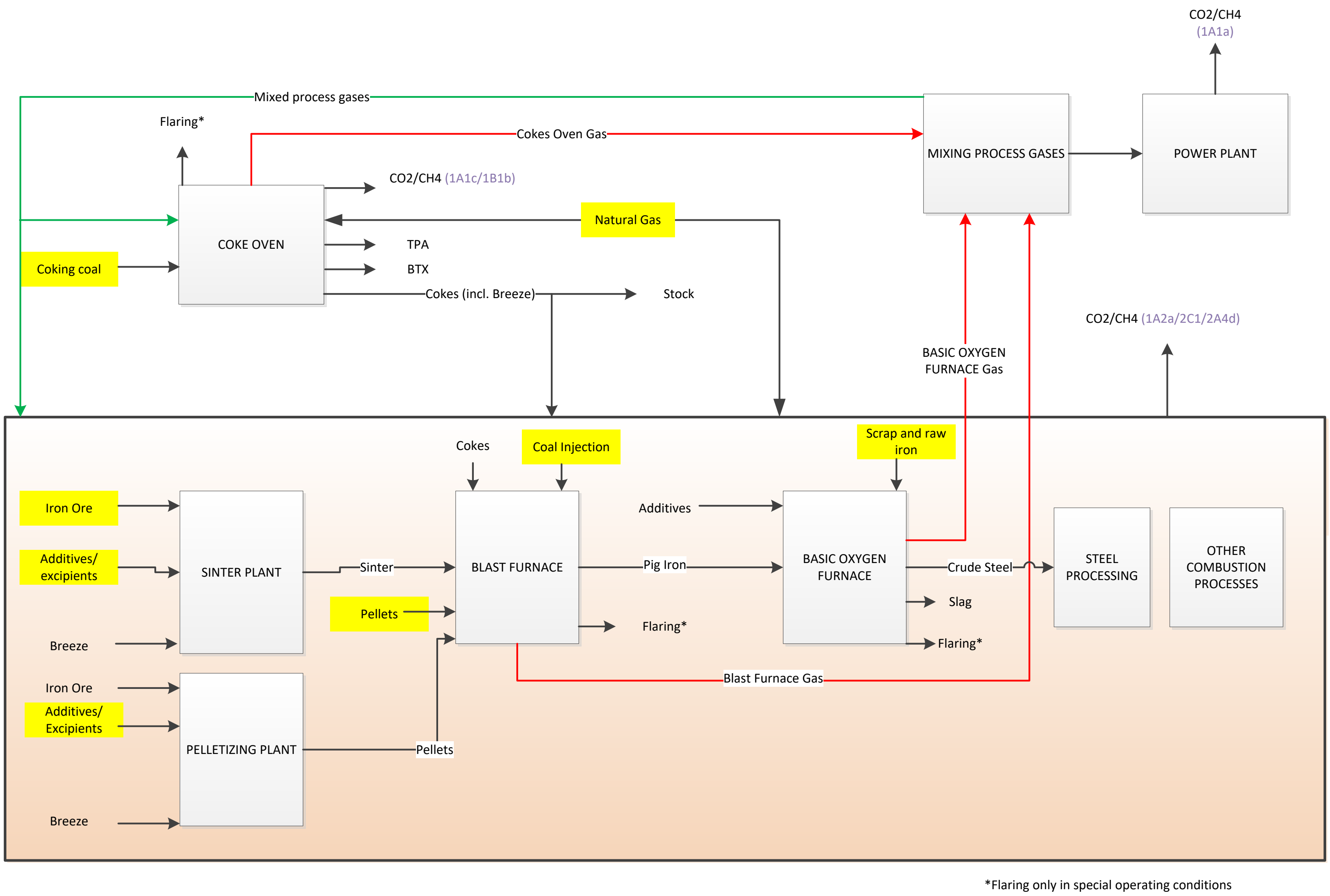


Figure 3.7 Production process of the Tata Steel integrated steel plant

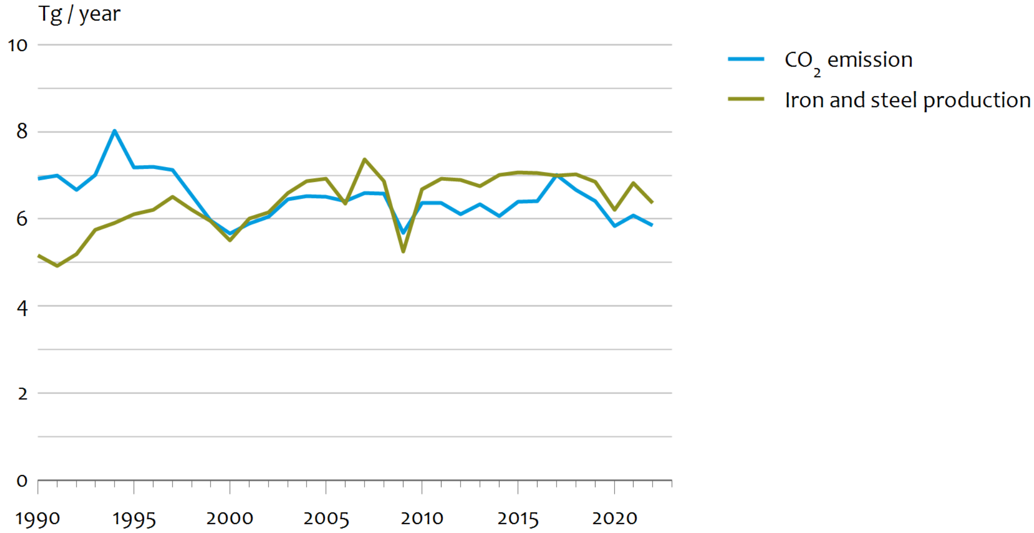


Figure 3.8 CO_2 emissions (Gg) and crude steel production (in kton) category 1A2a, 1990–2022

Non-ferrous metals (1A2b)
This sub-category consists mainly of two aluminium smelters (of which the last one ceased production in 2022). CO_2 emissions from anode consumption in the aluminium industry are included in 2C (Metal production). This small source category contributes only about 0.2 Tg CO_2 to the national total GHG Emissions Inventory, predominantly from the combustion of natural gas. Energy consumption in the aluminium industry is largely based on electricity, the emissions of which are included in 1A1a (Public electricity and heat production).

The amounts of liquid and solid fuels vary considerably between years, but both the amounts and the related emissions are almost negligible. The interannual variation of the IEFs for liquid fuels is largely a result of changes in the mix of underlying fuels (e.g. the share of LPG, which has a relatively low EF) and partly due to the small amounts used.

Chemicals (1A2c)
CO_2 emissions from this sub-category have decreased since 1990, mainly due to a large decrease in the consumption of natural gas during the same period. This is largely due to a decrease in cogeneration facilities in this industrial sector.
In response to review recommendation (E.2, 2022) and in line with the IPCC 2006 Guidelines (vol. 3, chapter 1, box 1.1 and vol. 3, chapter 3.9.4.2), the emissions from the combustion of chemical waste gas (in liquids) and phosphor oven gas (in solids) have been reallocated from 1A2c to 2B10 (for waste gases which are combusted within the same source category). The IPCC 2006 Guidelines (vol. 3, chapter 1, box 1.1) state that "Combustion emissions from fuels obtained directly or indirectly from the feedstock for an IPPU process will normally be allocated to the part of the source category in which the process occurs (these source categories are normally 2B and 2C). However, if the derived fuels are transferred for combustion in another source category, the emissions should be reported in the appropriate part of Energy Sector source categories (normally 1A1 or 1A2)". Therefore, all

combustion emissions from chemical waste gas which are produced and combusted within the chemical sector have been reallocated from 1A2c to 2B10.

Pulp, paper and print (1A2d)
In line with the decreased consumption of natural gas, CO_2 emissions have decreased since 1990. A substantial fraction of natural gas has been used for cogeneration. The relatively low CO_2 emissions since 1995 can be explained by the reallocation of emissions to the Energy sector due to the formation of joint ventures.

The amounts of liquid and solid fuel combustion vary considerably between years, but the amounts and related emissions are almost negligible. The interannual variation in the IEFs for liquid fuels is due to variable shares of derived gases (chemical waste gas) and LPG in total liquid fuel combustion.

Food processing, beverages and tobacco (1A2e)
CO_2 emissions from this sub-category increased in the 1990-1998 period, decreased in the 1998-2010 period, and has been rather stable from 2010 onwards. The decrease between 1998 and 2010 was due to the reallocation (since 2003) of joint ventures at cogeneration plants whose emissions were formerly allocated to 1A2e, but are now reported under Public electricity and heat production (1A1a).

The amounts of liquid and solid fuels vary considerably between years, but the amounts and related emissions are relatively small. The interannual variation in the IEFs for liquid fuels is due to variable shares of LPG in total liquid fuel combustion.

Non-metallic minerals (1A2f)
CO_2 emissions from this sub-category decreased in the 1990-2022 period as a result of the decreasing consumption of natural gas.

The amounts of liquid and solid fuels vary considerably between years, but the amounts and related emissions are relatively small. The interannual variation in the IEFs for liquid fuels is due to variable shares of LPG in total liquid fuel combustion which has a lower CO_2 EF.

Other (1A2g)
This sub-category comprises all other industry branches, including production of textiles, wood and wood products, and electronic equipment. It also includes GHG emissions from non-road mobile machinery (NRMM) used in industry and construction, which are described in section 3.2.7. Most of the CO_2 emissions from this sub-category stem from gas, liquid fuels, and biomass combustion.

3.2.5.2 Methodological issues

Details of methodologies, data sources and country-specific source allocation issues are provided in section 2.1 of the ENINA methodology report (Honig et al., 2024) and chapter 9 of the transport methodology report (Geilenkirchen et al., 2024). The emissions calculation for stationary combustion in category 1A2 follows the same steps as the calculation for Energy industries (1A1), see section 3.2.4.2. The only

difference is that for the iron and steel plant Tata (reported in 1A2a), an EF of 0.27 g N_2O/GJ (based on reported emissions from Tata Steel) and an EF of 0.44 g CH_4/GJ (standard EF for other bituminous coal) are used to calculate emissions from the iron and steel plant Tata in 1A2a.
The methodology for the calculation of NRMM emissions is described in section 3.2.7.2.

For 2022, approximately 99% of the fossil CO_2 emissions were calculated using country-specific or company-specific EFs. The remaining 1% of CO_2 emissions was calculated by means of default IPCC EFs. These remaining emissions are mainly the result of the combustion of other oil, lignite, and petroleum cokes.

An overview of the IEFs used for the principal fuels (up to 95% of the fuel use) in the Manufacturing industries and construction category (1A2) is provided in Table 3.13. As some emissions data in this sector originates from individual companies, the IEFs sometimes deviate from the standard emission factors. For reasons of confidentiality, detailed data on fuel consumption and EFs per CRF category and fuel is not presented in the NIR, but is available to reviewers on request.

Table 3.13 Overview of IEFs used for the most important fuels (up to 95% of fuel use) for the year 2022 in the Manufacturing industries and construction category (1A2)

Fuel	Amount of fuel used in 2022 (TJ NCV)	Implied emission factors (g/GJ)		
		CO_2 (x1000)	N_2O	CH_4
Natural gas	223,158	56.5	0.10	6.17
Coke oven / Gas coke	51,213	106.9	0.29	1.33
Other bituminous coal	37,316	93.4	0.28	0.44
Gas / Diesel oil	22,361	72.5	1.73	1.46
Solid biomass	18,498	109.6	4.00	32.52

Explanations for the IEFs

Natural gas

The standard CH_4 EF for natural gas is 5.7 g/GJ. Only for gas-powered CHP plants is a higher EF used, which explains the higher IEF for CRF 1A2.

Coke oven / Gas coke and other bituminous coal

For solid fuels, an EF of 0.27 g N_2O/GJ (based on reported emissions from Tata Steel) and an EF of 0.44 g CH_4/GJ (standard EF for other bituminous coal) are used to calculate emissions from the iron and steel plant. The standard EFs are used for solid fuel combustion in other sectors. Reported CO_2 emissions from other bituminous coal and coke oven/gas coke are based on emissions data from the ETS. Therefore, the CO_2 IEFs are different from the standard country-specific EF.

Gas / Diesel oil

Gas/Diesel oil is used in stationary and mobile combustion for which various EFs for CH_4 and N_2O are used.

Solid biomass
The CH_4 emission factor differs per sector, ranging between 30 and 300 g/GJ.

In the iron and steel industry, a substantial proportion of total CO_2 emissions is reported as process emissions in CRF 2C1, based on net losses calculated from the carbon balance of the process (coke and coal inputs in the blast furnaces and the blast furnace gas produced). Since the fraction of BF/OX gas captured and used for energy varies over time, the trend in the emissions of CO_2 accounted for by this source category should be viewed in association with the reported process emissions (see Figure 3.7). The emissions calculations for the iron and steel industry are based on a mass balance.

The fuel consumption data in 1A2g (Other) is not based on large surveys and therefore is the least accurate in this part of sub-category 1A2.

The methodology for the calculation of NRMM emissions is described in section 3.2.7.2.

3.2.5.3 Uncertainty and time series consistency

Uncertainty
The uncertainty in CO_2 emissions of this category is estimated to be about 9% (see Annex 2 for details). The uncertainty of fuel consumption data in the manufacturing industries is about 2% with the exception of that for derived gases included in solids and liquids (Olivier et al., 2009). The uncertainty of fuel consumption data takes into account the uncertainty in the subtraction of the amounts of gas and solids for non-energy/feedstock uses, including the uncertainty in the conversion from physical units to Joules, and the assumed full coverage of capturing blast furnace gas in total solid consumption and full coverage of chemical waste gas in liquid fuel consumption.

For natural gas, the uncertainty in the CO_2 EF is estimated to be 0.25% on the basis of the fuel quality analysis reported by Heslinga and Van Harmelen (2006) and further discussed in Olivier et al. (2009). The 2% uncertainty estimate in the CO_2 EF for liquids is based on an uncertainty of 2% in the EF for diesel. An uncertainty of 24% is assigned to solids, which reflects the uncertainty in the carbon content of blast furnace gas/oxygen furnace gas. BF/OX gas accounts for the majority of solid fuel use in this category.

Time series consistency
Emissions from stationary energy combustion are calculated from the energy statistics combined with country-specific EFs (at the beginning of the time series) or a combination of company-specific and country-specific EFs (at the end of the time series). Time series consistency is ensured for EFs and activity data for most sectors as follows:

- The country-specific EFs are based on company-specific data. Multi-year company-specific data from the most relevant companies has been used to calculate an average country-specific EF. As the same information is used to calculate both the country-specific EF and the company-specific EFs, the EFs are consistent for the complete time series.

- Energy statistics are prepared by Statistics Netherlands, using the same methodology for the complete time series. In 2015 and 2016, the energy statistics from 1990 onwards were revised, using the same methodology for all years. These revised energy statistics have been used from the 2017 submission onwards. The activity data is consistent for the complete time series.

3.2.5.4 Category-specific QA/QC and verification

The trends in CO_2 emissions from fuel combustion in the iron and steel industry, non-ferrous industry, food processing, pulp and paper and other industries are compared to trends in the associated activity data: crude steel and aluminium production, indices of food production, pulp and paper production, and cement and brick production. Large annual changes are identified and explained (e.g. changed allocation of fuel consumption due to joint ventures). Moreover, for the iron and steel industry, the trend in total CO_2 emissions reported as fuel combustion-related emissions (included in 1A2a) and industrial process emissions (included in 2C1) is compared to the trend in the activity data (crude steel production). A similar comparison is made for the total trend in CO_2 emissions from the chemical industry (sum of 1A2c and 2B) and trends split per main fuel type or specific process (chemical waste gas combustion and process emissions from ammonia production). IEF trend tables are checked for large changes and large interannual variations at different levels, which are explained in the NIR. Changes in the IEF are mainly due to changes in the type of fuel used. Furthermore, the IEFs of individual fuels are also compared to the default emission factors, and deviations from the standard EFs are explained in the NIR.

CO_2 emissions reported by companies (both in AERs and as part of the ETS) are validated by the competent authority and then compared (see also section 3.2.4.4). More details on the validation of the energy data can be found in Honig et al. (2024), section 2.1.

QA/QC and verification of NRMM data and emissions are described in section 3.2.7.4.

3.2.5.5 Category-specific recalculations

Stationary combustion

The energy statistics for 2015-2021 have been improved, the main improvements being seen in other bituminous coal consumption in 1A2a, other oil consumption in 1A2c, natural gas consumption in 1A2d, biogas and natural consumption in 1A2e, cokes and lignite consumption in 1A2f and solid biomass, lignite and natural gas consumption in 1A2gviii. Furthermore, an error has been corrected for refinery gas used at one company in 2018. These improvements resulted in the following changes in emissions (in Gg for fossil and biogenic emissions together):

1A2a. Iron and steel

	2015	2016	2017	2018	2019	2020	2021
CO_2	-0.001	-0.001	-0.001	-0.001	-0.001	-0.014	22.769
CH_4	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000
N_2O	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000

1A2b. Non-ferrous metals

	2015	2016	2017	2018	2019	2020	2021
CO_2	0.000	0.000	-0.000	0.052	0.041	0.052	0.727
CH_4	0.000	0.000	-0.000	0.000	0.000	0.000	0.000
N_2O	0.000	0.000	-0.000	0.000	0.000	0.000	0.000

1A2c. Chemicals

	2015	2016	2017	2018	2019	2020	2021
CO_2	-0.385	-0.072	0.139	29.123	6.957	4.644	5.614
CH_4	-0.000	-0.000	0.000	0.000	0.001	0.000	0.001
N_2O	-0.000	-0.000	0.000	0.000	0.000	0.000	0.000

1A2d. Pulp, paper and print

	2015	2016	2017	2018	2019	2020	2021
CO_2	-1.495	-1.441	-0.088	0.088	-0.631	19.675	25.816
CH_4	-0.000	-0.000	-0.000	0.000	-0.000	0.002	0.003
N_2O	-0.000	-0.000	-0.000	0.000	-0.000	0.000	0.000

1A2e. Food processing, beverages and tobacco

	2015	2016	2017	2018	2019	2020	2021
CO_2	7.153	-0.002	0.593	0.602	2.160	-4.191	-9.073
CH_4	0.001	0.000	0.000	0.000	0.000	-0.000	-0.001
N_2O	0.000	0.000	0.000	0.000	0.000	0.000	0.000

1A2f. Non-metallic minerals

	2015	2016	2017	2018	2019	2020	2021
CO_2	0.804	-10.787	0.053	-7.150	-5.247	-2.454	-13.312
CH_4	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.003
N_2O	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000

1A2gi. Other: Manufacturing of machinery

	2015	2016	2017	2018	2019	2020	2021
CO_2	0.000	-0.000	-0.000	-0.000	-0.020	-0.112	-0.471
CH_4	0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000
N_2O	0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000

1A2gii. Other: Manufacturing of transport equipment

	2015	2016	2017	2018	2019	2020	2021
CO_2	0.000	-0.000	-0.000	-0.000	-0.052	-0.000	0.825
CH_4	0.000	-0.000	-0.000	-0.000	-0.000	-0.000	0.000
N_2O	0.000	-0.000	-0.000	-0.000	-0.000	-0.000	0.000

1A2giii. Other: Mining (excluding fuels) and quarrying

	2015	2016	2017	2018	2019	2020	2021
CO_2	0.000	-0.000	-0.000	-0.000	-0.039	-0.000	0.000
CH_4	0.000	0.000	-0.000	-0.000	-0.000	-0.000	0.000
N_2O	0.000	-0.000	-0.000	-0.000	-0.000	-0.000	0.000

1A2giv. Other: Wood and wood products

	2015	2016	2017	2018	2019	2020	2021
CO_2	-0.000	-0.000	-0.000	-0.000	-0.138	-0.089	-0.079
CH_4	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	0.000
N_2O	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	0.000

1A2gv. Other: Construction

	2015	2016	2017	2018	2019	2020	2021
CO_2	0.004	0.004	0.065	-0.000	-0.003	-0.000	-0.171
CH_4	0.000	0.000	0.000	-0.000	-0.000	-0.000	-0.000
N_2O	0.000	0.000	0.000	-0.000	-0.000	-0.000	-0.000

1A2gvi. Other: Textile and leather

	2015	2016	2017	2018	2019	2020	2021
CO_2	0.000	0.000	-0.000	-0.450	11.063	10.266	0.014
CH_4	0.000	0.000	-0.000	-0.000	0.001	0.001	0.000
N_2O	0.000	0.000	-0.000	-0.000	0.000	0.000	0.000

1A2gviii. Other: Other

	2015	2016	2017	2018	2019	2020	2021
CO_2	17.252	16.668	16.242	16.527	2.494	46.571	80.121
CH_4	0.001	0.001	0.001	0.001	0.000	0.009	0.022
N_2O	0.000	0.000	0.000	0.000	0.000	0.001	0.003

Reallocation of waste gas
In response to review recommendation (E.2, 2022) and in line with the IPCC 2006 Guidelines (vol. 3, chapter 1, box 1.1 and vol. 3, chapter 3.9.4.2), the emissions from the combustion of chemical waste gas and phosphor oven gas have been reallocated from 1A2c to 2B10. This results in a reduction of emission in 1A2c (in Gg):

1A2c	1990	2005	2010	2015	2019	2020	2021
CO_2	-5701	-5603	-7899	-6450	-6792	-7584	-7446
CH_4	-0.308	-0.324	-0.396	-0.394	-0.387	-0.441	-0.420
N_2O	-0.009	-0.009	-0.011	-0.011	-0.011	-0.012	-0.012

Mobile combustion
Recalculations relating to NRMM are described in section 3.2.7.5.

3.2.5.6 Category-specific planned improvements
No category-specific improvements for stationary combustion have been planned. Planned improvements to the NRMM modelling are described in section 3.2.7.6.

3.2.6 *Transport (1A3)*

3.2.6.1 Source category description

Table 3.14 provides an overview of sources and emissions in this category in the Netherlands. CO_2 is by far the most important GHG within the Transport sector.

Table 3.14 Overview of emissions in the Transport sector (1A3) in the base year and the last two years of the inventory

Sector/category	Gas	1990	2021	2022	2022 vs 1990	Contribution to total in 2022 (%) by		
		Emissions in Tg CO_2-eq			%	sector	total gas	total CO_2-eq
1A3. Transport	CO_2	27.5	25.3	25.2	-8.5%	21.3%	19.0%	15.9%
	CH_4	0.2	0.1	0.1	-68.7%	0.1%	0.3%	0.0%
	N_2O	0.1	0.2	0.2	95.0%	0.2%	2.8%	0.1%
	All	27.8	25.6	25.4	-8.6%	21.5%		16.0%
1A3a. Civil aviation	CO_2	0.1	0.0	0.0	-61.9%	0.0%	0.0%	0.0%
1A3b. Road vehicles	CO_2	26.3	24.3	24.1	-8.1%	20.4%	18.3%	15.2%
	CH_4	0.2	0.1	0.1	-70.4%	0.1%	0.3%	0.0%
	N_2O	0.1	0.2	0.2	101.2%	0.2%	2.7%	0.1%
1a3b gasoline	CO_2	10.7	10.6	10.9	1.9%	9.2%	8.2%	6.9%
1a3b diesel oil	CO_2	13.0	13.3	12.8	-1.7%	10.8%	9.7%	8.1%
1a3b LPG	CO_2	2.6	0.3	0.3	-88.7%	0.2%	0.2%	0.2%
1a3b Natural gas	CO_2	0.0	0.1	0.1	>100%	0.1%	0.1%	0.1%
1A3c. Railways	CO_2	0.1	0.1	0.1	-33.9%	0.1%	0.0%	0.0%
1A3d. Domestic Navigation	CO_2	0.7	0.8	0.9	18.1%	0.7%	0.6%	0.5%
1A3e. Other Transportation	CO_2	0.3	0.1	0.1	-75.2%	0.1%	0.1%	0.1%

This sector comprises the following key categories:

1A3b	Road transportation: gasoline	CO_2
1A3b	Road transportation: diesel oil	CO_2
1A3b	Road transportation: LPG	CO_2
1A3b	Road transportation: gaseous	CO_2
1A3d	Domestic navigation	CO_2
1A3e	Other	CO_2

Overview of shares and trends in energy use and emissions
In 2022, transport was responsible for 16.0% of GHG emissions in the Netherlands. GHG emissions from transport increased by 31% between 1990 and 2006, from 27.8 to 36.3 Tg CO_2-eq. This increase was mainly due to an increase in diesel fuel consumption and resulting CO_2 emissions from road transport. Since 2006, GHG emissions from transport have decreased by 30% to 25.4 Tg CO_2-eq in 2022.
Total energy use and resulting GHG emissions from transport are summarised in Figure 3.9 and Figure 3.10, respectively. As these figures show, road transport accounts for the majority of energy use and GHG emissions in this category throughout the time series.

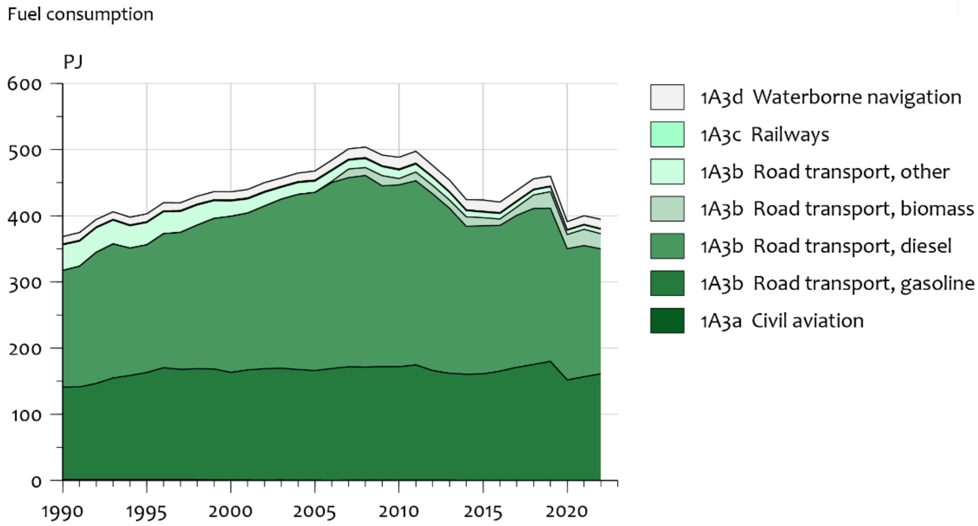


Figure 3.9 1A3 Transport – energy use of source categories in PJ, 1990–2022

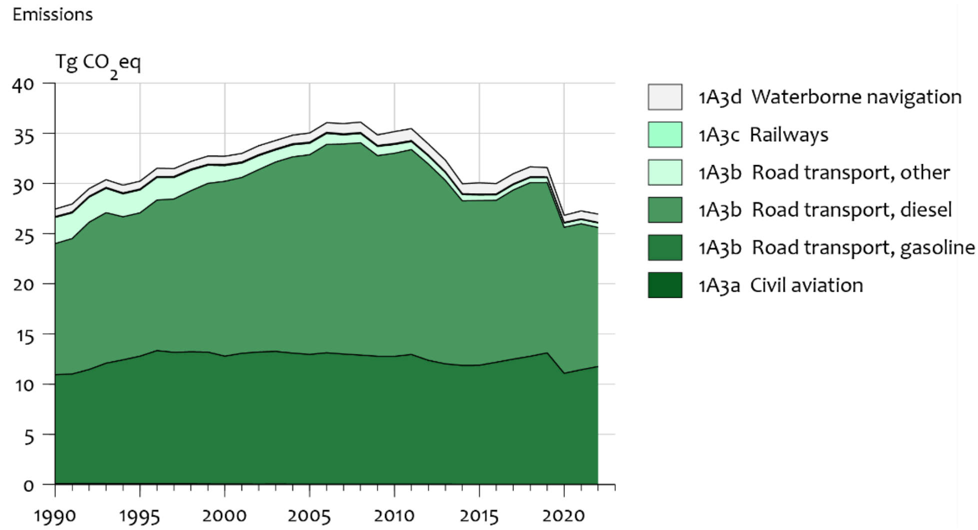


Figure 3.10 1A3 Transport – emissions levels of source categories, 1990–2022

Figure 3.10 shows that GHG emissions from transport steadily increased between 1990 and 2006. The increase is more or less in line with the increase in road transport volumes, although energy efficiency has increased (see Road transport). Between 2006 and 2008, emissions stabilised due to an increase in the use of biofuels in road transport. CO_2 emissions from biofuels are reported separately in the inventory and are not part of the national emissions totals (and are therefore not included in Figure 3.10). In 2009, GHG emissions from transport decreased slightly primarily due to the economic crisis and the resulting decrease in freight transport volumes. In 2010 and 2011, emissions increased slightly due to a decrease in the use of biofuels in 2010, and an increase in road transport volumes in 2011. Between 2011 and 2014, CO_2 emissions decreased by 16%. This can largely be attributed to an increase in cross-border refuelling resulting from an increasing difference in fuel prices between the Netherlands and Belgium/Germany (Geilenkirchen et al., 2017). Since 2014, GHG emissions have slightly increased. Due to an improving economy with more transport in the 2014-2019 period, CO_2 emissions have increased by 3%. In 2020 and

2021, there was much less road traffic due to the COVID-19 pandemic and the guidelines regarding social distancing. As a result, the emissions have decreased significantly compared to 2019.
Despite the resumption of road traffic in 2022, GHG emissions have decreased by 0.7% in 2022 compared to 2021.

Civil aviation (1A3a)
Given the small size of the Netherlands, there is hardly any domestic aviation. The share of domestic civil aviation (i.e. aviation with departure and arrival in the Netherlands, including emissions from overland flights which depart from and arrive at the same airport) in GHG emissions in the Netherlands was less than 0.1% throughout the entire time series. The use of jet kerosene for domestic aviation decreased from 1.0 PJ in 1990 to 0.4 PJ in 2022, and the use of aviation gasoline decreased from 0.2 PJ in 1990 to 0.05 PJ in 2022. GHG emissions from civil aviation decreased accordingly. In 2022, the use of jet kerosene for domestic aviation increased by 23% compared to 2021 following the decrease due to the coronavirus pandemic.

Road transport (1A3b)
The share of road transport (1A3b) in national GHG emissions increased from 11.6% in 1990 to 15.4% in 2022 Between 1990 and 2019, total GHG emissions from road transport increased from 26.6 to 28.8 Tg CO_2-eq, mainly due to an increase in transport volume. In 2020 and 2021, total GHG emissions decreased to 24.6 Tg CO_2-eq in 2021 due to the COVID-19 restrictions. Additionally, a daytime speed reduction to 100 km/h was imposed on motorways from March 2020, resulting in a reduction of fuel consumption by road transport on motorways.

Between 1990 and 2008, diesel fuel consumption increased by 60% (+105 PJ). This increase was caused by both a large increase in freight transport volumes and a growing number of diesel passenger cars and light-duty trucks in the Dutch car fleet.

Between 2008 and 2019, diesel fuel consumption decreased by 24% to 214 PJ. This decrease can be attributed to three factors: the improved fuel efficiency of the diesel passenger car fleet; a very modest growth of diesel road transport volumes; and an increase in cross-border fuelling. The fuel efficiency of the passenger car fleet in the Netherlands has improved in recent years as a result of increasingly stringent EU CO_2 emissions standards for new passenger cars and fiscal incentives for the purchase of fuel-efficient cars. In recent years, as more fuel-efficient cars have entered the car fleet, average fuel efficiency has improved (although it should be noted that improvements in fuel efficiency in the real world were much smaller than those indicated by type approval values). Moreover, road transport volumes were more or less stable between 2008 and 2014, mainly due to the economic crisis. In recent years, however, the economic upturn has resulted in an increase in transport volumes. Finally, an increase in excise duties for diesel fuel in the Netherlands in 2014 resulted in an increase in cross-border refuelling, especially for freight transport (Geilenkirchen et al., 2017).

Gasoline consumption increased from 140 to 169 PJ between 1990 and 1996 and subsequently fluctuated between 165 and 170 PJ until 2011. Subsequently, gasoline sales for road transport decreased to 155 PJ in 2014 but increased again to 171 PJ in 2019. The decrease between 2011 and 2014 can be attributed to a combination of improved fuel efficiency of the passenger car fleet, stabilisation of road transport volumes, and an increase in cross-border refuelling. The subsequent increase can be chiefly attributed to economic growth resulting in increased traffic volumes. Restrictions for social interaction during the coronavirus pandemic (such as the work-from-home policy) caused sales of both gasoline and diesel to decrease by 14% in 2021 compared to 2019.

Road transport increased again in 2022, but remained below the level of 2019. Gasoline sales increased by 2.4% to 150 PJ in 2022, but diesel sales to road transport continued to decline by 3.7% to 176 PJ. An increasingly cleaner fleet reduces emissions per traffic kilometre. Due to the high fuel prices as a result of the war in Ukraine, cross-border refuelling is bound to have played a greater role than in previous years. The pump price of diesel in the Netherlands in 2022 was generally slightly higher than the price in Germany (Dutch Ministry of Finance, 2023). The price of gasoline was also higher than in surrounding countries. Because emissions are calculated on the basis of the amount of fuel sold, increased cross-border refuelling results in fewer emissions.

LPG consumption for road transport decreased steadily throughout the time series: from 39 PJ in 1990 to 4 PJ in 2022, mainly due to the decreasing number of LPG-powered passenger cars in the car fleet. As a result, the share of LPG in energy use by road transport decreased significantly between 1990 and 2022, from 11% to 1%. The use of natural gas in road transport has increased in recent years and amounted to 3 PJ in 2022. Within the Transport sector, natural gas is mainly used for public transport buses, although the number of CNG-powered passenger cars and light-duty trucks has also increased in recent years.

Biofuels have been used in road transport since 2003. The use of biofuels increased from 0.1 PJ in 2003 to 24 PJ in 2021. In 2022, this was slightly lower at 22 PJ, which accounts for 6% of total energy use for road transport. This is a result of a legal obligation to use renewable energy for transport. For the most part, this obligation is met by the increasing use of biofuels, and also through electrification of road vehicles.

GHG emissions from road transport are 99% CO_2. The share of N_2O in total GHG emissions from road transport (in CO_2-eq) is small (0.74% in 2022). N_2O emissions from road transport increased from 0.3 Gg in 1990 to 0.9 Gg in 1997, then fluctuated between 0.8 and 0.9 until 2019, but have since decreased to 0.7 Gg in 2022. The increase in N_2O emissions up to 1997 resulted from the growing number of gasoline cars equipped with three-way catalysts (TWCs) in the passenger car fleet, as these emit more N_2O per vehicle–kilometre than those without a TWC. The subsequent stabilisation of N_2O emissions between 1997 and 2016, despite a further increase in transport volumes, can be explained by a combination of two factors:

1. N_2O emissions per vehicle–kilometre of subsequent generations of TWC-equipped gasoline cars have decreased (Kuiper and Hensema, 2012).
2. Recent generations of heavy-duty diesel trucks equipped with selective catalytic reduction (SCR) catalysts to reduce NO_x emissions emit more N_2O per vehicle–kilometre than older trucks (Kuiper and Hensema, 2012). In recent years, this has resulted in an increase in N_2O emissions from heavy-duty vehicles, which more or less offset the decrease in N_2O emissions from gasoline-powered passenger cars.

The share of CH_4 in GHG emissions from road transport (in CO_2-eq) is also small (0.25% in 2022). CH_4 emissions from road transport decreased by about 70% between 1990 and 2022. This was due to a reduction in VOC emissions, resulting from the implementation and subsequent tightening of EU emissions legislation for new vehicles. CH_4 emissions are estimated as a fraction of total VOC emissions. As almost the entire gasoline car fleet is currently equipped with catalysts and carbon canisters, the decrease in VOC emissions, and therefore CH_4 emissions, has stagnated in recent years.

Railways (1A3c)
Railways (1A3c) are a minor source of GHG emissions, accounting for less than 0.1% of total GHG emissions from Transport in the Netherlands in 2022. Diesel fuel consumption by railways has fluctuated between 0.7 and 1.5 PJ throughout the time series, even though transport volumes have grown. This decoupling between transport volumes and diesel fuel consumption has been caused by the increasing electrification of rail (freight) transport. In 2022, diesel fuel consumption by railways amounted to 0.8 PJ. Most rail transport in the Netherlands is electric, with total electricity use for rail transport amounting to over 5-6 PJ annually in recent years. GHG emissions resulting from electricity generation for railways are not reported under 1A3c but are included in 1A1a.

Waterborne navigation (1A3d)
(Domestic) waterborne navigation is a small source of GHG emissions in the Netherlands. Waterborne navigation in the Netherlands is mostly internationally orientated, i.e. ships either depart or arrive abroad. As emissions from international navigation are reported under Bunkers (1D, section 3.2.2), the share of (domestic) waterborne navigation in total GHG emissions from the transport sector is small, ranging between 2% and 4% throughout the time series (3% in 2022).

Domestic waterborne navigation includes emissions from passenger and freight transport within the Netherlands, including offshore operations and recreational craft. Fuel consumption for domestic waterborne navigation increased from 10 PJ in 1990 to 17 PJ in 2011, but then decreased to 10 PJ in 2020 before increasing again to 12 PJ in 2022. These fluctuations can partially be explained by changes in offshore operations.

In line with the fuel consumption trend, GHG emissions from domestic waterborne navigation increased from 0.7 Tg CO_2-eq in 1990 to 1.2 Tg in 2011 and then decreased to 0.7 Tg in 2020. In 2022, this amounted to 0.9 Tg.

Other transportation (1A3e)
Other transportation consists of pipeline transport with CO_2 and N_2O emissions occurring at natural gas compressor stations. This is a minor source, which accounted for 1.2% of total Transport sector GHG emissions in 1990 and only 0.3% in 2022.

Please note that:
- Emissions from fuels delivered to international aviation and navigation (aviation and marine bunkers) are reported separately in the inventory (see section 3.2.2).
- Emissions from military aviation and shipping are included in 1A5 (see section 3.2.8).
- Energy consumption for pipeline transport is not recorded separately in the national energy statistics, but CO_2 and N_2O combustion emissions for gas transport are included in 1A3e. CO_2 process emissions and the CH_4 emissions of gas transport are reported in 1B2b (Gas transmission and storage), while CO_2 and CH_4 emissions from oil pipelines are included in 1B2a (Oil transport) as described in section 3.3.2.
- CO_2 emissions from lubricant use in two-stroke engines in mopeds and motorcycles have been included into 1A3biv, in accordance with the 2006 IPCC Guidelines.
- Emissions from NRMM (non-road mobile machineries) are reported under various sub-categories, in line with the agreed CRF format:
  - Industrial and construction machinery: 1A2g;
  - Commercial and institutional machinery: 1A4a;
  - Residential machinery: 1A4b;
  - Agricultural machinery: 1A4c.

3.2.6.2 Methodological issues
This section gives a description of the methodologies and data sources used to calculate GHG emissions from transport in the Netherlands. Table 3.15 summarises the methods and types of EFs used for transport. More details on methodological issues can be found in Geilenkirchen et al. (2024).

Table 3.15 Overview of methodologies for the Transport sector (1A3)

CRF code	Source category description	Method	EF
1A3a	Civil aviation	T1	CS, D
1A3b	Road transport	T2, T3	CS, D
1A3c	Railways	T1, T2	CS, D
1A3d	Waterborne navigation	T1, T2	CS, D
1A3e	Pipeline transport	T2	CS, D

CS: Country-specific, D: Default

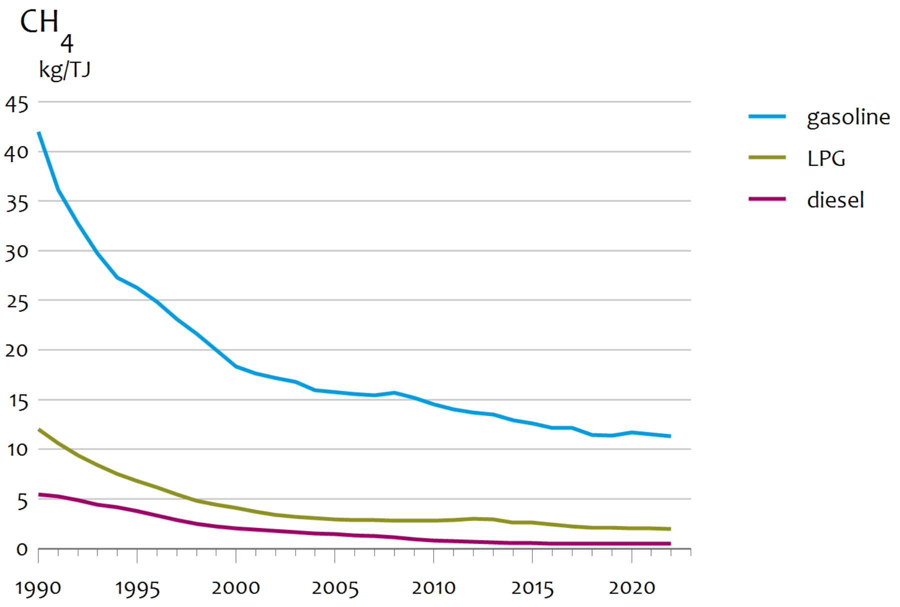
Civil aviation (1A3a)
GHG emissions from domestic civil aviation in the Netherlands are estimated using a Tier 1 methodology. Fuel deliveries for domestic and international aviation are derived from the Energy Balance. This includes deliveries of jet kerosene and aviation gasoline. The heating values and CO_2 EFs for aviation gasoline and kerosene are derived from Zijlema (2023). Country-specific values are used for aviation gasoline, whereas for jet kerosene default values from the 2006 IPCC Guidelines are used. Default EFs are also used for N_2O. For CH_4, the EF is based on the VOC-profiles in the CLEO-model as described below. Since domestic civil aviation is not a key source in the inventory, the use of a Tier 1 methodology is deemed sufficient.

Emissions of precursor gases (NO_x, CO, NMVOC and SO_2), reported in the CRF under Domestic aviation, are calculated from domestic LTO emissions, which are calculated by means of the CLEO model (Dellaert & Hulskotte, 2017) and are used for the NL PRTR, and domestic cruise emissions as provided by Eurocontrol to member countries. As the data provided by Eurocontrol does not include flights that did not submit a flight plan, scaling factors have been used to estimate the missing emissions.

Road transport (1A3b)
The activity data for calculating GHG emissions from road transport is derived from the Energy Balance. This includes fuel sales of gasoline, diesel, liquefied petroleum gas (LPG), natural gas (CNG and LNG) and biofuels. Table 2.1 in Geilenkirchen et al. (2024) provides an overview of the methodology used to distribute the Energy Balance data across the various CRF categories.

CO_2 emissions from road transport are calculated using a Tier 2 methodology. Country-specific heating values and CO_2 EFs are used. These were derived from measurement programmes, the most recent being performed in 2016 and 2017 with a follow-up for gasoline in 2017-2019, and have been brought up to date by Statistics Netherlands. A detailed description of the methodology currently used for calculating GHG emissions for road transport is provided in chapter 2 of Geilenkirchen et al. (2024). The EFs used are provided in Geilenkirchen et al. (2024) in Table 2.2B (for CH_4 and N_2O EFs) and Tables 2.2A and 2.7 (CO_2 EFs).

Figure 3.11 shows the implied N_2O and CH_4 EFs for road transport. The CH_4 EFs have decreased steadily for all fuel types throughout the time series due to EU emissions legislation for HC. The N_2O EFs for gasoline and LPG increased between 1990 and 1995 due to the increasing number of catalyst-equipped passenger cars in the car fleet, but have since decreased steadily, as described in section 3.2.6.1. The N_2O IEF for diesel has increased in recent years, mainly due to the increasing number of heavy-duty trucks and buses equipped with an SCR catalyst.



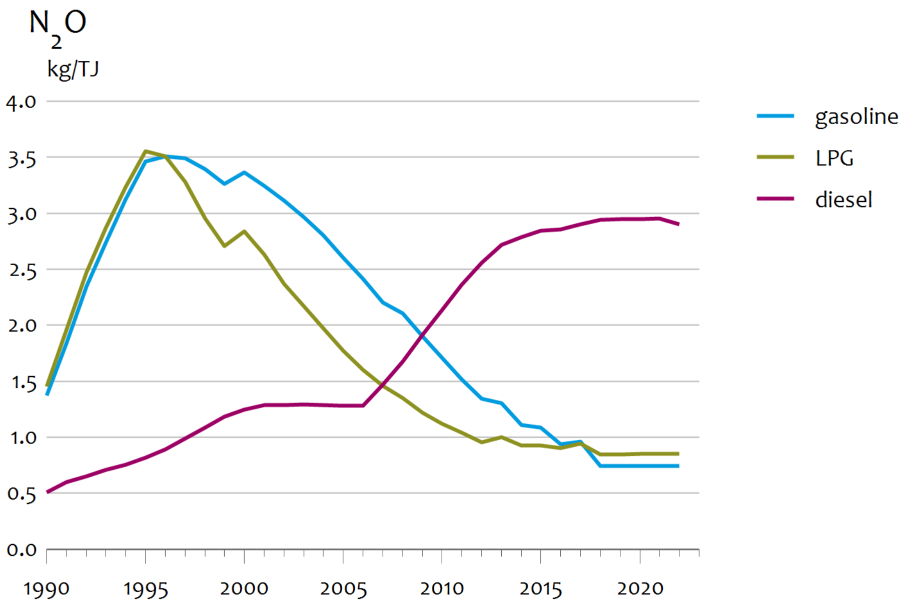


Figure 3.11 IEFs per fuel type for CH_4 (upper graph) and N_2O (lower graph) emissions by road transport, 1990–2022

Railways (1A3c)
Fuel deliveries to railways are derived from the Energy Balance. Since 2020, Statistics Netherlands has obtained diesel data from ProRail, which, in turn, receives the data from the railway operators. ProRail is responsible for the railway network of the Netherlands and is part of Vivens. Previously, Statistics Netherlands obtained this data from

Vivens, a cooperative of rail carriers that purchase diesel for the entire rail sector in the Netherlands.
CO_2 emissions from railways are calculated by means of a Tier 2 methodology, using the same country-specific CO_2 EFs as those used for road transport (Swertz et al., 2018). Due to a lack of country-specific EFs, CH_4 and N_2O emissions for railways are estimated using a Tier 1 methodology, using EFs that have been derived from the 2016 EEA Emission Inventory Guidebook.

Waterborne navigation (1A3d)
Diesel fuel consumption for domestic inland navigation is derived from the Energy Balance. Gasoline consumption for recreational craft is not reported separately in the Energy Balance, but is included under Road transport. In order to calculate GHG emissions from gasoline consumption by recreational craft, fuel consumption is estimated annually using an updated bottom-up approach derived from Hulskotte (in press in 2024). Gasoline sales data for road transport derived from the Energy Balance is corrected accordingly (as shown in Table 2.1 of Geilenkirchen et al., 2024).

The fuel consumption from the Energy Balance is allocated international bunkers and inland navigation. Each fuel supplier has to report its total fuel sales to Statistics Netherlands, and subsequently fills in a survey. In this survey, the fuel supplier indicates to which type(s) of shipping (inland navigation, fisheries, international shipping, etcetera) its fuels have been delivered. Within inland navigation, the distinction between domestic inland navigation (included in 1A3d) and international inland navigation (included in 1D International bunker fuels) is uncertain. Based on the survey and expert judgement by Statistics Netherlands, the fuel sales of each fuel supplier for inland navigation are attributed to either national or international navigation. This methodology is used consistently throughout the time series.

A Tier 2 methodology is used to calculate CO_2 emissions from domestic waterborne navigation using country-specific CO_2 EFs, while a Tier 1 method is used for CH_4 and N_2O emissions. A description of the country-specific EFs for CO_2 and the EFs used for CH_4 and N_2O, as well as the underlying methodology, is provided in Geilenkirchen et al. (2024); the EFs are included in Table 2.2.

Other transportation (1A3e)
The methodology used for calculating emissions from other transportation (Pipeline transport gaseous fuels) is described in section 3.3.

Fossil carbon in biofuels
Part of the carbon in certain types of biofuels has a fossil origin, and as such should be reported as fossil fuel. The following methodology is used:

1. Derive the total amount of biogasoline and biodiesel used for transport in the Netherlands from the Energy Balance, as reported annually by Statistics Netherlands.

2. Determine the share of various types of biogasoline and biodiesel used in the Dutch market, as reported annually by the Dutch Emissions Authority (NEa, 2023).
3. Apply the fossil fraction of the carbon content for biodiesel (Sempos, 2018) and biogasoline (Annex III of the EU Renewable Energy Directive, 2018/2001/EC).

Table 3.16 Share (in %, rounded) of various types of biofuels in total biofuel consumption for transport in the Netherlands (NEa, 2023)

	Biofuel type	**Fossil part of CC**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2022**
Bio Gas-oline	bio-ethanol	0	92	91	95	99	100	99	99	77	83	90	92
	bio-ETBE	63	0	1	2	0	0	1	1	11	0	2	0
	bio-MTBE	78	7	7	2	0	0	0	0	0	0	0	0
	bio-methanol	0	1	1	2	0	0	0	0	0	1	0	0
	bionafta	0	0	0	0	0	0	0	0	11	16	8	8
	total		100	100	100	100	100	100	100	100	100	100	100
Bio diesel	FAME	5.4	100	98	99	96	98	98	99	97	78	87	78
	HVO	0	0	2	1	4	2	2	1	3	22	13	21
	FAEE	0	0	0	1	0	1	0	0	0	0	0	0
	total		100	100	100	100	100	100	100	100	100	100	100

Table 3.16 presents the input for steps 2 and 3, i.e. the shares of various types of biofuels in total biogasoline and biodiesel use for transport in the 2011–2022 period, as reported by NEa (2023), and the fossil part of the carbon content per fuel type.

3.2.6.3 Uncertainty and time series consistency

Uncertainty estimates for the activity data and IEFs used for calculating transport emissions are presented in Table 2.5 of Geilenkirchen et al. (2024), which also shows the sources used to estimate uncertainties. Table 3.17 summarises the uncertainties for activity data and EFs per source category, fuel type and gas. The estimations of uncertainties in activity data are all derived from Statistics Netherlands.

The uncertainty estimates for N_2O and CH_4 for civil aviation, railways, and waterborne navigation are IPCC defaults. The uncertainties in EFs for road transport and CO_2 EFs for other source categories are based on expert judgements determined in workshops. Information on uncertainties is updated annually in accordance with methodological improvements and recalculations, following consultation with experts.

Table 3.17 Uncertainties for activity data and emission factors, category 1A3

CRF	Source category	Fuel type	Gas	Activity data	EFs
1A3a	Civil aviation	Avgas	CO_2	+- 10%	+- 4%
		Avgas	N_2O		-70% - +150%
		Avgas	CH_4		-57% - +100%
		Kerosene	CO_2		+- 4%
		Kerosene	N_2O		-70% - +150%
		Kerosene	CH_4		-57% - +100%
1A3b	Road transportation	gasoline	CO_2	+- 2%	+- 2%
		diesel	CO_2	+- 2%	+- 2%
		LPG	CO_2	+- 2%	+- 2%
		CNG	CO_2	+- 10%	+- 2%
		all	CH_4	+- 2%	+- 50%
		all	N_2O	+- 2%	+- 50%
1A3c	Railways	all	CO_2	+- 1%	+- 2%
		all	N_2O		-50% - +300%
		all	CH_4		-40% - +251%
1A3d	Waterborne navigation	all	CO_2	+- 5%	+- 2%
		all	N_2O		-40% - +140%
		all	CH_4		+- 50%

3.2.6.4 Category-specific QA/QC and verification

GHG emissions from transport are based on fuel sold. To check the quality of the emissions totals, activity data for road transport (i.e. energy use per fuel type) is also calculated using a bottom-up approach based on vehicle-kilometres travelled and specific fuel consumption per vehicle-kilometre for various vehicle types. A comparison between the fuel sales data and the bottom-up calculation of fuel consumption gives an indication of the validity of the (trends in the) fuel sales data. Figure 3.12 shows the time series for both fuel sold and fuel used for gasoline (including bioethanol) and diesel (including biodiesel) in road transport.

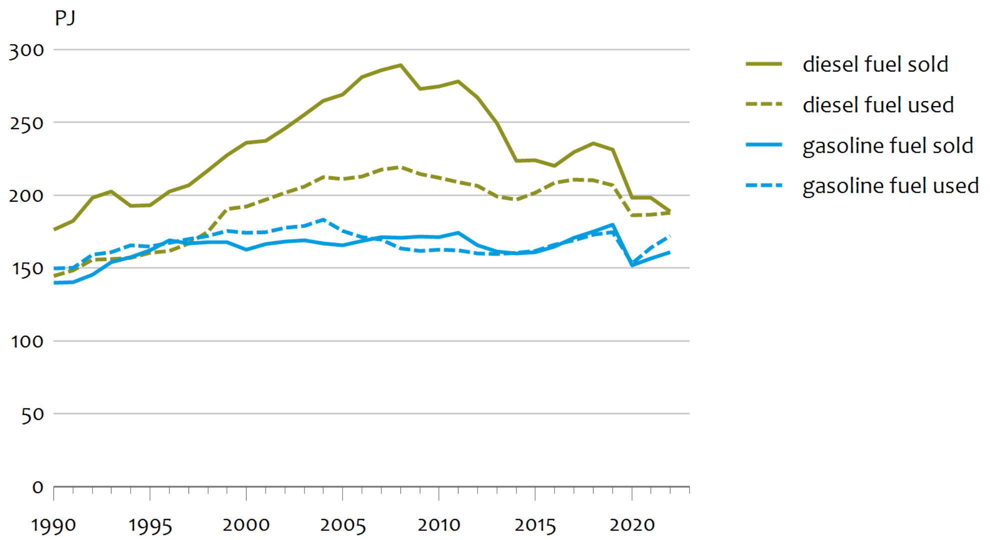


Figure 3.12 Fuel sold and fuel used for road transport in the Netherlands, 1990-2022

Between 1990 and 2022, the time series for fuel sold and fuel consumed show a strong correspondence for LPG and, as Figure 3.12 shows, somewhat less so for gasoline. However, the time series for diesel deviate: even though the trend is mostly comparable, diesel sales on Dutch territory were substantially higher than diesel consumption. The differences ranged between 12% and 37%. In recent years the difference between fuel used and fuel sold has almost disappeared.

The difference between diesel used and diesel sold in the 1990–2020 period can partly be explained by the use of diesel in long-haul distribution trucks which can travel several thousand kilometres on a full tank. Diesel fuel sold to long-haul trucks in the Netherlands is mostly consumed abroad and is therefore not included in the diesel consumption on Dutch territory. Although this omission is partially offset by the consumption by trucks that travel in the Netherlands but do not refuel here, it is expected that the impact of Dutch long-haul trucks refuelling in the Netherlands is dominant, given the small size of the country.

In order to validate the activity data for railways and waterborne navigation, as derived from the Energy Balance, the trends in fuel sales data for both source categories are compared with trends in transport volumes. Trends in energy use for waterborne navigation closely correspond with trends in transport volumes, although this does not necessarily hold for trends in domestic inland navigation. This would suggest that the growth in transport volumes mostly relates to international transport.

For railways, the correspondence between diesel deliveries and freight transport volumes is weak. This can be explained by the electrification of rail freight transport, with the exception for shunting activity which remain mainly on diesel. Figures compiled by Rail Cargo (2007, 2013) make clear that in 2007, only 10% of all locomotives used in the Netherlands were electric, whereas by 2012, the proportion of electric locomotives had increased to over 40% , due to the electrification of most freight rail lines. For this reason, there has been a decoupling of transport volumes and diesel deliveries in recent years in the time series. Consequently, the decline in diesel consumption for railways, as derived from the Energy Balance, is deemed plausible.

3.2.6.5 Category-specific recalculations

New data was derived from the Energy Balance, and the GHG emissions changed accordingly.

The sales of gasoline to road traffic in the Energy Balance concerns gasoline for road vehicles, NRMM and recreational vessels. Therefore, the change (increase) in the consumption of gasoline by NRMM and recreational vessels, as mentioned in sections 3.2.7 and 3.2.6.2, affects the amount of gasoline for road vehicles (decreases), and as a result, the emissions.

Gasoline consumption for motorcycles and mopeds has decreased due to a modified method in determining traffic performance. This results in a changed allocation of gasoline to other road vehicles.

The allocation of diesel across freight shipping, passenger shipping and recreational shipping has been changed by an adapted method to determine transport performance.

Compared to the NIR 2023: due to changes in activity data in 2021, more diesel has been allocated to heavy commercial vehicles and less to NRMM and light commercial vehicles in 2021.

By including new activity data on diesel consumption by agriculture into the Energy Balance in 2021, a reallocation of diesel has taken place. As a result, diesel sales to NRMM (sector 1A4c) decreased by 2 PJ in 2021 and diesel sales to road traffic increased by 2 PJ in 2021.

The allocation of LPG to road traffic has been improved. The allocation of LPG previously involved an allocation that was based on the use of the group of other fuels (LPG, CNG, LNG, hydrogen, alcohol, etcetera) and now concerns an allocation that is based on this group, excluding LNG and CNG. As a result, from 2010 onwards, less LPG has been allocated to heavy commercial vehicles and buses, and more LPG has been allocated to passenger cars and light commercial vehicles. For 2022, this means a major shift of 1.2 PJ (-98%) in LPG from heavy commercial vehicles and buses to passenger cars (+41%, 0.9 PJ) and light commercial vehicles (+37%, 0.3 PJ).

As mentioned before, the transport activity data has been updated. This resulted in the following changes in emissions (in Gg):

1A3b Road transportation

1A3b	**1990**	**2000**	**2005**	**2010**	**2015**	**2019**	**2020**	**2021**
CO_2	-11.41	-38.09	-50.18	-60.90	-4.42	-32.52	-11.84	67.45
CH_4	-0.35	-0.15	-0.13	-0.11	-0.09	-0.11	-0.10	-0.16
N_2O	0.00	0.00	0.00	0.00	0.01	0.00.	0.00	0.01

1A3bi Cars

1A3bi	**1990**	**2000**	**2005**	**2010**	**2015**	**2019**	**2020**	**2021**
CO_2	132.45	91.63	17.66	-85.10	-33.66	45.65	40.87	64.31
CH_4	0.04	0.01	0.01	0.00	0.00	0.00	0.00	-0.01
N_2O	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

1A3bii Light duty trucks

1Abii	**1990**	**2000**	**2005**	**2010**	**2015**	**2019**	**2020**	**2021**
CO_2	30.51	45.23	-102.53	-283.90	-72.25	-51.44	-61.55	-109.44
CH_4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.01
N_2O	0.00	0.00	0.00	-0.01	0.00	0.00	0.00	0.00

1A3biii Heavy duty trucks and buses

1A3biii	**1990**	**2000**	**2005**	**2010**	**2015**	**2019**	**2020**	**2021**
CO_2	-78.28	-108.92	110.64	379.15	168.08	51.08	76.25	175.34
CH_4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.05
N_2O	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01

1A3biv Motorcycles

1A3biv	**1990**	**2000**	**2005**	**2010**	**2015**	**2019**	**2020**	**2021**
CO_2	-96.09	-66.02	-75.95	-71.06	-66.58	-77.81	-67.41	-62.75
CH_4	-0.40	-0.16	-0.13	-0.11	-0.09	-0.11	-0.09	-0.09
N_2O	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

1A3d Domestic navigation

1A3d	**1990**	**2000**	**2005**	**2010**	**2015**	**2019**	**2020**	**2021**
CO_2	-17.13	1.33	12.84	22.51	28.80	42.07	45.19	47.02
CH_4	-0.01	0.00	0.01	0.01	0.02	0.03	0.03	0.03
N_2O	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

3.2.6.6 Category-specific planned improvements

No category-specific improvements have been planned.

3.2.7 Other sectors (1A4)

3.2.7.1 Source category description

Table 3.18 and Figure 3.13 present the subcategories and emissions trends in sector 1A4.

Table 3.18 Overview of emissions in the Other sectors (1A4) in the base year and the last two years of the inventory

Sector/category	Gas	1990	2021	2022	2022 vs 1990	Contribution to total in 2022 (%) by		
		Emissions in Tg CO_2-eq			%	sector	total gas	total CO_2-eq
1A4. Other sectors	CO_2	39.1	32.8	26.0	-33.5%	22.0%	19.7%	16.4%
	CH_4	0.6	1.8	1.4	113.2%	1.1%	7.3%	0.9%
	N_2O	0.0	0.1	0.1	14.1%	0.0%	0.8%	0.0%
	All	39.7	34.7	27.4	-31.1%	23.2%		17.3%
1A4a. Commercial/Institutional	CO_2	8.4	6.7	5.7	-32.0%	4.8%	4.3%	3.6%
	CH_4	0.1	0.0	0.0	-13.1%	0.0%	0.2%	0.0%
1A4a Natural gas	CO_2	7.8	6.4	5.4	-30.8%	4.5%	4.1%	3.4%
1A4b. Residential	CO_2	20.8	17.0	13.5	-35.2%	11.4%	10.2%	8.5%
	CH_4	0.5	0.4	0.3	-32.1%	0.3%	1.8%	0.2%
1A4b Natural gas	CO_2	19.9	16.8	13.3	-33.1%	11.3%	10.1%	8.4%
1A4c. Agriculture/Forestry/Fisheries	CO_2	9.9	9.1	6.8	-31.3%	5.7%	5.1%	4.3%
	CH_4	0.1	1.3	1.0	1096.3%	0.8%	5.2%	0.6%
1A4c liquids	CO_2	2.5	1.7	1.6	-35.8%	1.4%	1.2%	1.0%
1A4c Natural gas	CO_2	7.3	7.4	5.1	-29.8%	4.4%	3.9%	3.2%

Sector 1A4 comprises following key categories:

1A4	Liquids excl. 1A4c	CO_2
1A4a	Commercial/Institutional: gaseous	CO_2
1A4b	Residential gaseous	CO_2
1A4b	Residential: all fuels	CH_4
1A4c	Agriculture/Forestry/Fisheries: liquids	CO_2
1A4c	Agriculture/Forestry/Fisheries: gaseous	CO_2
1A4c	Agriculture/Forestry/Fisheries: all fuels	CH_4

Sub-category 1A4a (Commercial and institutional services) comprises commercial and public services, such as banks, schools and hospitals, and services related to trade (including retail) and communications; it also includes emissions from the production of drinking water and miscellaneous combustion emissions from waste handling activities and from wastewater treatment plants (WWTPs) as well as emissions from non-road mobile machinery (NRMM) used in the trade sector.

Sub-category 1A4b (Residential) relates to fuel consumption by households for space heating, water heating, and cooking. Space heating uses about three-quarters of the Netherlands' total consumption of natural gas. The residential sub-category also includes emissions from NRMM used by households.

Sub-category 1A4c (Agriculture, forestry and fisheries) comprises stationary combustion emissions from agriculture, horticulture, greenhouse horticulture, cattle breeding, and forestry. It also includes emissions from agricultural NRMM (1A4cii) and from fishing (1a4ciii).

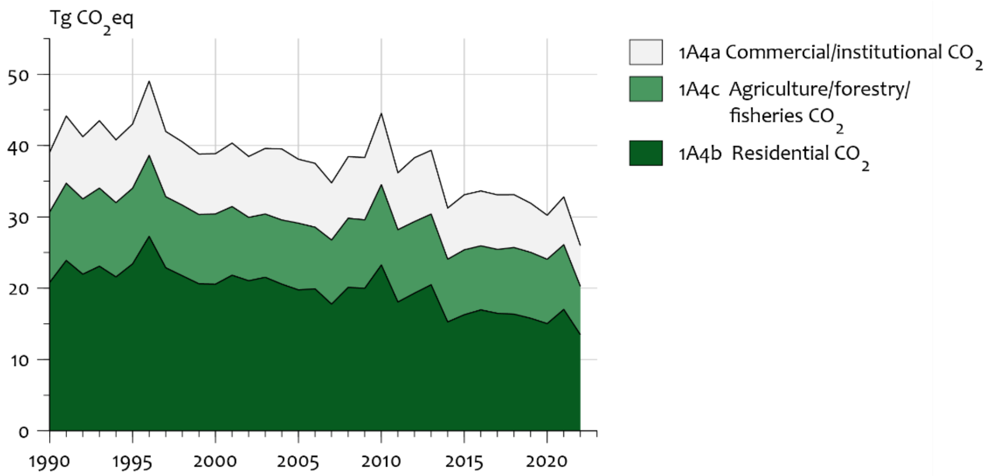


Figure 3.13 1A4 Other sectors – emissions levels of source categories, 1990–2022

Commercial and institutional services (1A4a)
CO_2 emissions in the Commercial and institutional services (1A4a) sub-category have decreased since 1990. The interannual variations in emissions are mainly caused by temperature: more natural gas is used during cold winters (e.g. 1996 and 2010), less in warm winters (e.g. 2014).

Energy use by NRMM used in trade increased from 6.4 PJ in 1990 to 6.7 PJ in 2021, with CO_2 emissions increasing accordingly. Energy use consists mostly of diesel fuel, although some gasoline is used, and in recent years, the use of biofuels has increased.

Residential (1A4b)
When corrected for the interannual variation in temperature, the trend in total CO_2 emissions (i.e. in gas consumption) is steady, with interannual variations of less than 5%. Only for the year 2022, a larger decrease can be seen, which is caused by the high natural gas prices (resulting in less heating by households).
The annual variations are much larger for liquid and solid fuels because of the smaller figures. Emissions from biomass consumption relate almost entirely to wood combustion.

In the residential category, CO_2 emissions have decreased since 1990 even though the number of households has increased. This is mainly due to the improved insulation of dwellings and the increased use of high-efficiency boilers for central heating.

Energy consumption by NRMM used in the residential sector decreased from 1.5 PJ in 1990 to 1.0 PJ in 2022, with CO_2 emissions decreasing accordingly. Energy use consists only of gasoline, and in recent years biofuels have also been applied.

Agriculture, forestry and fisheries (1A4c)
Most of the energy in this source sub-category is used for space heating and water heating, although some is used for cooling. The major fuel used is natural gas; hardly any solid fuels are used. NRMM used in

agriculture mostly uses diesel oil, although some biofuel and gasoline is used. Fishing mostly uses diesel oil combined with some residual fuel oil.

Total CO_2 emissions in the Agriculture, forestry and fisheries sub-category have decreased since 1990, mainly due to a decrease in gas consumption for stationary combustion as a result of various energy conservation measures. For example, in greenhouse horticulture the surface area of heated greenhouses has increased but their energy consumption has been reduced.

Part of the CO_2 emissions from the agricultural sector consists of emissions from cogeneration facilities which can also provide electricity to the national grid.

In addition, since the autumn of 2005, CO_2 emissions from two plants have been used for crop fertilisation in greenhouse horticulture. Total annual amounts are approximately 0.4 Tg CO_2. Because this CO_2 is delivered by two plants for crop fertilisation, less natural gas is combusted by the sector for producing CO_2 for crop fertilisation.

The CH_4 emissions in the Agriculture, forestry and fisheries sub-category have increased since 1990, due to the shift from natural gas combustion in boilers to the natural gas combustion in gas engines. The increase in CH_4 emissions is the result of the higher CH_4 emission factor for gas engines.

GHG emissions from agricultural NRMM (1A4cii) have been relatively constant throughout the time series, ranging between 1.0 and 1.4 Tg CO_2-eq.

CO_2 emissions from fisheries have significantly decreased, from 1.3 Tg in 2000 to 0.3 Tg in 2022. This is due to the decline in the number of fishing vessels in the Netherlands since 1990, along with a decrease in their engine power.

3.2.7.2 Methodological issues

Details of methodologies, data sources and country-specific source allocation issues are provided in:

- Honig et al. (2024), section 2.1: Stationary combustion;
- Visschedijk et al. (2024), chapters 21 and 25: Residential wood combustion and charcoal use;
- Geilenkirchen et al. (2024), chapter 9: Non-road mobile machinery.

This section provides a brief description of the methodology applied to stationary combustion (1A4ai, 1A4bi and 1A4ci) and mobile combustion (1A2gvii, 1A4aii, 1A4bii, 1A4cii and 1A4ciii).

Stationary combustion

The emissions from this source category are estimated by multiplying fuel use statistics by IPCC default and country-specific EFs (Tier 1 and Tier 2 method for CO_2 and CH_4 and Tier 1 method for N_2O).

Activity data
The activity data used in this sector is mainly derived from energy statistics supplied by Statistics Netherlands. For the following emission sources, other activity data is used:

- The activity data for charcoal consumption in barbecues is based on energy statistics from Statistics Netherlands and corrected for annual meat consumption.
- The activity data for residential wood combustion is based on (six-yearly) surveys by Statistics Netherlands; the results of these surveys are used to prepare a complete time series. See Visschedijk et al. (2024) for more details on these wood combustion statistics.
- The activity data for landfill gas is available from landfill site operators.

Emission factors
The following EFs are used for stationary combustion: for CO_2, IPCC default EFs are used (see Annex 5) for all fuels except natural gas, gas/diesel oil, LPG, and gaseous biofuels for which country-specific EFs are used. The Netherlands' list of fuels (Zijlema, 2024) specifies whether the EFs are country-specific or IPCC default values. For CH_4, country-specific EFs are used for all fuels except solid biomass and charcoal. For natural gas in gas engines, a higher EF is used than for boilers (see Honig et al., 2024). The CH_4 country-specific EF for residential gas combustion includes start-up losses, a factor mostly neglected by other countries. For N_2O, IPCC default EFs are used.

The IEF for CH_4 emissions from natural gas combustion in the residential sector (1A4bi) is the aggregate of the standard EF for gas combustion of 5.7 g/GJ plus the 35 g/GJ of total residential gas combustion that represents start-up losses. These occur mostly in cooking devices, but also in central heating and hot-water production devices. This results in an EF of 40.7 g/GJ. CH_4 emissions from start-up losses are six times higher than the CH_4 combustion emissions.

The IEF for CH_4 emissions from natural gas combustion in the agricultural sector (1A4ci) is an average of the EF gas engines and other stationary combustion. The increased use of internal combustion engines in CHP plants operating on natural gas has increased the IEF for methane in this category, as these engines are characterised by high methane emissions.

Mobile combustion

- Emissions from fisheries (1A4ciii) are calculated on the basis of IPCC Tier 2 methodologies. Fuel use data is combined with country-specific EFs for CO_2. CH_4 and N_2O emissions from fisheries are derived using a Tier 1 methodology. The EFs are presented in Geilenkirchen et al. (2024).
- Fuel consumption by NRMM is derived from the Energy Balance, which in turn uses the output of the EMMA model (Dellaert et al., 2024). CO_2 emissions from NRMM are estimated using a Tier 2 methodology (for the EF). Country-specific heating values and CO_2 EFs are used, as for road transport.

- CH_4 and N_2O emissions from NRMM are estimated using a Tier 3 methodology, using country-specific EFs. CH_4 EFs are presented in table 9.6. of Geilenkirchen et al. (2024).

Table 3.19 Overview of methods used for the calculation of emissions for NRMM and fisheries

CRF code	Source category description	Method	EF
1A2gii	Industry and construction	T2, T3	CS
1A4aii	Commercial/institutional	T2, T3	CS
1A4bii	Residential	T2, T3	CS
1A4cii	Agriculture/Forestry	T2, T3	CS
1A4aiii	National Fishing	T1, T2	CS, D

CS: Country-specific, D: Default

General

For 2022, more than 99% of the CO_2 emissions in 1A4 were calculated using country-specific EFs (mainly natural gas). The remaining (less than) 1% of CO_2 emissions were calculated by means of default IPCC EFs. These consist mainly of emissions from other kerosene and lignite.

An overview of the IEFs used for the most important fuels (up to 95% of the fuel use) in the *Other sectors (1A4)* is provided in Table 3.20.

Table 3.20 Overview of IEFs used for the most important fuels (up to 95% of fuel use) for the year 2022 in Other sectors (1A4)

Fuel	Amount of fuel used in 2022 (TJ NCV)	IEFs (g/GJ)		
		CO_2 (x 1000)	N_2O	CH_4
Natural gas	421,748	56.5	0.1	102.5
Solid biomass	24,947	113.5	4.1	186.1
Gas / Diesel oil	24,668	72.5	1.8	2.3

Explanations of the IEFs

- Natural gas: The standard CH_4 EF for natural gas is 5.7 g/GJ. Only for gas engines is a higher EF used (due to gas slip), which explains the higher EF for this sector.
- Gas/diesel oil: Gas/Diesel oil is used in stationary and mobile combustion for which different EFs for CH_4 and N_2O are used.
- Solid biomass: The implied CO_2 EF for solid biomass consists of a combination of wood combustion with an EF of 112 kg/GJ and solid biomass combustion with an EF of 109.6 kg/GJ. The implied CH_4 EF for solid biomass consists of a combination of residential wood combustion (with an EF of 140 g/GJ) and wood combustion in the services and agricultural sector (with an EF of 300 g/GJ).

Trends in the IEFs for most sectors can be explained by the composition of fuels used in that sector. The largest fluctuations are visible in the CH_4 EF for gaseous fuels. This is caused by the difference in CH_4 EF used for natural gas combusted in gas engines (ranging between 250 and 450 g/GJ) and the CH_4 EF used for natural gas combusted in other plants (5.7 g/GJ). Figure 3.14 shows the trend in natural gas combusted in gas engines and in other plants. The increase between 2005 and 2010 can be explained by the increased installation of gas engines in the agricultural sector in that period.

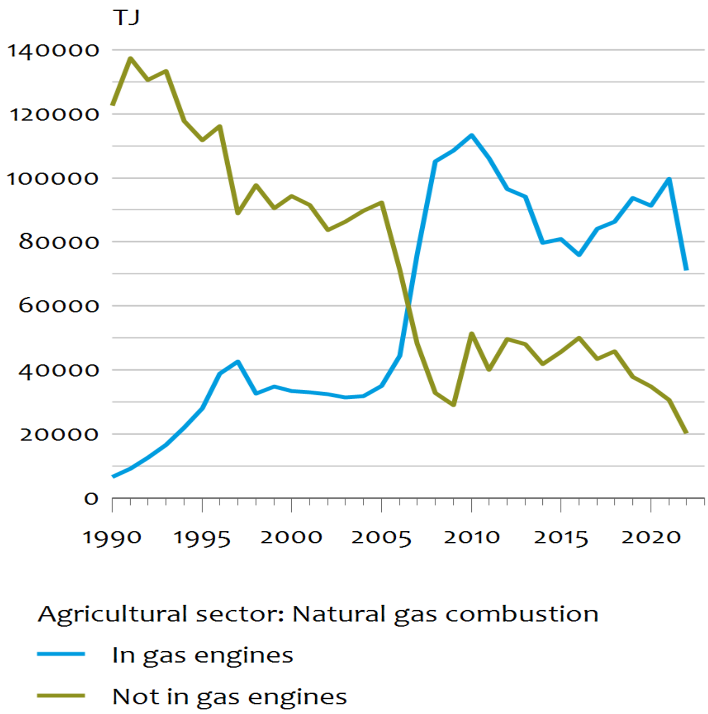


Figure 3.14 Trend in natural gas consumption in gas engines (with a relatively high emission factor) and other engines (with a relatively low emission factor) in the agricultural sector, 1990–2022

3.2.7.3 Uncertainty and time series consistency

Uncertainty

The uncertainty in total CO_2 emissions from this source category is approximately 5%, with uncertainty concerning the composite parts of approximately 5% for the Residential category, 10% for the Agriculture category, and 10% for the Services category (see Annex 2 for more details).

The uncertainty in the gas consumption data is similarly estimated at 5% for the Residential category, 10% for Agriculture, and 11% for the Services category. An uncertainty of 34% is assumed for liquid fuel use in the Services and Residential category. Since the uncertainty in small values in national statistics is generally greater than in larger values, as indicated by the high interannual variability of the data, the uncertainty in solid fuel consumption is estimated to be even higher, i.e. 36%.

For natural gas, the uncertainty in the CO_2 EF is estimated at 0.25% on the basis of the fuel quality analysis reported by Heslinga and Van Harmelen (2006) and discussed in Olivier et al. (2009). To the CO_2 EFs for liquids and solids, uncertainties of 2% and 10% respectively have been assigned. The uncertainty in the CH_4 and N_2O EFs is estimated to be much higher (50-100%).

As most of the fuel consumption in this source category is used for space heating, consumption has varied considerably per year due to variations in winter temperatures. For trend analysis, a method is used to correct the CO_2 emissions from gas combustion (the main fuel for heating purposes) for the varying winter temperatures. This involves the use of the number of 'heating degree days' under normal climate conditions, which is determined by the long-term trend, as explained in Visser (2005).

The uncertainty in activity data for NRMM is estimated to be 35-50% for diesel, 2% for gasoline, and 5% for LPG, as reported in Geilenkirchen et al. (2024). The uncertainty in the EFs is estimated to be 2% for CO_2 (all fuels): 50%/+300% for N_2O and -40%/+250% for CH_4. The CO_2 estimate was assumed to be equal to the estimate for road transport fuels, which in turn was based on expert judgement. The estimates for CH_4 and N_2O were derived from the 2006 IPCC Guidelines.

Time series consistency
Emissions from stationary energy combustion are calculated from the energy statistics combined with country-specific EFs (at the beginning of the time series) or from a combination of company-specific and country-specific EFs (at the end of the time series). Time series consistency is ensured for EFs and activity data: The country-specific EFs are based on company-specific data. Company-specific data from the most relevant companies in a number of years has been used to calculate an average country-specific EF. As the same information is used to calculate both the country-specific EF and the company-specific EFs, the EFs are consistent for the complete time series.
Energy statistics are consistent for the complete time series, as these are derived from the same data source (Statistics Netherlands).

3.2.7.4 Category-specific QA/QC and verification

Trends in CO_2 emissions from the three sub-categories were compared to trends in related activity data: number of households, number of people employed in the services sector, and the total surface area of heated greenhouses. Large annual changes were identified and explanations were sought (e.g. interannual changes in CO_2 emissions, by calculating temperature-corrected trends to identify the anthropogenic emissions trends). The trend tables for the IEFs were then used to identify large changes and large interannual variations at the category level, for which explanations were sought and included in the NIR. Changes in the IEF are mainly due to changes in the type of fuel used. Furthermore, the IEFs of individual fuels are also compared to the default emission factors, and deviations from the standard EFs are explained in the NIR. More details on the validation of the energy data can be found in Honig et al. (2024).

NRMM data and model
Significant effort was invested in recent years into checking and verification of NRMM modelling and outcomes.

As of 1 January 2022, all vehicles, including mobile machinery, that access the public road with a speed above 6 km/h must be registered in a national database and obtain a licence plate, similar to the existing registration of passenger cars and other road transport vehicles. This public database, maintained by the RDW (Dienst Wegverkeer, an administrative body of the Dutch government), can be queried and, for the first time, makes available a relatively complete overview of the Dutch NRMM fleet, which was notably lacking before. As the registry contains information on machine type, fuel type, and date of entry, this allows a further comparison with and validation of the modelled machine fleet, resulting in continuous updates to the model, especially to the estimated machine sales for some machinery types (see section 3.2.7.5.).

The modelled diesel usage for NRMM has been compared to a time series of 'red diesel' sales in the Netherlands between 1990 and 2012, compiled by Statistics Netherlands. Over this period, a separate excise duty rate for diesel sales to NRMM existed, providing a reference value for comparison with the model outcome. After implementing the model improvements discussed in section 3.2.7.5., the modelled diesel usage correlates slightly better with the available diesel sales statistics. For the 2009-2011 period, following the economic crisis, the model appears to underestimate the effect of the crisis and overestimates the diesel usage by 15-20%, compared to the sales statistics, indicating that further model improvements may be needed.

3.2.7.5 Category-specific recalculations

Stationary combustion

The energy statistics for 2015-2021 have been improved. The main improvements are evident in natural gas consumption in the commercial/institutional sector (1A4ai), in solid biomass combustion in the residential sector (as a result of a new method that also considers the increasing prices for natural gas in 2021 (1A4bi) and in natural gas and LPG consumption in the agricultural sector (1A4ci).
The changes in energy statistics (including the other small changes) resulted in the following changes in emissions (in Gg for fossil and biogenic emissions together):

1A4ai	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
CO_2	44.885	38.188	17.940	6.634	-2.226	0.829	57.588
CH_4	0.004	0.004	0.002	0.001	-0.000	0.000	0.012
N_2O	0.000	0.000	0.000	0.000	-0.000	0.000	0.000

1A4bi	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
CO_2	0.261	0.014	0.092	0.000	-0.417	0.002	43.730
CH_4	0.000	0.000	0.000	0.000	-0.000	0.000	0.056
N_2O	0.000	0.000	0.000	0.000	-0.000	0.000	0.004

1A4ci	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
CO_2	7.945	13.803	14.724	22.154	35.676	40.322	-18.354
CH_4	0.001	0.001	0.001	0.002	0.004	0.004	0.025
N_2O	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Non-road Mobile Machineries

Several updates have been implemented into the model and the input data:

1. For several machine types, previous rough estimates of the historical machine sales have been improved by analysing the size and composition (incl. construction year) of the current fleet for these machines, as registered in the RDW database on NRMM (see section 3.2.7.4.).
2. For several types of machinery used in gardening and landscaping (e.g. lawnmowers, chainsaws), fleet introduction data has been updated and improved, resulting in an increase in petrol consumption and related emissions.
3. The N_2O emission factor for diesel machinery has been updated, introducing a higher factor for diesel engines using selective catalytic reduction (SCR) aftertreatment (to reduce emissions of NO_x). The new emission factor is based on the EMEP/EEA Guidebook on NRMM.
4. A new diesel consumption total for agriculture has been provided by Wageningen Economic Research for the year 2021, resulting in a substantial decrease in 2 PJ of diesel in sector 1A4c, and also resulting in a reallocation/increase of emissions to heavy-duty trucks (1A3biii). GHG emissions are based on the amount of diesel sold, which has resulted in a shift of diesel from NRMM to road traffic in 2021 in sector 1A3b.

The changes that are described result in a modest increase of gasoline consumption and related emissions over the full time series. Furthermore, there is a significant increase in N_2O emissions from NRMM in recent years, where SCR after treatment is increasingly used in the NRMM fleet.

The gasoline sales to road traffic in the Energy Balance concerns gasoline for road vehicles, NRMM and recreational vessels. Therefore, the change (increase) in gasoline use for NRMM affects the amount of gasoline to road vehicles (decrease).

Diesel sales to NRMM are recorded as such in the Energy Balance. The diesel use of NRMM in Agriculture (1A4c.ii) and Construction industry (1A2g.vii) is in line with the Energy Balance. However, this is not yet the case for diesel intended for the NRMM in Industry (also part of 1A2g.vii). Diesel consumption data is used for the NRMM in Industry. The difference with the diesel sales data in the Energy Balance for NRMM in Industry (1A2g.vii) is attributed to diesel sales to the NRMM in Commercial/Institutional (1A4a.ii) in order to be in accordance with the Energy Balance for the total sales of diesel to NRMM. A detailed description of the methodology currently used for calculating GHG emissions for NRMM is provided in chapter 2 of Geilenkirchen et al. (2024).

As mentioned before, the activity data on NRMM has been updated. This resulted in the following changes in emissions (in Gg):

1A2g.vii Manufacturing industries and construction off–road vehicles and other machinery

1A2gvii	**1990**	**2000**	**2005**	**2010**	**2015**	**2019**	**2020**	**2021**
CO_2	102.16	61.44	13.00	0.83	-1.09	4.36	4.13	1.78
CH_4	-0.12	-0.07	-0.01	0.04	0.04	0.03	0.03	0.03
N_2O	0.00	0.00	0.00	0.00	0.00	0.02	0.02	0.02

1A4a.ii Commercial/institutional off–road vehicles and other machinery

1A4aii	**1990**	**2000**	**2005**	**2010**	**2015**	**2019**	**2020**	**2021**
CO_2	38.56	-122.54	-177.49	-261.23	-185.16	-159.90	-127.08	-135.20
CH_4	0.05	0.04	0.04	0.05	0.04	0.04	0.04	0.03
N_2O	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

1A4b.ii Residential off-road vehicles and other machinery

1A4bii	**1990**	**2000**	**2005**	**2010**	**2015**	**2019**	**2020**	**2021**
CO_2	-2.44	-1.96	-2.71	1.72	-1.44	-2.18	-3.05	-4.14
CH_4	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01
N_2O	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

1A4c.ii Agriculture/forestry/fishing off-road vehicles and other machinery

1A4cii	**1990**	**2000**	**2005**	**2010**	**2015**	**2019**	**2020**	**2021**
CO_2	22.04	20.18	18.93	19.63	20.42	14.18	15.10	-130.68
CH_4	-0.11	-0.10	-0.05	-0.03	-0.02	-0.01	-0.01	-0.01
N_2O	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.02

Fishing

The activity data on diesel and residual fuel oil has been updated for the 2010-2021 period. The CO_2 emission factors for diesel have been updated for the complete time series. This resulted in the following changes in emissions (in Gg):

1A4ciii Fishing

1A4ciii	**1990**	**2005**	**2010**	**2015**	**2019**	**2020**	**2021**
CO_2	-0.27	-0.52	29.14	0.31	0.28	0.32	0.27
CH_4	-	-	0.00	-0.00	0.00	-0.00	-0.00
N_2O	-	-	0.00	-0.00	0.00	-0.00	-0.00

3.2.7.6 Category-specific planned improvements

No category-specific improvements for stationary combustion have been planned.

As a major new source of information on the NRMM fleet has become available in 2022 (see section 3.2.7.4.), additional analysis of the new RDW registry is likely to result in further updates and model improvements in the NRMM calculation.

3.2.8 Other (1A5)

3.2.8.1 Source category description

Source category 1A5 (Other) consists of emissions from military aviation and navigation (in 1A5b); see Table 3.21. This sector has no key categories.

Table 3.21 Overview of emissions in the sector Other (1A5) in the base year and the last two years of the inventory

Sector/category	Gas	1990	2021	2022	2022 vs 1990	Contribution to total in 2022 (%) by		
		Emissions in Tg CO_2-eq			%	sector	total gas	total CO_2-eq
1A5 Other	CO_2	0.3	0.2	0.2	-32.6%	0.2%	0.2%	0.1%
	CH_4	0.0	0.0	0.0	-44.1%	0.0%	0.0%	0.0%
	N_2O	0.0	0.0	0.0	-42.9%	0.0%	0.0%	0.0%
	All	0.3	0.2	0.2	-32.8%	0.2%	0.2%	0.1%

3.2.8.2 Methodological issues

A country-specific top-down (Tier 2) method is used for calculating the emissions from fuel combustion from military aviation and navigation. Activity data for both aviation and navigation is derived from the National Energy Statistics and comprises all fuel delivered for military aviation and navigation purposes within the Netherlands, including fuel deliveries to militaries of other countries; the EFs are presented in Table 3.22. The CO_2 EFs were derived from the Ministry of Defence. whereas the EFs for N_2O and CH_4 were derived from Hulskotte (2004).

Table 3.22 Emission factors used for military marine and aviation activities.

Category		CO_2	CH_4	N_2O
Military ships	EF (g/GJ)	75.250	2.64	1.87
Military aviation	EF (g/GJ)	72.900	10.00	5.80
Total	Emissions in 2022 (Gg)	212	0.02	0.01

Source: Hulskotte (2004)

3.2.8.3 Uncertainty and time series consistency

The uncertainty in total CO_2 emissions from this source category is approximately 6%. Uncertainties for CH_4 and N_2O emissions from this category are substantially higher: 83% for CH_4 and 123% for N_2O.

3.2.8.4 Category-specific QA/QC and verification

The source category is covered by the general QA/QC procedures discussed in Chapter 1.

3.2.8.5 Category-specific recalculations

Activity data has been updated for military ships and aviation in 2015-2021. This resulted in the following changes in emissions (in Gg):

1A5b. Other: Mobile

	2015	2016	2017	2018	2019	2020	2021
CO_2	0.048	0.017	0.000	0.001	0.000	0.006	0.001
CH_4	0.000	0.000	0.000	0.000	0.000	0.000	0.000
N_2O	0.000	0.000	0.000	0.000	0.000	0.000	0.000

3.2.8.6 Category-specific planned improvements

No category-specific improvements have been planned.

3.3 Fugitive emissions from fuels (1B)

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

- 1B1 Solid fuels (coke manufacture);
- 1B2 Oil and gas (production, gas processing, hydrogen plant, refineries, transmission, distribution).

The following categories are key categories:

1B2	Fugitive emissions from oil and gas operations	CO_2
1B2c	Venting and flaring	CH_4

Table 3.23 shows that total GHG emissions in 1B decreased from 3.1 Tg CO_2-eq to 1.5 Tg CO_2-eq between 1990 and 2022.

Table 3.23 Overview of emissions in the Fugitive emissions from fuels sector (1B) in the base year and the last two years of the inventory

Sector/category	Gas	1990	2021	2022	2022 vs 1990	Contribution to total in 2022 (%) by		
		Emissions in Tg CO_2 eq			%	sector	total gas	total CO_2 eq
1B Fugitive emissions from fuels	CO_2	0.9	1.1	1.1	23.8%	0.9%	0.8%	0.7%
	CH_4	2.2	0.4	0.4	-82.5%	0.3%	2.1%	0.2%
	All	3.1	1.5	1.5	-51.8%	1.2%		0.9%
1B1. Solid fuels transformation	CO_2	0.1	0.1	0.1	-35.4%	0.1%	0.1%	0.0%
	CH4	0.0	0.0	0.0	-58.7%	0.0%	0.0%	0.0%
1B2. Oil and Natural Gas and Other Emissions from Energy Productions	CO_2	0.8	1.1	1.0	32.2%	0.9%	0.8%	0.6%
	CH4	2.2	0.4	0.4	-82.6%	0.3%	2.0%	0.2%

3.3.1 Solid fuels (1B1)

3.3.1.1 Source category description

Both CO_2 and CH_4 emissions in this source category are only a small part of the national totals. Fugitive emissions from this category relate to coke manufacture and charcoal production.

- Coke manufacture: The Netherlands currently has only one coke production facility at the Tata Steel iron and steel plant. A second independent coke producer in Sluiskil discontinued its activities in 1999.
- Charcoal production: In the past, another emission source in this category was the production of charcoal. The decrease in CH_4 emissions throughout the time series is explained by changes in charcoal production. Until 2009, the Netherlands had one large charcoal production location that served most of the Netherlands, and it also had a large market share in neighbouring countries. Production at this location stopped in 2010.

3.3.1.2 Methodological issues

Charcoal production

The following EFs have been used: 1990–1997: 0.03 kg CH_4/kg charcoal (IPCC 2006 Guidelines) and 1998–2010: 0.0000111 kg CH_4/kg charcoal (Reumermann and Frederiks, 2002). This sharp decrease in EF was applied because the operator changed from a traditional production system to the Twin Retort system (reduced emissions). More background information can be found in section 2.2.3.1 of the annex 'Methodology for the Calculation of Emissions to Air from the Sectors Energy, Industry and Waste' by Honig et al. (2024).

Coke production

To calculate emissions of CH_4 from coke production, the standard IPCC value of 0.1 g CH_4 /ton of coke produced is used.

CO_2 emissions related to transformation losses from coke ovens form only a relatively small part of the total emissions from the iron and steel industry in the Netherlands. Emission totals for the iron and steel industry can be found in section 3.2.5. The figures for emissions from transformation losses were originally based on national energy statistics of coal inputs and of coke and coke oven gas produced, from which a carbon balance of the losses was calculated. Any non-captured gas was by definition included in the net carbon loss calculation used for the process emissions. Because of uncertainty in the large input and output volumes of the coke oven, the amount of fugitive emissions calculated by means of the mass balance method was unrealistically high. Therefore, the method has been changed and the CO_2 EF for fugitives is determined on the basis of the conservative assumption that about 1% of coke oven input is lost in the form of fugitive emissions.
Industrial producers in the Netherlands are not obliged to report any activity data in their AERs, and only a limited set of activity data is published by Statistics Netherlands. For category 1B1, the production of coke oven coke registered by Statistics Netherlands is reported in the CRF. Detailed information on activity data and EFs can be found in the annex titled 'Methodology for the Calculation of Emissions to Air from the Sectors Energy, Industry and Waste' by Honig et al. (2024).

3.3.1.3 Uncertainty and time series consistency

The uncertainty in annual CO_2 emissions from coke production (included in 1B1b) is estimated to be about 15%. This uncertainty relates to the conservative assumption of the carbon losses in the conversion from coking coal to coke and coke oven gas. The uncertainty in annual CH_4 emissions from coke production and charcoal production is estimated to be about 10%.

The methodology used to estimate emissions from solid fuel transformation is consistent throughout the time series.

3.3.1.4 Category-specific QA/QC and verification

These source categories are covered by the general QA/QC procedures discussed in Chapter 1.

3.3.1.5 Category-specific recalculations

No recalculations have been performed.

3.3.1.6 Category-specific planned improvements

No improvements have been planned.

3.3.2 Oil and natural gas (1B2)

3.3.2.1 Source category description

Emissions from oil and natural gas comprise:

- emissions from oil and gas exploration, production, processing, flaring and venting (CO_2, CH_4, N_2O);
- emissions from oil and gas transmission (CO_2, CH_4, N_2O);
- emissions from gas distribution networks (pipelines for local transport) (CO_2, CH_4);
- emissions from oil refining (CH_4);
- emissions from hydrogen plants (CO_2).

Note that:

- Combustion emissions from oil and gas exploration and production are reported under 1A1c.
- Fugitive emissions from gas and oil exploration and production are included in fugitive emissions from combined venting and flaring (1B2c).
- CO_2 and N_2O combustion emissions from gas transmission are included in 1A3ei (Pipeline transport gaseous fuels). CO_2 process emissions and CH_4 emissions from gas transmission can still be found in 1B2b4 (Gas transmission and storage).
- CO_2 and CH_4 emissions from oil pipelines are included in 1B2a3 (Oil transport). This is consistent with the 2006 IPCC Guidelines.
- Fugitive CO_2 emissions from refineries are included in the combustion emissions reported in category 1A1b, as the fugitive emissions cannot be separated from the total emissions reported under 1A1b. Fugitive CH_4 emissions from refining can still be found in 1B2a4.
- Since the 2007 submission, process emissions of CO_2 from a hydrogen plant of a refinery (about 0.9 Tg CO_2 per year) were reported in 1B2a4. As refinery data specifying these fugitive CO_2 emissions has been available from 2002 onwards (environmental reports (AER) from the plant), these emissions have been re-allocated from 1A1b to 1B2a4.
- Due to the Dutch emission regulation for VOCs all possible sources included in 1B2a5 Distribution of oil products are equipped with abatement measures to capture fugitive emissions. There are no emission factors of CH_4 and CO_2 for this category in the IPCC guidelines and therefore these emissions are considered 'not applicable' (NA) and activity data is considered 'not estimated' (NE).
- There are no relevant emissions expected in the Netherlands in categories 1B2a6 Other, 1B2b6 Other, and 1B2d Other, which all have the notation key 'not occurring' (NO).

Gas production and gas transmission vary according to demand: in cold winters, more gas is produced. The gas distribution network was gradually expanding as new housing estates were being built, but is now stabilised at around $125*10^3$ km. PVC and PE are mostly used as materials for this expansion, replacing cast iron pipelines (see Honig et al., 2024).

The IEF for gas distribution has gradually decreased as the proportion of cast iron pipelines decreased due to their gradual replacement and the expansion of the network. Their present share of the total is less than 2%; in 1990, it was 10%. See the Methodological issues of Gas distribution in section 3.3.2.2.

Since the 1990's, CO_2 and CH_4 emissions from oil and gas production, particularly from flaring and venting, have been significantly reduced. This is due to the implementation of environmental measures to reduce venting and flaring, such as using formerly 'wasted' gas for energy production purposes.

3.3.2.2 Methodological issues

Oil and gas exploration, production, processing, flaring, and venting
Country-specific methods comparable to the IPCC Tier 3 method are used to estimate emissions of fugitive CH_4 and CO_2 from Oil and gas exploration, production and processing, and from venting and flaring (1B2). Each operator uses its own detailed installation data to calculate emissions and reports those emissions and fuel uses in aggregated form in its electronic AER (e-AER). Activity data is obtained from national energy statistics as a proxy and reported in the CRF tables. The data in the statistics can be adjusted retrospectively (changes in definitions/ allocation) and these changes will show up in the CRF tables.

Gas distribution
Since 2004, the gas distribution sector has annually recorded the number of leaks found per material of the pipeline, with detailed information on pipeline length per material. A five-yearly survey of leakages per length, material, and pressure range is conducted, covering the entire length of the grid. Total CH_4 emissions in m^3 are obtained from the Methane Emission from Gas Distribution (*Methaanemissie door Gasdistributie*) annual reports, commissioned by Netbeheer Nederland (Association of Energy Network Operators in the Netherlands) and compiled by KIWA (KiWA, multiple years). In the KIWA annual reports, the CH_4 emissions in m^3 are calculated using a bottom-up method that complies with the Tier 3 methodology described in the 2006 IPCC Guidelines, chapter 4. The IPCC Tier 3 method for calculating CH_4 emissions from gas distribution due to leakages (1B2b5) is based on country-specific EFs calculated from leakage measurements. Because of the availability of new sets of leakage measurements, Netbeheer Nederland commissioned an evaluation of the EFs being applied. As a result, the calculation of emissions of methane from gas distribution was improved for the NIR 2016 (KIWA, 2015).

In earlier submissions, the IPCC Tier 3 method for methane (CH_4) emissions from gas distribution due to leakages was based on two country-specific EFs: 610 m^3 CH_4 per km of pipeline for grey cast iron, and 120 m^3 CH_4 per km of pipeline for other materials.
These EFs were based on only seven measurements at one pressure level of leakage per hour for grey cast iron, and eighteen measurements at three pressure levels for other materials (PVC, steel, nodular cast iron and PE); these were subsequently aggregated to EFs for the pipeline material mix in 2004. As a result of adding a total of forty leakage measurements, an improved set of EFs could be derived. Based on this

total of 65 leakage measurements, the pipeline material mix in 2013, and the results of the leakage survey, three new EFs were calculated: 323 m^3 CH_4 per km of pipeline for grey cast iron, 51 m^3 CH_4 per km of pipeline for other materials with a pressure of <=200 mbar, and 75 m^3 CH_4 per km of pipeline for other materials with a pressure of >200 mbar. Using these improved EFs caused a reduction in the calculated CH_4 emissions for the 1990–2014 period.

Oil and gas transmission
Emissions of CO_2 and CH_4 due to the transmission of natural gas (1B2b4) are obtained from the VG&M ('*safety, health and environment'*) part of the NV Nederlandse Gasunie annual reports. The emissions of CO_2 presented in the annual reports are considered to be combustion emissions and are therefore reported under IPCC category 1A3ei (gaseous). Additionally, to give a complete overview of emissions, the amount of fugitive CO_2 emissions from gas transmission is calculated using the Tier 1 method with the new default IPCC EF of 8.8 E-7 Gg/106 m^3 of marketable Gas, adopted from the 2006 IPCC Guidelines, Chapter 4, Table 4.2.4. This figure has been applied to CRF category 1B2b4 for the whole time series.

For the NIR 2016, emissions of methane from gas transmission were evaluated and improved. As a result of the implementation of Gasunie's LDAR (Leak Detection and Repair) programme, new emissions data for CH_4 became available. Leakages at larger locations, such as the thirteen compressor stations, were all fully measured. In addition, fugitive emissions of methane from each of those locations were added to the emissions in the year after the facilities came into operation. The adjustments of the CH_4 emissions for the smaller locations were based on measurements of a sample from those locations and added for the whole time series. These improvements have been implemented in all submissions from the NIR 2016 onwards.

The emissions of CO_2 and CH_4 from the transport of crude oil are calculated on the basis of the default TIER 1 IPCC emission factors (IPCC 2006, Table 4.2.4), which are converted from kg/m3 to kg/Gg for the situation in the Netherlands. For the activity data, the volume of crude oil transported through the Netherlands to Germany and Belgium, as reported annually by Statistics Netherlands, are used.

Oil refining and hydrogen plant
Fugitive emissions of CH_4 from refineries in category 1B2a4 are based on a 4% share in total VOC emissions reported in the refinery AERs (Spakman et al., 2003) and in recent years have been directly reported in these AERs. These show significant annual fluctuations in CH_4 emissions, as the allocation of the emissions to either combustion or process has not been uniform over time; for more information, see Honig et al. (2024). Also, process emissions of CO_2 from the only hydrogen factory of a refinery in the Netherlands are reported in category 1B2a4. As Dutch companies are not obliged to report activity data, the AERs only include emissions.

The energy input of refineries from national energy statistics is taken as a proxy for activity data for this category and is reported in the CRF tables. The data in the statistics can be adjusted retrospectively (changes in definitions/allocation), and these adjustments will show up in the latest version of the CRF tables.

Detailed information on activity data and EFs of Oil and natural gas (1B2) can be found in section 2.4 of the annex titled 'Methodology for the Calculation of Emissions to Air from the Sectors Energy, Industry and Waste'; Honig et al. (2024).

3.3.2.3 Uncertainty and time series consistency

The uncertainty for flaring is based on expert judgement, estimated to be 50% for the activity data, 5% for the CO_2 emission factor and 50% for the CH_4 emission factor. The uncertainty for venting is estimated to be 50% for the activity data and 20% for the CO_2 and CH_4 emission factors.
For flaring, this uncertainty takes into account the variability in the gas composition of the smaller gas fields. For venting, it accounts for the high CO_2 content of the natural gas produced at some locations.

For CH_4 from gas transport and gas distribution, the uncertainty in the emissions is estimated to be 40% and 50%, respectively. This uncertainty refers to the limited number of actual leakage measurements for various types of materials and pressures, on which the Tier 3 methodology for methane emissions from gas distribution is based.

For CH_4 from oil refining and oil transport, the uncertainty is estimated to be 100% for both sources.

A consistent methodology is used to calculate emissions throughout the time series, relying on, among others, national energy statistics.

3.3.2.4 Category-specific QA/QC and verification

The source categories are covered by the general QA/QC procedures discussed in Chapter 1.

3.3.2.5 Category-specific recalculations

No category-specific recalculations have been performed.

3.3.2.6 Category-specific planned improvements

No improvements have been planned.

3.4 CO_2 transport and storage (1C)

Transport of combustion off-gases (containing CO_2) occurs from energy production facilities to nearby greenhouses to increase the CO_2 content of the greenhouse atmosphere (as a growth enhancer). The emissions from this activity are accounted for in the combustion emissions from the energy producers.

In 2019, a methodology was developed to account for the carbon capture and usage of CO_2 (CCU) from waste incineration facilities. The methodology includes the various types of usage. In earlier years, the amount of carbon capture was insignificant and this amount is still low in

2022; less than 1 kton of CO_2 (fossil and biogenic) was captured and used in the production of bicarbonate. More information is included in section 3.2.4.2.

4 Industrial processes and product use (CRF sector 2)

Major changes in the Industrial processes and product use (IPPU) sector compared to the National Inventory Report 2023

Emissions:	The total GHG emissions of the IPPU sector show a decrease (from 15.6 Tg CO_2-eq in 2021 to 13.8 Tg CO_2-eq in 2022). This was the result of a decrease in, primarily, CO_2 emissions (± -1.4 Tg) and N_2O emissions (± -0.3 Tg CO_2-eq, mainly within the chemical industry.
New key categories:	2A2 Lime production CO_2 2B4 Caprolactam production N_2O 2F6 Other HFC
No longer a key category:	2B7 Soda ash production CO_2
Methodologies:	Reallocation of chemical waste gas emissions from CRF 1A2c to CRF 2B10 resulted in a large increase of emissions in CRF 2, compared to the previous submissions.

4.1 Overview of the sector

Emissions of GHGs in this sector include the following:

- all non-energy-related emissions from industrial activities (including construction);
- all emissions from the use of F-gases (HFCs, PFCs (incl. NF_3) and SF_6), including their use in other sectors;
- N_2O emissions originating from the use of N_2O in anaesthesia and as a propelling agent in aerosol cans (e.g. cans of cream).

Fugitive emissions of GHGs in the Energy sector (not related to fuel combustion) are included in IPCC category 1B (Fugitive emissions). Table 4.1 and Figure 4.1 present the trends in total GHG emissions from the IPPU sector.

In 2022, IPPU contributed 8.7% to total national GHG emissions (including LULUCF) in comparison to 11.5% in 1990. The sector is a major source of N_2O emissions, accounting for 9.6% of total national N_2O emissions in 2022, of which the major share (0.6 Tg CO_2-eq, or 8.6% of total N_2O emissions) came from category 2B (Chemical industry).

Table 4.1 Overview of emissions in the Industrial production and product use sector, in the base year and the last two years of the inventory

Sector/category	Gas	1990	2021	2022	2022 vs 1990	Contribution to total in 2022 (%) by		
		Emissions in Tg CO_2-eq			%	sector	total gas	total CO_2-eq
2. Total Industrial Processes	CO_2	12.0	12.9	11.5	-3.7%	83.5%	8.7%	7.3%
	CH_4	0.4	0.4	0.4	13.1%	3.0%	2.2%	0.3%
	N_2O	6.5	1.0	0.6	-90.1%	4.6%	9.6%	0.4%
	HFC	4.7	1.2	1.0	-77.9%	7.5%	100.0%	0.7%
	PFC	2.4	0.1	0.1	-97.8%	0.4%	100.0%	0.0%
	SF_6	0.2	0.1	0.1	-41.1%	0.9%	100.0%	0.1%
	All	26.1	15.6	13.8	-47.2%	100.0%		8.7%
2A. Mineral industry	CO_2	1.4	1.1	1.1	-22.7%	7.9%	0.8%	0.7%
2B. Chemical industry	CO_2	9.8	11.3	10.0	2.0%	72.7%	7.6%	6.3%
	CH_4	0.3	0.4	0.4	17.6%	2.6%	2.0%	0.2%
	N_2O	6.3	0.9	0.6	-90.9%	4.1%	8.6%	0.4%
	HFC	4.7	0.2	0.1	-96.9%	1.0%	13.9%	0.1%
	PFC	0.0	0.02	0.01		0.1%	23.2%	0.0%
	All	21.1	12.8	11.1	-47.4%	80.7%		7.0%
2C. Metal Production	CO_2	0.5	0.1	0.0	-93.1%	0.2%	0.0%	0.0%
	PFC	2.4	0.01	NO	-100%	0.0%	0.0%	0.0%
	All	2.8	0.1	0.0	-98.9%	0.2%		0.0%
2D. Non-energy products from fuels and solvent use	CO_2	0.2	0.3	0.3	81.8%	2.5%	0.3%	0.2%
	CH_4	0.0	0.0	0.0	109.4%	0.0%	0.0%	0.0%
	All	0.2	0.3	0.3	81.8%	2.5%		0.2%
2E. Integrated circuit or semiconductor	PFC	0.02	0.04	0.04	77.0%	0.3%	76.8%	0.0%
2F. Product uses as substitutes for ODS	HFC	NO	0.9	0.9		6.5%	86.1%	0.6%
2G. Other	CO_2	0.0	0.0	0.0	102.3%	0.0%	0.0%	0.0%
	CH_4	0.1	0.1	0.1	-11.5%	0.4%	0.3%	0.0%
	N_2O	0.2	0.1	0.1	-65.1%	0.5%	1.1%	0.0%
	SF_6	0.21	0.12	0.13	-41.1%	0.9%	12.1%	0.1%
	All	0.5	0.2	0.2	-47.6%	0.9%		0.1%
2H. Other process emissions	CO_2	0.07	0.01	0.02	-65.6%	0.2%	0.0%	0.0%
Indirect CO_2 emissions	CO_2	0.9	0.5	0.5	-50.1%	3.0%	0.3%	0.3%

Sector/category	Gas	1990	2021	2022	2022 vs 1990	Contribution to total in 2022 (%) by		
			Emissions in Tg CO_2-eq		%	sector	total gas	total CO_2-eq
National total GHG emissions (incl. CO_2 LULUCF)	CO_2	168.4	143.9	132.1				
	CH_4	36.3	19.1	18.5				
	N_2O	16.1	7.1	6.6				
	HFCs	4.7	1.2	1.0				
	PFCs	2.4	0.1	0.1				
	SF_6	0.2	0.1	0.1				
	All	228.1	171.5	158.4				

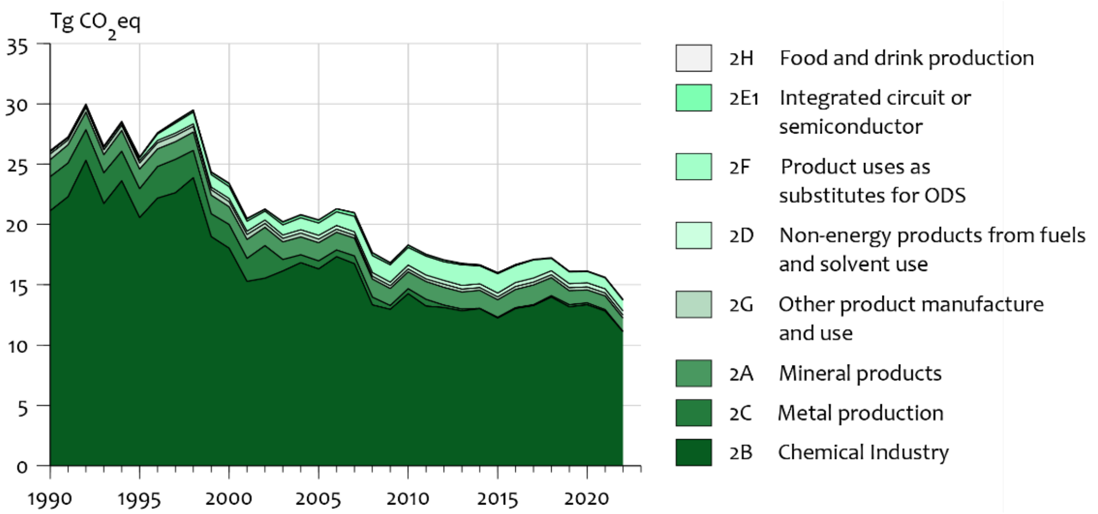


Figure 4.1 Sector 2 Industrial processes and product use – trends and emissions levels of source categories, 1990–2022

Figure 4.1 shows two major decreases in emissions in the chemical industry (2B); one in 1999 due to a reduction in HFC-23 emissions from HCFC-22 production, the second in 2008 as a result of the production of nitric acid under EU-ETS regulation, resulting in a sharp reduction in N_2O emissions.

In the Netherlands, many industrial processes take place in one or two companies. Because of the sensitivity of data from these companies, only total emissions are reported, in accordance with the Aarhus Convention. Emissions at installation level and production data are treated as confidential unless a company has no objection to publication. All confidential information is, however, available for the inventory compilation, and the ENINA Task Force has direct access to it. ENINA can also provide this information to official review teams once they have signed a confidentiality agreement.

In response to review recommendation (E.2, 2022) and in line with the IPCC 2006 Guidelines (vol. 3, Chapter 1, box 1.1 and vol. 3, Chapter 3.9.4.2), the emissions from combustion of waste gases occurring within the same source category are allocated to CRF 2. This includes chemical waste gas and phosphor oven gas emissions from the chemical industry (reported in CRF 2B10).

The main categories (2A–H) in the IPPU sector are discussed in the following sections.

4.2 Mineral products (2A)

4.2.1 Category description

Table 4.2 presents the CO_2 emissions related to the sub-sectors in this category 2A.

Table 4.2 Overview of the sector Mineral Industry (2A), in the base year and the last two years of the inventory

Sector/category	Gas	1990	2021	2022	2022 vs 1990	Contribution to total in 2022 (%) by		
		Emissions in Tg CO_2-eq			%	sector	total gas	Total CO_2-eq
2A. Mineral industry	CO_2	1.4	1.1	1.1	-22.7%	7.9%	0.8%	0.7%
2A1. Cement production	CO_2	0.4	0.0	0.0	-100.0%	0.0%	0.0%	0.0%
2A2. Lime production	CO_2	0.2	0.2	0.2	22.6%	1.4%	0.2%	0.1%
2A3. Glass production	CO_2	0.1	0.1	0.0	-100.0%	0.0%	0.0%	0.0%
2A4a Ceramics	CO_2	0.1	0.1	0.1	-8.4%	0.9%	0.1%	0.1%
2A4b Other uses of Soda Ash	CO_2	0.1	0.1	0.1	67.7%	0.8%	0.1%	0.1%
2A4d Other	CO_2	0.5	0.6	0.6	34.5%	4.7%	0.5%	0.4%

Sector 2A comprises the following key categories:

2A1	Cement production	CO_2
2A2	Lime production	CO_2
2A4d	Other	CO_2

The following processes are included in 2A4a: production of bricks, roof tiles, floor tiles, wall tiles, vitrified clay pipes and refractory products, and other ceramic products. Process-related CO_2 emissions from ceramics originate from the calcination of carbonates in the clay.

CO_2 emissions from other process-uses of carbonates (2A4d) originate from:

- limestone use for flue gas desulphurisation (FGD);
- limestone and dolomite use in iron and steel production;
- dolomite consumption (mostly used for road construction).

4.2.2 Methodological issues

For all the source categories, the methodologies used to estimate emissions of CO_2 comply with the 2006 IPCC Guidelines, volume 3. More detailed descriptions of the methods and EFs used can be found in section 2.2.3.2 ‘Non-fossil process emissions’ of the methodology report Honig et al. (2024).

2A1 (Cement clinker production)

Because of changes in raw material composition over time, it is not possible to reliably estimate CO_2 process emissions on the basis of clinker production activity data and a default EF. For that reason, the only cement producer in the Netherlands chose to base the calculation of CO_2 emissions on the carbonate content of the process input (Honig et al., 2024). Thus, process emission data was obtained from the company's AER until June 2020, when the company closed down. Since no cement production has taken place since, NO has been reported from the emission year 2021 onwards.

2A2 (Lime production)

CO_2 emissions occur in two plants in the sugar industry, where limestone is used to produce lime for sugar juice purification. Limestone use depends on the level of beet sugar production. This activity data is obtained from the sugar company's annual reports. Approximately 375 kg of limestone is required for each ton of beet sugar produced (SPIN, 1992).
The emissions are calculated using the IPCC default EF of 440 kg CO_2 per ton of limestone. Activity data is available from the environmental reports of the two plants for 1990 and from 2003 onwards. Interpolation was performed for the years 1991-2002.
Lime production does not occur in the paper industry in the Netherlands.

2A3 (Glass production)

Until the 2015 submission, CO_2 emissions were based on plant-specific EFs and gross glass production; for the method, see Honig et al. (2024). From the 2015 submission onwards, the CO_2 figures have been based on the verified EU-ETS Emission Reports of the glass production companies.

2A4a (Ceramics)

The calculation of CO_2 emissions from the manufacturing process of ceramic products in the Netherlands complies with the Tier 1 method as described in the 2006 IPCC Guidelines, volume 3, Chapter 2, sect. 2.34, and based on Olivier et al (2009):

$$CO_2 \text{ emissions} = Mc \times (0.85EFls + 0.15EFd)$$

Where:

Mc = mass of carbonate consumed (tonnes);
0.85 = fraction of limestone;
0.15 = fraction of dolomite;
EFls = EF limestone (0.440 ton CO_2/ton limestone);
EFd = EF dolomite (0.477 ton CO_2/ton dolomite).

Based on Olivier et al (2009).
The mass of carbonate consumed (Mc) is determined as follows:

$$Mc = Mclay \times cc$$

Where:

Mclay = amount of clay consumed, calculated by multiplying the national production data for bricks and roof tiles, vitrified clay pipes, and refractory products by

the default loss factor of 1.1 from the 2006 Guidelines. National production data is obtained from the ceramics trade organisation.
cc = default carbonate content of clay (0.1), adopted from the 2006 Guidelines.

2A4b (Other uses of soda ash)
For 2001 and 2002, net domestic consumption of soda ash was estimated by taking the production capacity of 400 kton as a basis, then adding the import figures and deducting the export figures for the relevant year. For 1990–2000 and from 2003 onwards, these figures have been estimated by extrapolating from the 2001 and 2002 values. This extrapolation incorporates the trend in chemicals production as this is an important user of soda ash. Emissions are calculated using the standard IPCC EF of 415 kg CO_2 per ton of soda ash (Na_2CO_3) (2006 IPCC Guidelines, volume 3, Chapter 2, Table 2.1).

2A4d (Other)
This category consists of three components. CO_2 emissions are based on:

- *consumption of limestone for flue gas desulphurisation (FGD) in the coal-fired power plants:* emission data is obtained from ETS-reports;
- *limestone and dolomite use in crude steel production*: from 2000 onwards, data reported in the AERs of Tata Steel has been used to calculate CO_2 emissions for the 1990–2000 period, CO_2 emissions have been calculated by multiplying the average IEF (107.9 kg CO_2 per ton of crude steel produced) over the 2000–2003 period by crude steel production, using the IPCC default EF (limestone use: EF = 0.440 t/t; dolomite use: EF = 0.477 t/t);
- *apparent dolomite consumption (mostly in road construction):* these emissions are calculated by means of the following formula: CO_2 emissions from dolomite use = (Total net dolomite use – Dolomite use in agriculture) * EF dolomite. Total net dolomite use is available until 2003 from Statistics Netherlands. It is assumed that the emissions by this sector have remained constant from 2004 onwards.

4.2.3 Uncertainty and time series consistency

Uncertainty
The uncertainty analysis outlined in Annex 2 and presented in Table A2.3 provides the estimates of uncertainties per IPCC source category. Uncertainty estimates used in the Tier 1 analysis are based on expert judgement as no detailed information is available on the emissions reported by the facilities (cement clinker production, limestone and dolomite use, and soda ash production).

For the emission categories under 2A, uncertainties are in the range of 50-75%. This is mainly determined by the relatively high uncertainty in the emission factors, although for ceramics (2A4a) and lime production (2A2) the activity data is also relatively uncertain; 50% and 75%, respectively.

The uncertainties of the IPCC default EFs used for some processes are not assessed. However, as these are minor sources of CO_2, this absence of data has not been given any further consideration.

Time series consistency
Consistent methodologies have been applied to all source categories. The time series involves a certain amount of extrapolation with respect to the activity data for soda ash use and emissions data for glass production, thereby introducing further uncertainties in the earliest part of the time series for these sources.

4.2.4 Category-specific QA/QC and verification
The source categories are covered by the general QA/QC procedure discussed in Chapter 1.

4.2.5 Category-specific recalculations
No category-specific recalculations have been performed.

4.2.6 Category-specific planned improvements
An error has been identified in the 2022 emissions during the initial checks by the EU on the inventory of the Netherlands. Inadvertently, the CO_2 emissions of 2A3 in 2022 are a factor 1000 too low. As the underlying dataset has already been finalised and this deviation is below the threshold of significance, we have included this as a specific point of improvement and we will ensure that this issue is corrected in the 2025 submission.

4.3 Chemical industry (2B)

4.3.1 Source category description
The national inventory of the Netherlands includes emissions of GHGs from the following source categories reported in category 2B (Chemical industry):

- *Ammonia production (2B1): CO_2 emissions*: natural gas is used as feedstock for ammonia production. CO_2 is a by-product of the chemical separation of hydrogen from natural gas. During the process of ammonia (NH_3) production, hydrogen and nitrogen are combined and react together to form ammonia.
- *Nitric acid production (2B2): N_2O emissions*: The production of nitric acid (HNO_3) generates N_2O, a by-product of the high-temperature catalytic oxidation of ammonia. Two companies are responsible for the N_2O emissions from nitric acid production in the Netherlands.
- *Caprolactam production (2B4a): N_2O emissions*: Caprolactam is produced in the Netherlands as part of the production cycle for nylon materials, and has been manufactured by one company since 1952. As a result, this emission source is responsible for all (100%) N_2O emissions by the caprolactam industry in the Netherlands. N_2O emissions from caprolactam production in the Netherlands are not covered by the EU-ETS.
- *Silicon carbide production (2B5a): CH_4 emissions*: petrol cokes are used during the production of silicon carbide. The volatile compounds in the petrol cokes form CH_4.

- *Titanium dioxide production (2B6): CO_2 emissions*: these arise from the oxidation of coke used as a reductant.
- *Soda ash production (2B7): CO_2 emissions:* these are related to the non-energy use of coke.
- *Petrochemical and carbon black production (2B8): emissions:* For each subsector below one plant is present in the Netherlands:
  - methanol: CH_4 (2B8a);
  - ethylene: CH_4 (2B8b);
  - ethylene oxide: CO_2 (2B8d);
  - acrylonitrile: CO_2/CH_4/N_2O (2B8e);
  - carbon black: CH_4 (2B8f).
- *Fluorochemical production (2B9):*
  - *by-product emissions – production of HCFC-22 (2B9a1): HFC-23 emissions:* Chlorodifluoromethane (HCFC-22) is produced at one plant in the Netherlands. Tri-fluoromethane (HFC-23) is generated as a by-product during the production of chlorodifluoromethane and emitted through the plant condenser vent;
  - *by-product emissions – other – handling activities (2B9b3): emissions of HFCs:* one company repackages HFCs from large units (e.g. containers) into smaller units (e.g. cylinders) and trades in HFCs. Many companies import small units with HFCs and sell them in the trading areas.
- *Other (2B10): CO_2 emissions*:
  - *Industrial gas production:* Hydrogen and carbon monoxide are mainly produced from the use of natural gas as a chemical feedstock. During the gas production process, CO_2 is emitted.
  - *Carbon electrode production:* For the production of carbon electrodes, (petroleum) coke is used as a feedstock. During this process, CO_2 is emitted.
  - *Activated carbon production:* the Netherlands is home to one of world's largest manufacturers of activated carbon, for which peat is used as a carbon source, and CO_2 is a by-product.
- *Other (2B10):* CO_2, CH_4 and N_2O emissions:
  - Combustion emissions of waste gases (chemical waste gas and phosphor oven gas) occurring within the same category where the waste gases are produced (i.e. the chemical sector) have been reallocated from 1A2c to 2B10 in response to review recommendation (E.2, 2022) and in line with the IPCC 2006 Guidelines (vol. 3, Chapter 1, box 1.1 and vol. 3, Chapter 3.9.4.2). The IPCC 2006 Guidelines (vol. 3, Chapter 1, box 1.1) state that "Combustion emissions from fuels obtained directly or indirectly from the feedstock for an IPPU process will normally be allocated to the part of the source category in which the process occurs. These source categories are normally 2B and 2C. However, if the derived fuels are transferred for combustion in another source category, the emissions should be reported in the appropriate part of Energy Sector source categories (normally 1A1 or 1A2)". Therefore, all combustion emissions from chemical waste gas which are produced and combusted within the chemical sector have been reallocated from 1A2c to 2B10.

Remarks:
- Adipic acid (2B3), glyoxal (2B4b), glyoxylic acid (2B4c) and calcium carbide (2B5b) are not produced in the Netherlands. As a result, the Netherlands does not report these emissions in the CRF under 2B.
- Many processes relating to this source category take place in only one or two companies. Because of the company data confidentiality requirements, emissions from 2B5 and 2B6 are included in 2B8g.

Overview of shares and trends in emissions
Table 4.3 gives an overview of the proportions of emissions from the main category Chemical Industry (2B). Emissions from this category contributed 9.3% of the total national GHG emissions (including LULUCF) in 1990 and 7.0% in 2022.

Table 4.3 Overview of the sector Chemical industry (2B), in the base year and the last two years of the inventory

Sector/category	Gas	1990	2021	2022	2022 vs 1990	Contribution to total in 2022 (%) by		
		Emissions in Tg CO_2-eq			%	sector	total gas	total CO_2-eq
2B. Chemical industry	CO_2	9.8	11.3	10.0	2.0%	72.7%	7.6%	6.3%
	CH_4	0.3	0.4	0.4	17.6%	2.6%	2.0%	0.2%
	N_2O	6.3	0.9	0.6	-90.9%	4.1%	8.6%	0.4%
	HFC	4.7	0.2	0.1	-96.9%	1.0%	13.9%	0.1%
	PFC	0.0	0.0	0.0		0.1%	23.2%	0.0%
	All	21.1	12.8	11.1	-47.4%	80.7%		7.0%
2B1. Ammonia production	CO_2	2.7	2.1	1.8	-31.7%	13.3%	1.4%	1.2%
2B2. Nitric acid production	N_2O	5.4	0.2	0.1	-97.5%	1.0%	2.0%	0.1%
2B4. Caprolactam production	N_2O	0.7	0.4	0.1	-81.1%	0.9%	1.9%	0.1%
2B7. Soda ash production	CO_2	0.1	0.0	0.0	-100.0%	0.0%	0.0%	0.0%
2B8. Petrochemical and carbon black production	CO_2	0.3	0.6	0.5	62.7%	4.0%	0.4%	0.3%
	CH_4	0.3	0.4	0.4	17.4%	2.6%	1.9%	0.2%
2B9. Fluorochemical production	HFC	4.7	0.2	0.1	-96.9%	1.0%	13.9%	0.1%
	PFC	NO	0.0	0.0		0.1%	23.2%	0.0%
2B10. Other chemical industry	CO_2	6.7	8.6	7.6	13.4%	55.4%	5.8%	4.8%

This sector comprises the following key categories:

2B	Fluorochemical production	HFC
2B1	Ammonia production	CO_2
2B2	Nitric acid production	N_2O
2B8	Petrochemical and carbon black production	CO_2
2B8	Chemical industry: Petrochemical and carbon black production	CH_4
2B10	Other	CO_2
2B10	Other	N_2O

Figure 4.2 shows the trend in CO_2 equivalent emissions for category 2B (Chemical industry) in the 1990–2022 period.

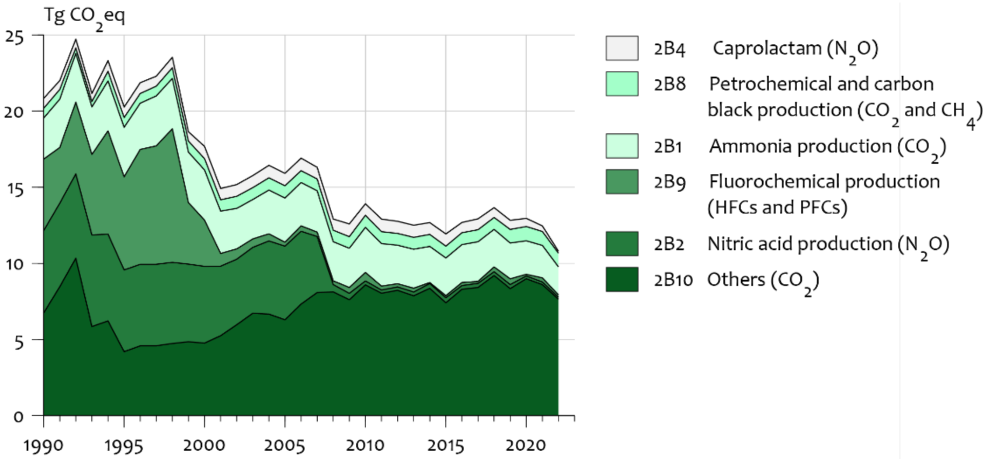


Figure 4.2 2B Chemical industry – trend and emissions levels of source categories, 1990–2022

Mainly due to a reduction in HFC-23 emissions from HCFC-22 production (by implementation of a thermal convertor in 1998), total GHG emissions from 2B (Chemical industry) decreased between 1990 and 2001. Between 2001 and 2007, total GHG emissions from 2B also remained stable. As Figure 4.2 (above) and Table 4.4 (below) show, the main decrease in N_2O emissions took place in 2008 as a result of a reduction measure relating to the production of nitric acid. From 2008 onwards, this process has been brought under EU-ETS. A major reduction was achieved by a change in the nitric acid production process. Since 2008, total GHG emissions from 2B have remained relatively stable.

Table 4.4 Trend in N_2O emissions from Chemical industry (2B) (Gg CO_2-eq)

Year	2B2 Nitric acid production	2B4a Caprolactam production	2B8e Acrylonitrile production	Total
1990	5411	658	219	6288
1991	5486	585	220	6290
1992	5539	577	224	6340
1993	6016	532	220	6767
1994	5698	697	234	6628
1995	5367	691	240	6298
1996	5353	706	248	6307
1997	5353	652	255	6260
1998	5327	688	262	6277
1999	5096	615	270	5981
2000	5042	803	277	6122
2001	4565	741	284	5591
2002	4301	770	292	5363
2003	4326	792	299	5417
2004	4802	819	306	5927

Year	2B2 Nitric acid production	2B4a Caprolactam production	2B8e Acrylonitrile production	Total
2005	4837	816	313	5967
2006	4784	824	321	5929
2007	3680	766	329	4775
2008	477	731	335	1544
2009	421	837	343	1600
2010	257	752	350	1360
2011	208	824	327	1358
2012	225	795	348	1369
2013	243	798	330	1372
2014	317	777	339	1432
2015	329	802	302	1433
2016	240	672	341	1253
2017	266	714	348	1328
2018	251	646	309	1206
2019	264	600	342	1206
2020	178	534	379	1091
2021	180	367	359	905
2022	134	124	312	570

Nitric acid production (2B2)
Technical measures (optimising the platinum-based catalytic converter alloys), which were implemented at one of the nitric acid plants in 2001, resulted in an emissions reduction of 9% compared to 2000. During 2002–2006, the emissions fluctuations were caused by variations in production levels.

Technical measures (as a result of bringing production under the EU-ETS) implemented at all nitric acid plants in the third quarter of 2007 resulted in an emission reduction of 23% compared to 2006. In 2008, the full effect of the measures was reflected in lower emissions; a reduction of 90% compared to 2006. The further reduction in 2009 was primarily caused by the economic crisis. Because of the closure of one of the plants and an improved catalytic effect in another, emissions decreased again in 2010. The reduction in 2011 was caused by an improved catalytic effect in two of the plants. After 2011, the fluctuations in N_2O emissions from the nitric acid plants were mainly caused by operating conditions (such as unplanned stops) and to a lesser extent by variations in production level.

In former NIRs (such as the 2020 NIR), all significant reduction measures for N_2O emissions from nitric acid production in 2007 and 2008 have been described, with details per plant.

Caprolactam production (2B4a) and Acrylonitrile production (2B8e)
As a result of government funding, a reduction measure was implemented in the caprolactam production plant in 2021, resulting in

lower 2B4a emissions. Furthermore, the fluctuations in emissions from these sources are mainly caused by variations in production level.

Fluorochemical production (2B9)
Table 4.5 presents the trends in HFC emissions from the categories HCFC-22 production and HFCs/PFCs from handling activities during the 1990–2022 period. Emissions of HFC-23 increased by approximately 35% in the 1995–1998 period due to increased production of HCFC-22. However, in the 1998–2000 period, emissions of HFC-23 decreased by 69% following the installation of a thermal converter (TC) at the plant. The removal efficiency of the TC (kg HFC-23 processed in TC/kg HFC-23 in untreated flow/year) is the primary factor, and the production level is the secondary factor influencing the variation in emission levels between 2000 and 2008.

Due to the economic crisis, HCFC-22 production levels were much lower in the last quarter of 2008 and 2009, resulting in lower HFC-23 emissions. Following the economic recovery, the HCFC-22 production was much higher in 2010, resulting in higher HFC-23 emissions. After 2010, emission fluctuations are mainly caused by the fluctuations in the removal efficiency of the TC and to a lesser extent by the production level. The significant emission fluctuations in sub-category 2B9b3 (Handling activities) during the 1992–2022 period can be explained by the large fluctuations in handling activities, which depend on customer demand.

Table 4.5 Trends in HFC-23 by-product emissions from the production of HCFC-22 and HFC emissions from handling activities (2B9a and 2B9b) (Gg CO_2-eq)

Year	2B9a: HFC-23	2B9b3: HFCs	Total
1990	4697	0	4697
1991	3658	0	3658
1992	4687	25	4712
1993	5243	52	5295
1994	6653	131	6784
1995	6103	12	6116
1996	7299	248	7547
1997	7110	667	7777
1998	8257	517	8774
1999	3646	397	4043
2000	2566	470	3035
2001	726	112	837
2002	477	202	679
2003	440	116	556
2004	376	93	469
2005	208	44	252
2006	297	44	342
2007	257	28	285
2008	225	19	243

Year	2B9a: HFC-23	2B9b3: HFCs	Total
2009	163	126	289
2010	414	102	516
2011	176	41	217
2012	133	60	192
2013	199	35	234
2014	38	23	61
2015	99	29	127
2016	133	18	151
2017	85	25	110
2018	186	24	210
2019	229	101	329
2020	81	20	101
2021	216	29	245
2022	129	15	144

4.3.2 *Methodological issues*

For all chemical industry source categories, the methodologies used to estimate GHG emissions

- should *not* be subtracted from the production emissions.
- 2B2 (Nitric acid production): The emissions figures are based on data reported by the nitric acid manufacturing industry and are included in the emissions reports under EU-ETS and the national Pollutant Release and Transfer Register (PRTR). In the years before these were available, an IPCC Tier 2 method was used to estimate N_2O emissions. Until 2002, N_2O emissions from nitric acid production were based on IPCC default EFs. N_2O emissions measurements made in 1998 and 1999 resulted in a new EF of 7.4 kg N_2O/ton nitric acid for total nitric acid production. Plant-specific EFs for the 1990–1998 period are not available. Therefore, these EFs were used to recalculate emissions for the 1990–1998 period.
- 2B4a (Caprolactam production): From 2015 onwards, N_2O emissions have been obtained from the company's AER. Results for 2005–2014 were recalculated with the help of the insights provided by the updated and improved N_2O emissions measurement programme. The 1990–2004 values were recalculated using the 'new' average IEF for 2005–2015. Information about the methods used before 2015 can be found in Honig et al. (2024), section 4.1.
- 2B5 (Carbide production): The activity data (petcoke) (confidential) and the IPCC default EF are used to calculate CH_4 emissions.
- 2B6 (Titanium dioxide production): Activity data, EF and emissions are confidential. CO_2 emissions are calculated on the basis of the non-energy use of coke and a plant-specific EF.
- 2B7 (Soda ash production): the notation code 'NO' has been included in the CRF tables from 2010 onwards, as soda ash production has stopped. See Honig et al. (2024) for earlier years.

- 2B8 (Petrochemicals and carbon black production):
  - 2B8a: methanol, CH_4;
  - 2B8b: ethylene, CH_4;
  - 2B8e: acrylonitrile, CO_2; CH_4; N_2O;
  - 2B8f: carbon black, CH_4;
  - 2B8g: melamine production, CO_2.

    The CO_2 and CH_4 process emissions from these minor sources are calculated by multiplying the IPCC default EFs by the annual production figures from the AERs (Tier 1). The N_2O emissions from 2017 onwards have been based on measurements. For the 1990–1994 and 2010–2016 periods, the emissions were recalculated with the help of the 2017 emission and production levels and the production levels in both periods. Emissions for the 1995–2009 period are determined by extrapolation between 1994 and 2010.
- 2B8d (Ethylene oxide production): CO_2 emissions are estimated on the basis of capacity data by using a default capacity utilisation rate of 86% (based on Neelis et al., 2005) and applying the default EF of 0.86 t/t ethylene oxide. From 2020 onwards, EU petrochemistry data has been used as a new source. As it is not possible to find current activity data for ethylene production in the Prodcom database from EUROSTAT, the Netherlands cannot supply activity data to verify this assumption. For reasons of confidentiality all above-mentioned sources of 2B8, 2B5 and 2B6 are included in 2B8g.
- 2B9a1 (production of HCFC-22): This source category is identified as a trend key source of HFC-23 emissions. Emission figures are obtained from the company’s AER. This company determines the HFC-23 load in the untreated flow by a continuous flow meter in combination with an in-line analysis of the composition of the stream. The amount of HFC-23 destroyed in the Thermal Converter is registered.
- 2B9b3 (Handling activities: HFCs): Emission figures are obtained from the company’s AER.
- 2B10 (Other), process emissions: Because no IPCC methodologies exist for these processes (and the 2019 Refinement-methodology for H_2 is not implemented yet), country-specific methods and EFs are used. These refer to:
  - The production of industrial gases: With natural gas as input (chemical feedstock), industrial gases, e.g. H_2 and CO, are produced. Originally, emissions were calculated by assuming that CO_2 is stored in the product, for which a storage factor of 80% was derived. However, since 2012, better data is available from the verified ETS emission reports. From these reports, it appeared that no storage of CO_2 occurs in the production of industrial gases, and that a storage factor approach was incorrect. These ETS reports have recently been re-examined resulting in a recalculation for this submission of the 1990-2018 time series. More specifically, this resulted in a recalculation of emissions from 1990 to 2012, and in a shift from combustion (1A2c) to process emissions (2B10) from 2012 onwards.
  - Production of carbon electrodes: CO_2 emissions are estimated on the basis of fuel use (mainly petcoke and coke). A small

oxidation fraction (5%) is assumed, on the basis of data reported in the AERs.
   - Production of activated carbon: From 2013 onwards, CO_2 emissions from activated carbon production in the Netherlands have been included in the EU-ETS. Therefore, as from the 2015 submission, the figures are based on the verified EU-ETS Emission Reports of the activated carbon producer. For the years 2004 and 2005, peat use data has been obtained from the AERs and the emissions have been calculated with the help of the C content of the peat in 2013. For the years before 2003, no peat use and C content data is available. Therefore, emissions for the 1990–2003 period are kept equal to those of 2004. Emissions for the 2005–2012 period have been determined by extrapolation between 2004 and 2013.
- 2B10 (Other), waste gas combustion: The combustion of waste gas is calculated according to the methods described in section 3.2.4.2. For chemical waste gas, company-specific EFs have been derived for a selection of (the largest) companies from 1995 onwards. For the remaining companies, the default EF is used. If data from any of the selected companies was missing, a company-specific EF for the missing company was used (derived in 1995). For the 1990–1994 period, a country-specific EF that is based on an average EF for four (large) companies has been used. For phosphorus gas, company-specific EFs have been derived for the single company and have been used in the emissions inventory (since 2006). For years prior to 2006, EFs from the Netherlands' list of fuels (Zijlema, 2024) are used. This fuel was only used until 2012, when the single company using this fuel ceased operation.

Activity data for estimating CO_2 emissions is based on data for the feedstock use of fuels provided by Statistics Netherlands.

4.3.3 *Uncertainty and time series consistency*

Uncertainty

The uncertainty analysis outlined in Annex 2 (presented in Tables A2.1 and A2.2) provides estimates of uncertainties according to IPCC source categories.

The uncertainty in annual CO_2 emissions from ammonia production is estimated to be in the range of 30%. Uncertainties for other categories are much higher. For 2B8 Petrochemical and carbon black production (both for CO_2 and CH_4) and for category 2B10 Other, uncertainties are in the range of 70%; this is determined by uncertainties in both the activity data and emission factors (both in the range of 50%, estimated by expert judgement).

As N_2O emissions from HNO_3 production in the Netherlands are included in the EU-ETS, all companies continuously measure their N_2O emissions. This has resulted in a lower annual emissions uncertainty of approximately 8%.

The uncertainty in HFC-23 emissions from HCFC-22 production is estimated to be approximately 15%. For HFC emissions from handling activities, the uncertainty is estimated to be about 20%. These figures are all based on expert judgement.

Time series consistency
Consistent methodologies are used throughout the time series for the sources in this category. A certain amount of extrapolation is involved with respect to emission data for acrylonitrile production, thereby introducing further uncertainties for the 1995–2009 period.

4.3.4 Category-specific QA/QC and verification

The source categories are covered by the general QA/QC procedures discussed in Chapter 1.

From 2008 onwards, N_2O emissions from HNO_3 production in the Netherlands have been included in the EU-ETS. For this purpose, the companies developed monitoring plans approved by the NEa (Dutch Emissions Authority). In 2018, the companies' emissions reports (2017 emissions) were independently verified and submitted to the NEa, where they were compared with those reported in the CRF tables for the year 2017. No differences were found between the emissions figures in the CRF tables and those in the emissions reports under EU-ETS. As described under 4.3.2, the availability of ETS reports improved the quality of the calculations. For emission year 2020, the ETS-report and AER of the largest of the two HNO_3 producers in the Netherlands were compared. The reported emissions are exactly the same. However, emission figures for the other HNO_3 producer cannot be compared because it is situated in the Chemelot industrial zone. Chemelot only reports emissions of the total estate to the ETS, not from individual companies. Therefore, no comparison could be made for this smaller producer.

Emissions from petrochemical and carbon black production are either not included in the ETS, or situated on the Chemelot estate (which only reports the total). Therefore, no emission verification to ETS reports can be made.

For the production of HCFC-22 (2B9a1), the operators' data in annual environmental reports (including confidential information) is verified on an annual basis by the competent authority and the Dutch inventory IPPU expert, consecutively.

4.3.5 Category-specific recalculations

CO_2 emissions in 2B1 and 2B10 have been updated for the 2015-2021 period, due to updated energy statistics (use of natural gas as feedstock). Furthermore, we have corrected an error in the CO_2 emissions in 2021 for 2.B.10. This results in the following differences in CO_2 emissions (in kton CO_2):

	2015	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
2.B.1	+0.006	+0.005	+0.004	+0.004	+0.001	+0.078	-0.426
2.B.10	+0.001	+0.001	+0.001	+0.001	+0.001	+0.031	-16.821

Reallocation of waste gas
In response to review recommendation (E.2, 2022) and in line with the IPCC 2006 Guidelines (vol. 3, Chapter 1, box 1.1 and vol. 3, Chapter 3.9.4.2), the emissions from the combustion of chemical waste gas and phosphor oven gas occurring in the same source category (i.e. the chemical sector) have been reallocated from 1A2c to 2B10. This results in increased emissions in 2B10 (in Gg):

2B10	**1990**	**2005**	**2010**	**2015**	**2019**	**2020**	**2021**
CO_2	+5701	+5603	+7899	+6450	+6792	+7584	+7446
CH_4	+0.308	+0.324	+0.396	+0.394	+0.387	+0.441	+0.420
N_2O	+0.009	+0.009	+0.011	+0.011	+0.011	+0.012	+0.012

Please note that part of the emissions were reallocated to 2B1 (instead of to 2B10) in 1993, because these emissions resulted from ammonia production. For other years, this distinction was not possible, and all emissions from the combustion of waste gases in the chemical sector have been allocated to 2B10.

4.3.6 *Category-specific planned improvements*
For future submissions it is intended to apply the 2019 Refinement for hydrogen production.

4.4 Metal production (2C)

4.4.1 *Source category description*
The national inventory of the Netherlands includes GHGs emissions related to two source categories belonging to 2C (Metal production):

- *Iron and steel production (2C1): CO_2 emissions:* the Netherlands has one integrated iron and steel plant (Tata Steel, previously known as Corus and/or Hoogovens). The process emissions from anode use during steel production in the electric arc furnace are also included in this category.
- *Aluminium production (2C3): CO_2 and PFC emissions:* the Netherlands had two primary aluminium smelters: Zalco, previously known as Pechiney (partly closed by the end of 2011) and Aldel (closed by the end of 2013). Towards the end of 2014, Aldel restarted its plant under the name Klesch Aluminium Delfzijl, and in 2017, there was a further restart under the name Damco Delfzijl. Electrolysis ended in 2021, while the rest of the company closed when the company went bankrupt in 2022. Since then, no aluminium production has taken place in the Netherlands.
  CO_2 is produced by the reaction of the carbon anodes with alumina and by the reaction of the anode with other sources of oxygen (especially air). PFCs (CF_4 and C_2F_6) are formed during the phenomenon known as the anode effect, which occurs when the concentration of aluminium oxide in the reduction cell electrolyte drops below a certain level.

The following sources of GHG emissions do not exist in the Netherlands:

- Ferroalloys production (2C2): the small ferroalloy trading companies in the Netherlands do not produce ferroalloys.;
- magnesium production (2C4);
- lead production (2C5);

- zinc production via electro-thermic distillation or the pyrometallurgical process (2C6);
- other metal production (2C7).

Overview of shares and trends in emissions
Table 4.6 provides an overview of emissions in CRF 2C.

Table 4.6 Overview of the Metal production sector (2C), in the base year and the last two years of the inventory

Sector/category	Gas	1990	2021	2022	2022 vs 1990	Contribution to total in 2022 (%) by		
		Emissions in Tg CO_2-eq			%	sector	total gas	total CO_2-eq
2C. Metal Production	CO_2	0.45	0.10	0.03	-93.1%	0.2%	0.0%	0.0%
	PFC	2.37	0.01	NO	-100.0%	0.0%	0.0%	0.0%
	All	2.83	0.12	0.03	-98.9%	0.2%	0.0%	0.0%
2C1. Iron and steel production	CO_2	0.04	0.02	0.02	-63.7%	0.1%	0.0%	0.0%
2C3. Aluminium production	CO_2	0.41	0.08	0.02	-96.3%	0.1%	0.0%	0.0%
	PFC	2.37	0.01	NO	-100.0%	0.0%	0.0%	0.0%

This sector comprises the following key categories:

2C3	Aluminium production	CO_2
2C3	Aluminium production	PFC

From 2003 onwards, the level of the PFC emissions from aluminium production (2C3) has decreased sharply because reduction measures (side feed to point feed) were taken (see Table 4.7). From then on, emissions have depended mainly on the number of anode effects and little on production level. PFC emissions have decreased further since 2011 as a result of the closures of Zalco and Aldel. The restart of Aldel (under the name Klesch Aluminium Delfzijl since 2015, and Damco since 2017) has resulted in increases in PFC emissions from 2015 onwards. Electrolysis ended in 2021, while the rest of the company closed when the company went bankrupt in 2022. This resulted in a reduction of CO_2 emissions in 2022, while PFC emissions did not occur in 2022.

Table 4.7 Emissions of CF_4 and C_2F_6 from Aluminum production (2C3) (Gg CO_2-eq)

Year	PFC14 (CF_4)	PFC116 (C_2F_6)	Total
1990	1,839	535	2,374
1991	1,825	525	2,349
1992	1,659	474	2,132
1993	1,683	472	2,154
1994	1,614	453	2,067
1995	1,566	441	2,007
1996	1,745	474	2,220
1997	1,865	500	2,365
1998	1,372	446	1,819
1999	1,017	394	1,411
2000	1,066	413	1,479
2001	1,018	395	1,414
2002	1,565	642	2,207
2003	349	117	466
2004	89	22	111
2005	74	18	92
2006	51	12	62
2007	82	19	102
2008	60	15	75
2009	36	9	45
2010	51	10	60
2011	71	15	86
2012	13	3	16
2013	8	2	10
2014	0	0	0
2015	5	1	6
2016	10	2	12
2017	10	2	12
2018	17	3	20
2019	20	4	25
2020	20	4	24
2021	12	2	15
2022	NO	NO	0

4.4.2 *Methodological issues*

The methodologies used to estimate GHG emissions in all source categories of metal production comply with the 2006 IPCC Guidelines. More detailed descriptions of the methods and EFs used can be found in Honig et al. (2024: sections 2.1.3.3 and 2.2.3.2 (iron and steel production) and 2.2.3.7 (aluminium production)).

Iron and steel production (2C1)
As mentioned in section 3.2.5 (for sub-category 1A2a), the calculation for this category is based on a carbon mass balance, which is not included in the NIR for reasons of confidentiality but can be made available for review purposes. Process emissions, e.g. from the conversion of pig iron to steel, are also obtained from the carbon mass balance.

CO_2 emissions have been calculated for the 1990–2000 period by multiplying the average IEF (8.3 kg CO_2 per ton of crude steel produced) over the 2000–2003 period by the annual crude steel production. From 2000 onwards, data reported in the carbon mass balance of Tata Steel has been used to calculate CO_2 process emissions.

For anode use in the electric arc furnace, an EF of 5 kg CO_2/ton steel produced is used.

Combustion emissions are reported under 1A1c (flaring), 1A2a, 1B1b (CH_4 coke production).

Aluminium production (2C3)
Up to emission year 2017, a Tier 1a IPCC method (IPCC, 2006) was used to estimate CO_2 emissions from the anodes used in the primary production of aluminium, with aluminium production serving as activity data. From emission year 2018 onwards (2020 submission), the CO_2 figure has been obtained directly from the AERs.

Estimations of PFC emissions from primary aluminium production reported by the two facilities are based on the IPCC Tier 2 method for the 1990–2017 period. EFs are plant-specific and confidential and are based on measured data. From emission year 2018 onwards, the emission data has been obtained from ETS reports.

4.4.3 *Uncertainty and time series consistency*

Uncertainty
The uncertainty analysis explained in Annex 2 provides estimates of uncertainties per IPCC source category. The uncertainty in annual CO_2 emissions is estimated at 5-6% both for iron and steel production and for aluminium production, whereas the uncertainty in PFC emissions from aluminium production is estimated to be in the range of 40%. The uncertainty in the activity data is estimated at 2% for aluminium production and 3% for iron and steel production. The uncertainty in the EFs for CO_2 (from all sources in this category) is estimated at 5%, and the EF for PFC from aluminium production at slightly over 40%.

Time series consistency
A consistent methodology has been used throughout the complete time series.

4.4.4 *Category-specific QA/QC and verification*

The source categories are covered by the general QA/QC procedures discussed in Chapter 1. For the source category 2C1, the activity and emissions data in the AERs was compared with the EU-ETS monitoring reports. No differences were found. The confidential production data for pellet and sinter production can be made available to the review team.

4.4.5 *Category-specific recalculations*

The carbon mass balance for the Tata Steel plant has been updated for the year 2021, resulting in an CO_2 emission correction in 2.C.1.a from 83.4 kton CO_2 in the previous submission to 18.8 kton CO_2 in this submission. The total emission from Tata Steel in 2021 (as reported in CRF 1.A.2.a, 1.B.1.b and 2.C.1.a together) has changed only slightly (+0.68 kton CO_2 in 2021).

4.4.6 *Category-specific planned improvements*

As a result of the 2021 review (question I.24), performing CH_4 process emissions calculations from sinter production was planned for this submission. We did not manage to do so because of lack of time, and setting other priorities, also because this is below the threshold of significance (it will add approximately 0.02 Gg CH_4 to the national total).

4.5 Non-energy products from fuels and solvent use (2D)

4.5.1 *Source category description*

Table 4.8 presents an overview of the sector non-energy products from fuels and solvent use. The CO_2 emissions reported in categories 2D1 and 2D2 stem from the direct use of specific fuels for non-energy purposes, which results in partial or full oxidation during use (ODU) of the carbon contained in the products, e.g. candles. CO_2 emissions reported in category 2D3 stem from urea use in SCR in diesel vehicles.

Table 4.8 Overview of the sector non-energy products from fuel and solvent use (2D), in the base year and the last two years of the inventory

Sector/category	Gas	1990	2021	2022	2022 vs 1990	Contribution to total in 2022 (%) by		
		Emissions in Tg CO_2-eq			%	sector	total gas	total CO_2-eq
2D. Non-energy products from fuels and solvent use	CO_2	0.2	0.3	0.3	81.8%	2.5%	0.3%	0.2%
	CH_4	0.0	0.0	0.0	109.4%	0.0%	0.0%	0.0%
	All	0.2	0.3	0.3	81.8%	2.5%	0.0%	0.2%
2D1. Lubricant use	CO_2	0.1	0.1	0.1	9.6%	0.7%	0.1%	0.1%
2D2. Paraffin wax use	CO_2	0.1	0.2	0.2	109.4%	1.6%	0.2%	0.1%
2D3. Other non-specified	CO_2	NO	0.03	0.03		0.2%	0.0%	0.0%

Overview of shares and trends in emissions

The small CO_2 and CH_4 emissions from 2D1 and 2D2 remained fairly constant between 1990 and 2022. CO_2 emissions from urea use in diesel vehicles (2D3) increased from 0 to 30 kton between 2005 and 2022.

4.5.2 *Methodological issues*

The methodologies used to estimate GHG emissions in 2D1, 2D2 and 2D3 comply with the 2006 IPCC Guidelines, volume 3, as described in Honig et al. (2024), section 2.2.3.1.

A Tier 1 method is used to estimate emissions from lubricants and waxes using IPCC default EFs. For the use of lubricants and waxes, Oxidised During Use (ODU) factors of 20% and 100%, respectively, have been used (adopted from IPCC 2006 Guidelines). CO_2 emissions from urea-based catalysts are estimated by means of a Tier 3 methodology, using country-specific cO_2 EFs for various vehicle types. More detailed descriptions of the method and EFs used can be found in Geilenkirchen et al. (2024).

The activity data is based on fuel use data from Statistics Netherlands.

4.5.3 *Uncertainty and time series consistency*

Uncertainty

The uncertainty analysis outlined in Annex 2 and presented in Tables A2.1 and A2.2 provides estimates of the uncertainties per IPCC source category.

The uncertainty in the CO_2 EF is estimated at approximately 50% in the ODU factor for lubricants. The uncertainty in the activity data (such as domestic consumption of these fuel types) is generally large as it is based on production, as well as on import and export figures. It is also estimated at 50%, resulting in an overall uncertainty of approximately 70% for category 2D1 Lubricant use.
Uncertainties in category 2D2 (Paraffin wax use) and 2D3 (Non-energy products from fuels and solvent use) are high; mostly determined by uncertainties in the activity data (100%). Overall approach 1 uncertainties for these categories are estimated at over 100%.

Time series consistency

Consistent methodologies and activity data have been used to estimate emissions throughout the time series.

4.5.4 *Category-specific QA/QC and verification*

The source categories are covered by the general QA/QC procedures discussed in Chapter 1.

4.5.5 *Category-specific recalculations*

Two recalculations have been implemented in this submission:

2.D.1: Lubricant use:

The activity data for lubricant consumption has been updated for the complete time series. This results in the following changes in CO_2 emissions in 2.D.1 (in kton CO_2):

	1990	**2005**	**2010**	**2015**	**2020**	**2021**
CO_2	+0.36	+0.31	+0.25	+0.05	-0.39	-0.08

2.D.3: Other (urea use):
The activity data for urea consumption in catalytic reduction has been updated, resulting in increased CO_2 emissions for the 2005-2018 period and decreased CO_2 emissions for the 2019-2021 period. The changes are (in kton CO_2):

	2005	2010	2015	2020	2021
CO_2	+3.16	+15.66	+8.28	-3.16	-3.77

4.5.6 Category-specific planned improvements
No improvements have been planned.

4.6 Electronics industry (2E)

4.6.1 Source category description
PFCs (incl. NF_3) and SF_6 are both used and emitted in Semiconductor manufacture. PFC emissions are reported in 2E1, SF_6 emissions are included in 2G2.
PFC and SF_6 emissions from thin-film transistor (TFT) flat panel displays (2E2), Photovoltaics (2E3), Heat transfer fluid (2E4) manufacturing and Other sources (2E5) do not occur in the Netherlands, and are therefore not identified in the inventory.

Overview of shares and trends in emissions
The contribution made by PFC emissions from category 2E to the total national inventory of PFC emissions was 0.01% in 1990 and 76.8% in 2022. The latter figure corresponds to 0.04 Tg CO_2-eq and accounts for 0.03% of national total GHG emissions in 2022 (Table 4.9).

Table 4.9 Overview of the sector Integrated circuit or semiconductor (2E) in the base year and the last two years of the inventory

Sector/category	Gas	1990	2021	2022	2022 vs 1990	Contribution to total in 2022 (%) by		
		Emissions in Gg CO_2-eq			%	sector	total gas	total CO_2-eq
2E1. Integrated circuit or semiconductor	PFC	22.7	36.1	40.3	77.0%	0.3%	76.8%	0.0%

This sector comprises no key categories.

Due to an increasing production level in the semiconductor manufacturing industry, PFC emissions increased from 23 Gg CO_2-eq in the base year to 277 Gg CO_2-eq in 2007. The post-2007 decrease was mainly caused by an intensive PFC (incl. NF_3) reduction scheme (see Table 4.10).

Table 4.10 Emissions trend from the use of PFCs (incl. NF_3) in the Electronics industry (2E1) (Gg CO_2-eq)

Gas	1990	1995	2000	2005	2010	2015	2019	2020	2021	2022
PFC	23	45	236	230	186	77	39	28	36	40

4.6.2 *Methodological issues*

The methodology used to estimate PFC emissions from semiconductor manufacture complies with the 2006 IPCC Guidelines, as described in Honig et al. (2024), section 2.2.3.8.

Activity data on the use of PFCs in semiconductor manufacture was obtained from the only manufacturing company (confidential information); EFs are also confidential. Detailed information on the activity data and EFs can be found in the methodology report (Honig et al., 2024).

4.6.3 *Uncertainty and time series consistency*

Uncertainty

The uncertainty analysis outlined in Annex 2 provides estimates of the uncertainties per IPCC source category. The uncertainty of PFC (incl. NF_3) emissions is estimated at about 25%. The uncertainty in the activity data for the PFC (incl. NF_3) sources is estimated at 5%; for the EFs, the uncertainty is estimated at 25%. All these figures are based on expert judgement.

Time series consistency

Consistent methodologies have been used to estimate emissions from these sources throughout the time series.

4.6.4 *Category-specific QA/QC and verification*

The source categories are covered by the general QA/QC procedures discussed in Chapter 1.

4.6.5 *Category-specific recalculations*

There have been no category-specific recalculations.

4.6.6 *Category-specific planned improvements*

No improvements have been planned.

4.7 Product use as substitutes for ODS (2F)

4.7.1 *Source category description*

The national inventory comprises the following sub-categories within this category:

- stationary refrigeration (2F1): HFC emissions;
- mobile air-conditioning (2F1): HFC emissions;
- foam-blowing agents (2F2): HFC emissions (included in 2F6);
- fire protection (2F3): HFC emissions (included in 2F6);
- aerosols (2F4): HFC emissions (included in 2F6);
- solvents (2F5): HFC emissions (included in 2F6);
- other applications (2F6): HFC emissions from 2F2, 2F3, 2F4 and 2F5 are allocated to 2F6.

In the Netherlands, many processes relating to the use of HFCs take place in only one or two companies. For data sensitivity reasons, only the sum of the HFC emissions of 2F2–2F5 is reported (included in 2F6).

There are no emissions from 2F1b (Domestic refrigeration) in the Netherlands because no HFCs are used for domestic refrigeration. In the 1990s, CFCs were replaced by propane.

Overview of shares and trends in emissions
Due to increased HFC consumption as a substitute for (H)CFC use, the contribution made by HFC emissions from category 2F to national total HFC emissions was 0% in 1990 and 86.1% in 2022. This corresponds with 0.89 Tg CO_2-eq and accounts for 0.6% of national total GHG emissions in 2022 (see Table 4.11).

Table 4.11 Overview of the sector Product use as substitutes for ODS (2F) in the base year and the last two years of the inventory

Sector/category	Gas	1990	2021	2022	2022 vs 1990	Contribution to total in 2022 (%) by		
		Emissions in Tg CO_2-eq			%	sector	total gas	total CO_2-eq
2F. Product uses as substitutes for ODS	HFC	NO	0.91	0.89	100%	6.5%	86.1%	0.6%
2F1. Stationary refrigeration and Mobile air-conditioning	HFC	0.0	0.78	0.76	100%	5.5%	73.7%	0.5%
2F6. Other	HFC	0.0	0.13	0.13	100%	0.9%	12.4%	0.1%

This sector comprises one key category:
2F1 Refrigeration and mobile air-conditioning HFC

From the 2019 submission onwards, the calculation method (via a stock model) for Stationary refrigeration (2F1) has been replaced (see Honig et al., 2024). The new method has used the Refrigerants Registration System to estimate emissions from 2013 onwards. This system is the result of a European mandatory requirement, whereby building owners are required to register refrigerants.

Emissions for 2F1 have been calculated up to 2020. This is the most recent year for which emissions data is available due to delayed reporting. Due to the phasing-out of refrigerants with a high GWP, emissions decreased from 1.028 Tg in 2015 to 0.481 Tg in 2020 (see Table 4.12). In 2017, emissions increased slightly, but decreased rapidly in 2018. This is the result of the phasing-out of some more high-GWP refrigerants. Emission data for 2021 and 2022 was kept equal to 2020.

With the new method, emission figures are available for:
- 4 sectors: Commercial, Industrial, Stationary air cons and Transport refrigeration;
- 4 emission sources: leakage, filling, dismantling and refrigerant management;
- 5 HFCs: HFC-125, HFC-134a, HFC-143a, HFC-23 and HFC-32.

It appears that leakage emissions are the major emissions source from stationary refrigeration. Emissions from refrigerant management, filling, and dismantling are almost negligible.

Table 4.12 Emissions trends per sub-category from the use of HFCs as substitutes for ODS (Gg CO_2-eq)

Year	2F1 Stationary refrigeration HFCs	2F1 Mobile air-conditioning: HFC134a	2F6 Other applications: HFCs	HFCs Total
1990	NO	NO	NO	NO
1991	NO	NO	NO	NO
1992	NO	NO	NO	NO
1993	NO	NO	NO	NO
1994	9	2	57	68
1995	36	8	183	227
1996	84	16	432	532
1997	129	28	680	837
1998	160	49	774	983
1999	188	76	773	1,037
2000	256	111	627	994
2001	329	149	351	828
2002	396	186	165	746
2003	469	222	153	843
2004	537	256	199	992
2005	602	286	141	1,029
2006	666	312	160	1,138
2007	737	333	222	1,293
2008	810	352	242	1,404
2009	868	368	210	1,446
2010	911	372	191	1,474
2011	920	377	273	1,570
2012	952	382	213	1,546
2013	1,138	384	181	1,703
2014	928	385	172	1,486
2015	1,020	386	188	1,594
2016	805	386	199	1,390
2017	907	378	207	1,492
2018	511	363	136	1,010
2019	481	345	134	960
2020	467	329	132	928
2021	467	303	130	900
2022	467	282	129	878

4.7.2 *Methodological issues*

The methodology used to estimate emissions in category 2F comply with the 2006 IPCC Guidelines, volume 3, IPCC Tier 2 methods and are described in Honig et al. (2024), sections 2.2.3.9–2.2.3.11.

The activity data used to estimate emissions of F-gases is derived from the following sources:

- Stationary refrigeration (2F1): until 2012, HFCs consumption data was obtained from the annual reports by PricewaterhouseCoopers. From 2013 onwards, the Refrigerants Registration System has been used to estimate emissions.
- For mobile air-conditioning (2F1), the number of cars (by year of construction) and the number of scrapped cars (by year of construction) were obtained from Statistics Netherlands. The amounts of recycled and destroyed refrigerants were obtained from ARN, a waste-processing facility (personal communication).
- Other applications (2F6): HFC emissions from 2F2, 2F3, 2F4 and 2F5:
  Until the 2016 submission, consumption data on HFCs was obtained from annual reports by PricewaterhouseCoopers. From 2015 onwards, no consumption data on HFCs has been available. Therefore, until the 2021 submission, emissions from these sources were kept equal to the 2014 emissions. From the 2022 submission onwards, a new estimation method has been developed and introduced. Trends from Belgium and Germany have been used to scale the 2014 emissions onwards. This is described in Honig et al. (2024).

Stationary air conditioning (2F1)

From the 2019 submission onwards, figures have been used from the Refrigerants Registration System, which includes information about leakage and the filling of (new) installations and dismantling.
Data collection within the Refrigerants Registration System takes place as follows:

- Data at plant level (amounts of leakages, filling of (new) installations and dismantling) is registered continuously by mechanics at the installation companies.
- The figures are checked by the inspection authorities every other year.
- Following approval, the figures are aggregated and delivered to the NL-PRTR.
- The NL-PRTR calculates the emissions.

Because of the complexity of the system, there is a time-lag for making data available. This means that in this submission, final figures are provided up to and including 2020. The 2021 and 2022 figures are kept equal to the last year for which figures are available (2020).
In the 2025 submission, the 2021 figures from the current submission will be replaced by the final figures for 2021.

As a result of (EU) review comments, IPCC extrapolation methods (Trend Extrapolation or Surrogate Data) were investigated to prevent over- or underestimation in the last two years. However, the Trend Extrapolation is not recommended if the trend is fluctuating. This applies here because the mix of high and lower GWP refrigerants has been random throughout the years and no trend can be detected. Moreover, the Surrogate Data technique is inappropriate because no data can be found that has any correlation with the random-like use of refrigerants with different GWPs. So to conclude, an extrapolation cannot be performed and therefore, the emissions from the last two years are kept at the same level. However, over the past few years, a decreasing trend seems to appear. If this continues over the next years, a Trend Extrapolation method will be considered again. No extrapolation was performed for this submission because the emission seems to have stabilised from 2019 on.

EFs used to estimate emissions of F-gases in this category are based on the following:

- Stationary refrigeration: Until the 2016 submission, annual leak rates from surveys (Baedts et al., 2001) were used. Since the figures from the Refrigerants Registration System are used, implied emission factors can be derived.
- Mobile air-conditioning: Annual leak rates from surveys (Baedts et al., 2001) and other literature (Minnesota Pollution Control Agency, 2009; YU & CLODIC, 2008).
- Other applications (2F6): IPCC default EFs.

More detailed descriptions of the methods and EFs used can be found in the methodology report (Honig et al., 2024), as indicated in section 4.1.

4.7.3 Uncertainty and time series consistency

Uncertainty

The uncertainty analysis outlined in Annex 2 provides estimates of uncertainties per IPCC source category. On the basis of expert judgement, the uncertainty in HFC emissions from HFC consumption is estimated at approximately 40-50%, mostly determined by uncertainties in activity data.

Time series consistency

Consistent methodologies have been used to estimate emissions from Mobile air-conditioning (2F1) and Other applications (2F6).

For Stationary refrigeration (2F1), two methods were used to estimate emissions, as described above. The stock model method was used for the 1990–2012 period, and the Refrigerants Registration System method has been used from 2013 onwards.

For the stock model method, activity data was derived from the sales figures of individual HFCs to the total cooling sector in the Netherlands. Until the 2016 submission, these were available annually via a trade flow study. However, the trade flow study stopped following the 2016 submission (reporting year 2014). From the reporting year 2015 onwards, the annual sales figures has not been sufficiently reliable to allow for a split into the annual filling of new installations and the refilling of existing installations. It has also not been possible to divide the sales among the various subsectors. Therefore, a stock model was set up for the complete sector to determine the refilling of existing installations, the filling of new installations, and other values. To determine these various values, a fixed leakage percentage was used.

The starting year of the stock model was the year in which a certain HFC is used as cooling agent for the first time. The only actual input variables were the sales figures from HFCs. The other parameters (the filling of new installations, total stock, dismantling amounts, emissions) were calculated using the model.
The new method, as used from the 2019 submission onwards (emissions 2013 and further) uses figures from the Refrigerants Registration System that contains data from 2013 onwards. In this system, data about leakages, filling of new installations, dismantling, etcetera is collected from the commercial, industrial, and transport refrigeration and stationary air-conditioning sectors. Data on leakages, filling of (new) installations, dismantling, etcetera is not calculated but obtained directly from the system.

This new method provides more accurate data than the stock model method. All equipment with a content >3 kg is covered by the Refrigerants Registration System. This is the best source available in the Netherlands. In addition, the emissions calculated by means of the new method are lower than those from the old stock model method. The stock model gave higher emissions, which is probably due to the assumption that usage figures were the same as the sales figures, and to the fact that a fixed leakage percentage of 5.8% was used; in the new method the average leakage rate for 2013–2017 was approximately 4%.

As described above, the two methods are completely different. The old method uses default leakage percentages, whereas the new method is based on real refrigerant use schemes. Therefore, a comparison is unrealistic. In the 2021 submission, the Overlap splicing technique from the IPCC Guidelines was used to create a consistent time series, thereby recalculating the 1990-2012 series. The formula used is described in Guidebook Chapter 5 (Time series consistency), section 5.3.3.1. The overlap period used is 2013-2015.

On the basis of the new method, as described earlier, real leakage percentages appear lower than the default guidebook factors. This is the reason why the old time series is higher than the new one; using the Overlap splicing technique, the emissions from 1990 to 2012 have been lowered to fit the 2013-2019 series.

As described in section 4.7.2, no trend extrapolation for 2021 and 2022 has been applied; emissions have been kept equal to the 2020 emissions.

4.7.4 *Category-specific QA/QC and verification*

The source categories are covered by the general QA/QC procedures discussed in Chapter 1. From the implementation of the new method, the refrigerant use data has been available at a high level of reliability.

4.7.5 *Category-specific recalculations*

As described in section 4.7.2, there is a time-lag for making data available. In this submission, the 2020 figure of 2F1 (HFCs from stationary refrigeration) was replaced by the new calculated value. In the previous submission, the 2021 emission was assumed to be equal to the 2019 emission. In this submission, this has been updated and the 2021 emission is assumed to be equal to the 2020 emission.

4.7.6 Category-specific planned improvements

The Netherlands continues to work on further improving the new method for Other applications (2F6), but there is still a lack of the required activity data.

4.8 Other product manufacture and use (2G)

4.8.1 Source category description

This source category comprises emissions related to Other product manufacture and use (2G) in:

- Electrical equipment (2G1): SF_6 emissions (included in 2G2).
- Other (2G2): SF_6 emissions from sound-proof windows, electron microscopes, and the electronics industry.
- N_2O from product uses (2G3): N_2O emissions from the use of anaesthesia and aerosol cans.
- Other industrial processes (2G4):
  - Fireworks: CO_2, CH_4 and N_2O emissions.
  - Degassing of drinking water: CH_4 emissions.

Table 4.13 presents 2G emissions in the base year, as well as in the last two years of the inventory.

Table 4.13 Overview of the sector Other product manufacture and use (2G) in the base year and the last two years of the inventory (in Gg CO_2-eq)

Sector/category	Gas	1990	2021	2022	2022 vs 1990	Contribution to total in 2022 (%) by		
		Emissions in Gg CO_2-eq			%	sector	total gas	total CO_2-eq
2G. Other	CO_2	0.2	0.2	0.4	102.3%	0.0%	0.0%	0.0%
	CH_4	58	51	51	-11.5%	0.4%	0.3%	0.0%
	N_2O	200	71	70	-65.1%	0.5%	1.1%	0.0%
	SF_6	213	124	125	-41.1%	0.9%	0.0%	0.1%
	All	471	246	247	-47.6%	0.9%	0.0%	0.1%
2G2. SF_6 and PFCs from other product use	SF_6	213	124	125	-41.1%	0.9%	100.0%	0.1%
2G3. N_2O from product uses	N_2O	197	68	65	-67.0%	0.5%	1.0%	0.0%
2G4. Other	CO_2	0.2	0.2	0.4	102.3%	0.00%	0.00%	0.00%
	CH_4	58	51	51	-11.5%	0.4%	0.3%	0.0%
	N_2O	3	2	5	66.8%	0.03%	0.07%	0.00%

This sector comprises no key categories.

In the Netherlands, many processes relating to the use of SF_6 take place in only one or two companies. Because of the sensitivity of data from these companies, only the sum of the SF_6 emissions in 2G1 and 2G2 is reported (both included in 2G2).

Overview of shares and trends in emissions
Table 4.14 presents the trend in emissions from the use of SF_6 during the 1990–2022 period.

Table 4.14 Emissions from the use of SF_6, 1990–2022 (Gg CO_2-eq)

Gas	1990	1995	2000	2005	2010	2015	2019	2020	2021	2022
SF_6	213.1	263.5	234.6	157.5	108.1	115.1	120.7	128.4	123.9	125.5

The decrease in SF_6 emissions since 2000 was mainly caused by:
- the closure of the only manufacturer of high-voltage installations at the end of 2002;
- an intensive PFC reduction scheme in the Semiconductor manufacture sector (2E1);
- the use of leak detection equipment in Electrical equipment (2G1).

N_2O emissions from 2G3 decreased by 67.0% in the 1990–2022 period. N_2O emissions from anaesthesia decreased due to better dosing in hospitals and other medical institutions.
Domestic sales of cream in aerosol cans increased sharply between 1990 and 2022. For this reason, emissions of N_2O from food aerosol cans also increased sharply.

The low CO_2 and CH_4 emissions remained fairly constant between 1990 and 2022. CO_2, CH_4 and N_2O emissions from fireworks showed a peak in 2000 because of the millennium celebrations.

4.8.2 *Methodological issues*
The source category Electrical equipment (2G1) comprises SF_6 emissions by users of high-voltage circuit breakers and by the only international test laboratory for power switches. Figures for emissions from circuit breakers were obtained from the annual inventory by the company, DNV. The methodologies used in earlier years are described in Honig et al. (2024), see sections 2.2.3.12 and 2.2.3.13.
The country-specific methods used for the sources of semiconductor manufacture, sound-proof windows, and electron microscopes are in line with IPCC Tier 2 methods.

Figures for the use of SF_6 in semiconductor manufacture, sound-proof windows and electron microscopes were obtained from individual companies (confidential information).

EFs used to estimate the emissions of SF_6 in this category are based on the following:
- semiconductor manufacture: confidential information from the only company;
- sound-proof windows: the EF used for production is 33% (IPCC default); the EF (leak rate) used during the lifetime of the windows is 2% per year (IPCC default);
- electron microscopes: confidential information from one company.

Country-specific methodologies are used for the N_2O sources in 2G3. A full description of the methodology is provided by Visschedijk et al. (2024). The methodologies used to estimate the emissions from 2G3 are:

- anaesthesia: The major hospital supplier of N_2O for anaesthetic use reports the consumption data for anaesthetic gas in the Netherlands annually. The EF used for N_2O in anaesthesia is 1 kg/kg gas used. It is assumed that the sales of N_2O for anaesthesia is equal to the consumption;
- aerosol cans: The national aerosol organisation (NAV) reports data on the annual sales of N_2O-containing spray cans. The EF for N_2O from aerosol cans is estimated to be 7.6 g/can (on the basis of data provided by one producer) and is assumed to be constant over time.

The methodologies used to estimate emissions of 2G4 are:
- fireworks: Country-specific methods and EFs are used to estimate emissions of CO_2, CH_4 and N_2O.
- degassing of drinking water: A country-specific methodology and EF are used to estimate CH_4 emissions, this being the main source of CH_4 emissions in this category.

The activity data used in 2G4 is derived from the following sources:
- fireworks: data on annual sales from the trade organisation;
- production of drinking water: volume and fuel use from Statistics Netherlands;
- cigarettes and cigars: volume from excise duty statistics and the trade organisation.

The EFs used in 2G4 are based on the following:
- Fireworks: CO_2: 43.25 kg/t; CH_4: 0.825 kg/t; N_2O: 1.935 kg/t (Visschedijk et al., 2024).
- Production of drinking water: 2.47 tons $CH_4/10^6$ m^3 (Visschedijk et al., 2024).
- Smoking cigarettes and cigars: CO_2: 294 kg/t; CH_4: 1.625 kg/t; N_2O: 0.065 kg/t (Visschedijk et al., 2024).

4.8.3 *Uncertainty and time series consistency*

Uncertainty

The uncertainty analysis outlined in Annex 2 provides estimates of the uncertainties by IPCC source category. The uncertainty in SF_6 emissions from 2G2 (SF_6 use) is estimated to be 34% (IPCC Tier 3a method). For the activity data and the EFs, the uncertainty is estimated at approximately 30% and 15%, respectively.

Uncertainties for the other source categories under 2G range from 15% (N_2O emissions from Other product manufacture and use) to over 50% (CO_2 and CH_4).

Time series consistency

Consistent methodologies have been applied to all source categories. The quality of the N_2O activity data needed was not uniform for the complete time series, requiring some extrapolation from the data. This is not expected to significantly compromise the accuracy of the estimates, which is still expected to be sufficient.

4.8.4 *Category-specific QA/QC and verification*

The source categories are covered by the general QA/QC procedures discussed in Chapter 1.

4.8.5 *Category-specific recalculations*

CO_2, CH_4 and N_2O emissions have been recalculated for CRF 2.G.4 in the complete time series. This is due to two recalculations:

- The activity data for fireworks has been updated for the complete time series:
  - The import/export statistics from Eurostat have been corrected for the last few years and are now in line with the statistics from Statistics Netherlands. It was decided to use the import/export statistics from Statistics Netherlands.
  - The activity data has been moved one year (assuming that fireworks imported/exported in year x is ignited on 1 January at 0:00 h of year x+1).
  - The fraction of illegal fireworks has been made consistent for the complete time series.
- The activity data for production of drinking water has been updated for 2020 and 2021.

These recalculations result in the following changes in emissions (in kton CO_2, ton CH_4 and ton N_2O):

		1990	**2005**	**2010**	**2015**	**2020**	**2021**
Fireworks	CO_2 (kton)	-0.03	-0.08	-0.09	-0.10	-0.51	+0.02
	CH_4 (ton)	-0.66	-1.49	-1.65	-1.82	-9.32	+0.42
	N_2O (ton)	-1.55	-3.48	-3.68	-4.26	-21.87	+1.00
Drinking water	CH_4 (ton)					+64.18	-74.07

4.8.6 *Category-specific planned improvements*

There have been no category-specific planned improvements

4.9 Other (2H)

4.9.1 *Source category description*

This category comprises CO_2 emissions from Food and drink production (2H2). In the Netherlands, this concerns the calcination process in the sugar industry, as described in section 4.2.2 under lime production (2A2). CO_2 process emissions in this source category do not only occur from lime production, but are also related to the non-energy use of fuels: coke and anthracite. Carbon is oxidised during these processes, resulting in CO_2 emissions. CO_2 process emissions in the paper industry (2H1) do not occur in the Netherlands.

Overview of shares and trends in emissions

Emissions in 2022 decreased by 65.6% compared to the emissions in 1990 (see Table 4.15).

Table 4.15 Overview of the sector Other process emissions (2H) in the base year and the last two years of the inventory

Sector/category	Gas	1990	2021	2022	2022 vs 1990	Contribution to total in 2022 (%) by		
		Emissions in Tg CO_2-eq			%	sector	total gas	total CO_2-eq
2H. Other process emissions	CO_2	0.07	0.01	0.02	-65.6%	0.2%	0.0%	0.0%

This sector comprises no key categories.

4.9.2 *Methodological issues*

The methodology used to estimate the GHG emissions complies with the 2006 IPCC Guidelines, volume 3, as described in Honig et al. (2024), section 2.2.3.1.

CO_2 emissions are calculated on the basis of the non-energy use of fuels by the food and drink industry recorded by Statistics Netherlands in national energy statistics on coke consumption, multiplied by an EF. The EF is based on the national default carbon content of the fuels (see Annex 5), assuming that the carbon is fully oxidised to CO_2.

4.9.3 *Uncertainty and time series consistency*

Uncertainty
The uncertainty analysis outlined in Annex 2 provides estimates of the uncertainties per IPCC source category. The uncertainty in the emissions of this category is estimated to be around 5% (2% and 5% uncertainty in activity data and EF, respectively).

Time series consistency
Consistent methodologies and activity data are used throughout the time series for this source.

4.9.4 *Category-specific QA/QC and verification*

The source categories are covered by the general QA/QC procedures discussed in Chapter 1.

4.9.5 *Category-specific recalculations*

Activity data for the non-energy use of cokes has been updated in the energy statistics for the years 2015-2021. This results in the following changes in CO_2 emissions (in kton CO_2):

	2015	2016	2017	2018	2019	2020	2021
CO_2 (kton)	+0.002	+0.002	+0.003	-0.998	-0.004	-0.000	-0.004

4.9.6 *Category-specific planned improvements*

No improvements have been planned.

5 Agriculture (CRF sector 3)

Major changes in the Agriculture sector compared to the National Inventory Report 2023

Emissions:	Total emissions from the Agriculture sector decreased in 2022 to a level of c. 18.0 Tg CO_2-eq.
New Key categories:	3B1 Growing cattle CH_4
No longer Key category:	
Methodologies and recalculations:	• The N_2O emissions from manure treatment of veal calves has been calculated on the basis of the annual TAN excretion instead of a fixed value (3B1). • The N content of manure sent to treatment facilities has been based on the mandatory transport certificates instead of on defaults for the years 2018-2022. This affects N_2O and CH_4 emissions from manure treatment (3B). • The NH_3 emissions from manure management have been recalculated, thus affecting the indirect N_2O emissions (3Ba5) • Bedding material has been added to the calculations resulting in higher N_2O emissions throughout the time series from crop production (3D). • The N_2O emissions from crop residues (3Da4) have been recalculated for the complete time series. The area of mown grasslands changed, due to the inclusion of mown natural grasslands as well as to the shift to the agricultural census instead of the grassland survey.

	• The N_2O emissions related to losses/gains in soil organic matter content have been added to the time series (3Da5). • Final usage rates of inorganic fertilisers, compost, liming, and urea differ from the preliminary rates. This affects the N_2O emissions from Agricultural soils (3D), Liming (3G) and Urea application (3H).

5.1 Overview of the sector

Emissions of GHGs from Agriculture include all anthropogenic GHG emissions from the agricultural sector, except for:

- Emissions from fuel combustion. These emissions are included in 1A2g Manufacturing industries and construction – Other and 1A4c Other sectors – Agriculture/Forestry/Fisheries, and
- CO_2 emissions through land use in agriculture (CRF sector 4 Land Use, Land Use Change and Forestry; see Chapter 6).

Table 5.1 provides an overview of the contribution made by the Agriculture sector subdivided in the relevant subcategories to the total greenhouse gas emissions in the Netherlands. Emissions are given for 1990, 2021 and 2022. Table 5.1 also provides the relative difference between 2022 and 1990, and presents the contribution the various sources and gases make to the total emissions of the Agriculture sector, to the national emissions per greenhouse gas and to the national emissions in terms of CO_2 equivalent.
Emissions of GHGs in this sector include the following:

- 3A Enteric fermentation (CH_4);
- 3B Manure management (CH_4 and N_2O);
- 3D Crop production and agricultural soils (N_2O);
- 3G Liming (CO_2);
- 3H Urea application (CO_2).

The IPCC categories Rice cultivation (3C), Prescribed burning of savannahs (3E), Field burning of agricultural residues (3F), Other carbon-containing fertilisers (3I) and Other (3J) do not occur in the Netherlands. Throughout the 1990-2022 period, Field burning of agricultural residues was prohibited in the Netherlands (article 10.2 of the Environmental Management Act, or *'Wet Milieubeheer'* in Dutch).

This chapter discusses the national emissions from agriculture and their trends. All emissions are calculated using the NEMA model (Netherlands Emission Model Agriculture). A detailed description of the NEMA model and the exact methods used to calculate the emissions can be found in Van der Zee et al. (2024). The activity data used to calculate the emissions are summarised in Van Bruggen et al. (2024). The activity data that could not be included in the CRF is added to Van Bruggen et al. (2024). The calculation method of the volatile substances excreted is described in Bannink et al. (2018). The calculation method of the nitrogen excretion is described in Statistics Netherlands (2010).

In 2022, agriculture contributed 11.4% of the national GHG emissions in comparison to 11.0% in 1990. This sector is a major contributor to national total CH_4 and N_2O emissions; in 2022, agriculture accounted for 71.0% of total CH_4 emissions and for 72.4% of total N_2O emissions (Table 5.1).

Table 5.1 Overview of emissions in the Agriculture sector, in the base year 1990 and the last two years of the inventory

Sector/category	Gas	1990	2021	2022	2022 vs 1990	Contribution to total in 2022 (%) by		
		Emissions in Tg CO_2-eq			%	sector	total gas	total CO_2-eq
3. Agriculture	CO_2	0.2	0.1	0.1	-51.7%	0.5%	0.1%	0.1%
	CH_4	16.4	13.0	13.1	-20.0%	72.9%	71.0%	8.3%
	N_2O	8.6	4.9	4.8	-44.3%	26.6%	72.4%	3.0%
	All	25.2	18.0	18.0	-28.5%	100.0%		11.4%
3A. Enteric fermentation	CH_4	10.3	9.1	9.2	-11.4%	50.8%	49.4%	5.8%
3B. Manure management	CH_4	6.1	4.0	4.0	-34.5%	22.1%	21.6%	2.5%
	N_2O	0.8	0.7	0.7	-22.0%	3.6%	9.8%	0.4%
	All	6.9	4.6	4.6	-33.0%	25.7%		2.9%
3D. Agriculture soils	N_2O	7.8	4.2	4.1	-46.7%	23.0%	62.6%	2.6%
3G. Liming	CO_2	0.2	0.03	0.03	-82.4%	0.2%	0.0%	0.0%
3H. Urea application	CO_2	0.00	0.06	0.06	3662.0%	0.3%	0.0%	0.0%
National total GHG emissions (incl. LULUCF)	CO_2	168.4	143.9	132.1	-21.6%			
	CH_4	36.3	19.1	18.5	-49.0%			
	N_2O	16.1	7.1	6.6	-58.7%			
	Total	228.1	171.5	158.4	-30.5%			

5.1.1 *Overview of shares and trends in emissions*

Figure 5.1 shows the trend in total GHG emissions from the sector Agriculture. Please note that the contributions of 3G Liming and 3H Urea application are so small that they are barely visible in the figure.

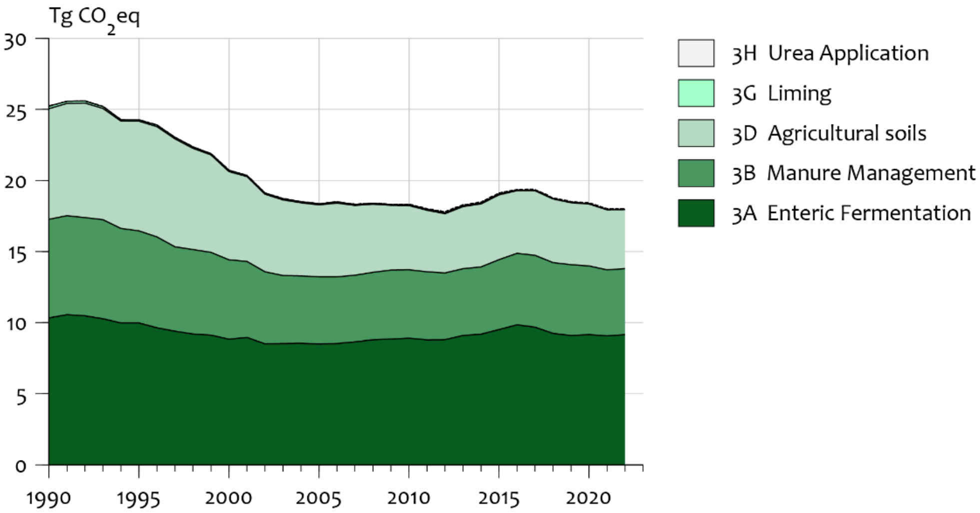


Figure 5.1 Sector 3 Agriculture – trend and emission levels of source categories, 1990–2022

Trend in methane emissions
In broad terms, the CH_4 emissions from agriculture showed a decline from 1990 to 2005, after which the emissions increased again, peaking in 2016. After 2016, the emissions decreased until 2022. The trends in methane emissions are mainly explained by changes in the number of mature dairy cattle and pigs. The time series of CH_4 emissions are available in section 9.3 of Van Bruggen et al. (2024).

Trend in nitrous oxide emissions
From 1990 to 2012, the Netherlands saw a decline in N_2O emissions due to a decrease in organic and inorganic N fertiliser application, a decrease in animal numbers, and a decrease in grazing. Emissions increased in 2013-2017, while 2018 and 2019 show a decrease. Emissions increased in 2020 and decreased in 2021 and 2022. The decrease in 2022 is mainly due to a decrease in the use of artificial fertilisers. The time series of N_2O emissions are available in section 9.2 of Van Bruggen et al. (2024).

Trend in carbon dioxide emissions
The CO_2 emissions from agriculture reported here are limited to the emissions resulting from liming and urea application. The CO_2 emissions decreased from 1990 until 2008 due to a decrease in the application of liming products in the Netherlands. After 2008, CO_2 emissions increased as more urea was applied as an artificial fertiliser. CO_2 emissions peaked in 2012 after which they plateaued until 2016, when a strong decrease could be observed. In 2017, there was an increase in CO_2 emissions followed by a decrease in 2018. Between 2018 and 2020, CO_2 emissions remained stable with relatively small fluctuations between years. The CO_2 emission increased in 2021 and 2022, due to increased liming and urea application. The time series of CO_2 emissions from agriculture are available in section 9.6 of Van Bruggen et al. (2024).

5.1.2 *Overview of trends in activity data*

Animal numbers are the primary activity data used in the emissions calculations for manure management (3B) and agricultural soils (3D). Most animal numbers come from the annual agricultural census performed by Statistics Netherlands. Animal categories that are (no longer) surveyed in the agricultural census or where the agricultural census was deemed uncertain, are covered by RVO's Identification and Registration system (I&R). Table 5.2 presents an overview of the various animal categories. The entire time series of the animal numbers in the Netherlands can be found in Annex 2 of Van Bruggen et al. (2024). More information on the determination of the animal numbers can be found in section 2 of Van der Zee et al. (2024).

Table 5.2 Animal numbers in 1990–2022 (x 1,000)

Animal category	**1990**	**1995**	**2000**	**2005**	**2010**	**2015**	**2020**	**2021**	**2022**
Cattle	4,926	4,654	4,069	3,797	3,975	4,134	3,719	3,732	3,766
Mature dairy cattle	1,878	1,708	1,504	1,433	1,479	1,622	1,593	1,571	1,571
Other mature cattle	120	146	163	151	115	80	58	56	53
Growing cattle	2,929	2,800	2,402	2,213	2,381	2,432	2,068	2,105	2,143
Sheep	1,702	1,674	1,305	1,361	1,130	946	954	916	910
Ewes	790	771	680	647	558	523	562	532	550
Young stock and males	913	903	625	714	571	423	393	385	360
Swine	13,915	14,397	13,118	11,312	12,255	12,603	11,860	11,372	11,235
Swine (>25 kg)	8,724	8,801	8,015	6,749	7,131	7,005	6,447	6,203	6,115
Young stock (<25 kg)	5,191	5,596	5,102	4,563	5,124	5,598	5,414	5,169	5,120
Goats	61	76	179	292	353	470	633	643	645
Mature female goats	37	43	98	172	222	292	441	451	456
Young stock and males	23	33	80	120	131	178	192	193	189
Horses	370	400	417	433	441	417	410	417	417
Mules and asses	1	1	1	1	1	1	1	1	1
Poultry	91,680	88,243	102,579	91,726	99,880	104,760	96,431	90,666	89,493
Other livestock									
Rabbits	786	488	392	360	299	381	335	321	300
Does	105	64	52	48	39	48	38	38	35
Young stock	681	424	340	312	260	333	297	283	266
Furbearing animals	554	463	589	697	962	1,023	435	NO	NO

Between 1990 and 2022, the total number of cattle decreased by 24%. This is due to higher production rates per animal and production quotas.

Between 2012 and 2016, the number of cattle increased as dairy farmers anticipated the abolition of milk production quotas. However, this resulted in exceeding the European phosphate production ceiling. The Dutch government implemented new policies in accordance with the phosphate production ceiling: the phosphate reduction scheme followed by the phosphate quota introduced in 2018 (MLNV, 2017). These policies resulted in a decrease in cattle (all categories) that can be kept in the Netherlands and resulted in a decrease in cattle numbers from 2017 to 2022.

The total number of sheep (ewes, rams and lambs) decreased by 47% between 1990 and 2022.

The total number of swine decreased by 19% between 1990 and 2022. Increased production rates per animal resulted in a decrease in swine numbers until 2004, after which animal numbers increased. The increase levelled off after 2011 and was stable until 2015. Between 2016 and 2022, a slow decrease was observed. The number of young stock of swine (piglets up to 25 kg) has been stable between 1990 and 2022, showing that the productivity of the sows has increased.

There was an overall decrease in numbers of poultry by 2% between 1990 and 2022. An increase in the number of poultry was observed between 1990 and 2002. As a direct result of the avian flu outbreak in 2003, poultry numbers decreased by almost 30%. In 2004, poultry numbers increased again. In 2010, the number of poultry was equal to the 2002 number. From 2011 onwards, poultry numbers have stabilised, with small annual fluctuations. 2021 and 2022 were marked by large outbreaks of avian influenza.

The total number of goats increased by 961% between 1990 and 2022. This increase is due to an increased demand for goat milk and goat cheese. This increase halted in 2010, when goats were culled due to the outbreak of Q fever, but resumed in 2011.

The total number of horses increased by 13% between 1990 and 2022.

The total number of mules and asses increased by 16% between 1990 and 2022. On the basis of expert judgement, the number of mules and asses between 1990 and 2009 was set at 1000 animals. Since 2010, animal numbers have become available from the agricultural census.

The number of rabbits decreased by 62% between 1990 and 2022 due to a decrease in demand for rabbit meat.

No fur-bearing animal is held in the Netherlands. The production of fur from foxes ceased in 2008 following a ban. The production of fur from minks ceased in 2021. The number of fur-bearing animals increased by 46% between 1990 and 2019. However, due to the 2020 coronavirus pandemic, all mink farms ceased operations as the production of fur from minks was banned. This resulted in a 20% decrease in mink between 1990 and 2020. From 2021 onwards, no mink has been held in the Netherlands.

Emissions from alpacas in the Netherlands have not been included in the inventory as there is no detailed information on their numbers. Alpacas are mostly kept as pets or as a tourist attraction. Animal numbers are expected to be in the same range as mules and asses, i.e. no more than a couple of thousand animals. The threshold for a mandatory inclusion of a new source is 0.05% of national total GHG emissions or 500 kt CO_2-eq, whichever is lower. In the case of the Netherlands, this is the threshold of 0.05%, namely 79 kt CO_2-eq[6]. According to the Tier 1 default values, the combined emission per alpaca is ~325.7 kg CO_2-eq (3A and 3B). To reach the threshold of 79 kt CO_2-eq, more than 240,000 alpacas would need to be present in the Netherlands. This is highly unlikely as the highest estimate we found for alpacas in the Netherlands is 4,000 animals.

The calculations of CH_4 emissions from sheep, goats and pigs are based on different activity data than the calculations of N_2O emissions (see sections 5.2 and 5.3). CH_4 emissions from sheep, goats and pigs are based on the average number of animals present multiplied by the default IPCC emission factors. N_2O emissions are based on the N excretion. The N excretion has been estimated by the Working group on Uniformity of calculations of Manure and mineral data (WUM). The WUM does not provide N excretions for all animal categories individually. The N excretion of the rams and lambs is included in the N excretion of the ewes. The N excretion of the male goats and goat kids is included in the N excretion of female goats. The N excretion of piglets is included in the N excretion of the sows. Hence, for the calculation of N_2O emissions, the male and young sheep and goats and the piglets are omitted.

The amount of applied manure and fertilisers are important activity data for the calculation of emissions from agricultural soils (3D), Liming (3G) and Urea application (3H). For agricultural soils, the application method is also important, as methods developed to reduce the NH_3 emissions have higher N_2O emissions. Between 1990 and 2022, the application of animal manure in kg N decreased by 24%. The reduction is caused by the introduction of more stringent manure application limits. Manure applied to soils during pasturing decreased by 71% due to a reduction of the number of cattle as well as to a decrease in pasturing. The application of inorganic N fertilisers decreased by 47% due to more stringent application limits as well as a more efficient usage of animal manure, resulting in a reduced demand for inorganic N fertilisers.

[6] Total emission from the Netherlands in 2022 is 158 Tg CO2-eq. The threshold (0.05%) is thus 79 kt CO_2-eq.

The Tier 1 emission factors from the 2006 IPCC guidebook are:
-> CH_4 from enteric fermentation: 8 kg CH_4 per head per year.
-> CH_4 from manure management: 0.955 kg CH_4 per head.
This emission can be calculated by combining the VS excretion, the emission factor of the storage system and body weight. The VS excretion is 11.5 kg VS (1000 kg animal mass)$^{-1}$ day^{-1}, combined with the high-productivity solid storage emission factor in a cool climate of 3.5 g CH_4 kg VS^{-1} and a bodyweight of 65 kg: 11.5/1000*65*3.5/1000*365 = 0.955 kg CH_4 per head.
-> N_2O from manure management: 0.282857 kg N_2O.
This emission can be calculated by combining the nitrogen excretion rate, animal weight and the emission factor from the guidebook. The default nitrogen excretion rate for western Europe is: 0.38 kg N (1000 kg animal mass per day)$^{-1}$ Nex = 0.38 * 65/1000 * 365 = 9.0 kg N, emission factor of 2%
N_2O emission manure management: 9.0 * 0.02 * (44/28) = 0.282857 kg N_2O per head.

Therefore, the total CO_2 equivalent per alpaca is: ((8 + 0.955) * 28) + (0.282857 * 265) = ~325.7 kg CO_2 equivalent.

Compost application increased by 287% between 1990 and 2022.
Sewage sludge application decreased by 94% between 1990 and 2022.

Detailed information on data sources can be found in Chapter 2 of Van der Zee et al. (2024).

5.2 Enteric fermentation (3A)

5.2.1 Source category description

Methane emissions are a by-product of enteric fermentation, the digestive process by which organic matter (mainly carbohydrates) is degraded and utilised by micro-organisms under anaerobic conditions. Both ruminant animals (e.g. cattle, sheep and goats) and non-ruminant animals (e.g. swine, horses, mules and asses) produce CH_4, but ruminants produce considerably more per unit of feed intake. Enteric fermentation from poultry is not estimated due to the negligible amount of CH_4 production in this animal category. The 2019 refinement of the IPCC Guidelines does not provide a default EF for enteric CH_4 emissions from poultry.

The CH_4 emissions from enteric fermentation have decreased from 10.3 Tg CO_2-eq in 1990 to 9.2 Tg CO_2-eq in 2022 (-11.4% compared to 1990, see Table 5.3). The overall decrease is almost entirely due to the decrease in CH_4 emissions from cattle. Cattle accounted for the majority (89%) of CH_4 emissions from enteric fermentation in 2022. Swine contributed 5% and the animal categories sheep, goats, horses and mules and asses accounted for the remaining 6%. The reduction of CH_4 emissions from cattle is caused by a decrease in animal numbers, partly undone by an increase in EF for mature dairy cattle (higher production/animal; Table 5.4) and white veal calves (dietary changes to also include roughages in the diet).

The source category enteric fermentation includes emissions from:

- Mature dairy cattle (3A1a);
- Other mature cattle (3A1b);
- Growing cattle (3A1c);
- Sheep (3A2);
- Swine (3A3);
- Goats (3A4);
- Horses (3A4);
- Mules and asses (3A4).

Table 5.3 Overview of the sector Enteric fermentation (3A) in the base year and the last two years of the inventory

Sector/category	Gas	1990	2021	2022	2022 vs 1990	Contribution to total in 2022 (%) by		
		Emissions in Tg CO_2-eq			%	sector	total gas	total CO_2-eq
3A. Enteric fermentation	CH_4	10.3	9.1	9.2	-11.4%	50.8%	49.4%	5.8%
3A1. Cattle	CH_4	9.2	8.1	8.2	-10.9%	45.4%	44.2%	5.2%
Mature dairy cattle	CH_4	5.8	6.0	6.0	3.7%	33.4%	32.5%	3.8%
Other mature cattle	CH_4	0.2	0.1	0.1	-51.4%	0.6%	0.6%	0.1%
Growing cattle	CH_4	3.1	2.0	2.0	-34.8%	11.3%	11.0%	1.3%
3A2. Sheep	CH_4	0.4	0.2	0.2	-46.7%	1.1%	1.1%	0.1%
3A3. Swine	CH_4	0.6	0.5	0.5	-19.3%	2.6%	2.5%	0.3%
3A4. Other livestock	CH_4	0.2	0.3	0.3	54.3%	1.7%	1.6%	0.2%

This sector comprises the following key categories:

3A1	Mature dairy cattle	CH_4
3A1	Other mature cattle	CH_4
3A1	Young cattle	CH_4

5.2.2 *Methodological issues*

For all the sub-source categories, the methodologies used to estimate emissions follow the 2006 IPCC Guidelines. Detailed information on calculation methods and EFs can be found in Chapter 3 of Van der Zee et al. (2024). An overview of the activity data can be found in Statistics Netherlands (2019 through 2023); Van Bruggen et al. (2024).

Cattle (3A1)

A Tier 3 method is used to calculate emissions from mature dairy cattle. For the EF calculation for mature dairy cattle, the Netherlands is split into two regions because of differences in diets: North-West and South-East. Cattle in the North-West (NW) mainly have a grass diet, while those in the South-East (SE) have a larger fraction of maize in their diet. Data used between 1990 and 2012 is published in Annex 3 of Van Bruggen et al. (2014). An annual update of cattle diets is published by Statistics Netherlands, (2019 through 2023). Table 5.4 presents the IEFs for the various cattle categories reported, including the subdivision into the NW and SE regions for mature dairy cattle. A Tier 2 method is used to calculate emissions from other mature cattle and growing cattle. The IEF for growing cattle is a weighted average calculated from all cattle sub-categories except dairy cows and suckling cows and female fatteners > 2 years (Annex 27 of Van Bruggen et al., 2024).

Table 5.4 IEFs for methane emissions from enteric fermentation specified according to CRF animal category (kg CH_4/animal/year)

Animal category	1990	1995	2000	2005	2010	2015	2020	2021	2022
Mature dairy cattle	110.4	114.4	120.0	124.6	127.7	128.7	136.5	135.6	136.9
Of which NW region	111.0	115.4	121.7	126.0	129.6	130.9	136.6	135.1	136.7
Of which SE region	109.9	113.5	118.4	123.2	126.3	127.1	136.4	136.0	137.1
Other mature cattle	70.3	71.3	72.1	76.7	78.1	79.1	77.9	77.6	77.6
Growing cattle	38.3	38.6	35.4	34.4	35.0	36.4	33.5	33.9	34.1

For both mature dairy cattle and other mature cattle, EFs increased primarily because of an increase in total feed intake in the 1990–2022 period. For mature dairy cattle, a change in the feed nutrient composition partly counteracted this effect. Moreover, the average weight of mature dairy cattle and the average milk production have increased over time, resulting in a higher gross energy intake of mature dairy cattle in 2022 compared to 1990, with a decrease in animal numbers (Statistics Netherlands, 2023). The IEFs of 2022 are higher than 2021 because the feed intake was higher.

For growing cattle, the decrease in EFs between 1990 and 2022 can be explained by a decrease in the average total feed intake due to an increased share of veal calves in the population of growing cattle. This is counteracted, however, by an increase in EF for white veal calves, as they are fed increasing amounts of roughage to comply with animal welfare considerations. The number of white veal calves and rosé veal calves can be found in Annex 2 of Van Bruggen et al. 2024. The EF for veal calves can be found in Annex 27 of Van Bruggen et al. (2024).

Sub-source categories with a Tier 1 method
According to the IPCC Guidelines, no Tier 2 method is required if the share of a sub-source category is less than 25% of the total emission from a key source category. This is the case for the following sub-source categories:

Sheep (3A2)
The animal category sheep has a 1.1% share in the total CH_4 emissions from enteric fermentation. Therefore, the IPCC 2006 default (Tier 1) EF of 8 kg CH_4/animal has been used. Changes in emissions from sheep are explained entirely by changes in livestock numbers.

Swine (3A3)
The animal category swine has a 2.6% share in the total CH_4 emissions from enteric fermentation. Therefore, the IPCC 2006 default (Tier 1) EF of 1.5 kg CH_4/animal has been used. Changes in emissions from swine are explained entirely by changes in livestock numbers.

Other livestock (3A4)
The sub-source category ‘Other livestock’ comprises goats, horses, and mules and asses. These animal categories have a combined share in total CH_4 emissions from enteric fermentation of 1.7%. Therefore, the IPCC 2006 default (Tier 1) EFs are used for goats, horses and mules and

asses (5, 18 and 10 kg CH_4/animal, respectively). Changes in emissions from these animal categories are explained entirely by changes in livestock numbers.

5.2.3 *Uncertainty and time series consistency*

Uncertainty

The uncertainty analysis explained in Annex 2 provides estimates of uncertainty according to IPCC source categories. The uncertainty of CH_4 emissions from enteric fermentation ranges between 10% and 42%, mostly determined by the uncertainties in the emission factors (e.g. the uncertainty in the EF for 3A3 Swine is estimated at 40%, whereas for 3A1a Mature dairy cattle, the uncertainty is estimated at 15%). Uncertainties for the activity data are estimated between 1% (for 3A1, Young cattle) and 17% (3A2, 3A4 Other).

Time series consistency

A consistent methodology is used throughout the time series; see section 5.2.2. Emissions are calculated as the product of livestock numbers and EFs. Livestock numbers are collected in an annual census and the I&R and are published by Statistics Netherlands and RVO, respectively. Consistent methods are used to compile the census to ensure continuity of the collected data. Time series corrections have been implemented to ensure consistency following the switch from the annual census to the I&R. EFs are either constant (default IPCC) or calculated/modelled from feed intake data collected through an annual survey by Statistics Netherlands, (2019 through 2023).

5.2.4 *Category-specific QA/QC and verification*

This source category is covered by the general QA/QC procedures discussed in Chapter 1.

5.2.5 *Category-specific recalculations*

There have been no category-specific recalculations.

5.2.6 *Category-specific planned improvements*

No improvements have been planned.

5.3 Manure management (3B)

5.3.1 *Source category description*

Overview of shares and trends in emissions

Both CH_4 and N_2O are emitted during the handling and storage of manure from all animal categories. These emissions are related to the quantity and composition of the manure, and to the various types of manure management systems used.

In the Netherlands, CH_4 emissions from manure management contribute 2.5% to national total GHG emissions and 22.1% to the GHG emissions of the Agriculture sector (Table 5.5). CH_4 emissions from manure management are particularly related to cattle and swine manure (Figure 5.2). Cattle and swine manure management contributed 12.3% and 9.3%, respectively, to the total GHG emissions of the Agriculture sector in 2022. CH_4 emissions from manure management of poultry are a minor key source and have decreased drastically over time (-85.2% from 1990 to 2022).

In 2022, N_2O emissions from manure management contributed 0.4% to national total GHG emissions and 3.6% to the Agriculture sector. Nitrous oxide emissions from manure management from cattle contributed 1.6% to the Agriculture sector total (Table 5.5. and Figure 5.3).

The source category Manure management includes emissions from:
- Mature dairy cattle (3B1a);
- Other mature cattle (3B1b);
- Growing cattle (3B1c);
- Sheep (3B2);
- Swine (3B3);
- Goats (3B4);
- Horses (3B4);
- Mules and asses (3B4);
- Poultry (3B4);
- Rabbits (3B4);
- Fur-bearing animals (3B4);
- Indirect emissions (3B5).

Table 5.5 Overview of the sector manure management (3B) in the base year and the last two years of the inventory

Sector/category	Gas	1990	2021	2022	2022 vs 1990	Contribution to total in 2022 (%) by		
		Emissions in Tg CO_2-eq			%	sector	total gas	total CO_2-eq
3B. Manure management	CH_4	6.1	4.0	4.0	-34.5%	22.1%	21.6%	2.5%
	N_2O	0.8	0.7	0.7	-22.0%	3.6%	9.8%	0.4%
	All	6.9	4.6	4.6	-33.0%	25.7%		2.9%
3B1. Cattle (total)	CH_4	1.8	2.2	2.2	22.9%	12.3%	12.0%	1.4%
3B2. Sheep	CH_4	0.0	0.0	0.0	-46.7%	0.0%	0.0%	0.0%
3B3. Swine	CH_4	3.8	1.7	1.7	-55.5%	9.3%	9.1%	1.1%
3B4. Poultry	CH_4	0.5	0.1	0.1	-85.2%	0.4%	0.4%	0.0%
3B4. Other livestock	CH_4	0.0	0.0	0.0	-25.9%	0.1%	0.1%	0.0%
3B1. Cattle (total)	N_2O	0.3	0.3	0.3	-7.6%	1.6%	4.3%	0.2%
3B2. Sheep	N_2O	0.0	0.0	0.0	-76.8%	0.0%	0.0%	0.0%
3B3. Swine	N_2O	0.1	0.1	0.1	-36.7%	0.4%	1.2%	0.0%
3B4. Poultry	N_2O	0.0	0.0	0.0	-14.3%	0.1%	0.3%	0.0%
3B4. Other livestock	N_2O	0.0	0.1	0.1	134.9%	0.4%	1.0%	0.0%
3B5. Indirect emissions	N_2O	0.3	0.2	0.2	-41.6%	1.1%	3.1%	0.1%

This sector comprises following key categories:

3B1	Mature dairy cattle	CH_4
3B3	Swine	CH_4
3B4	Poultry	CH_4
3B5	Indirect emissions	N_2O

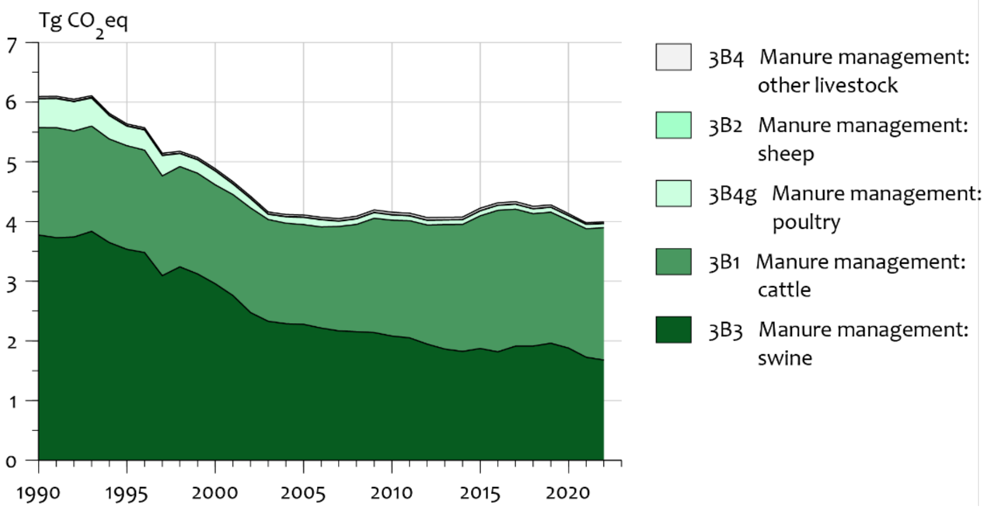


Figure 5.2 Category 3B Manure management – trend and emissions levels of source categories for CH_4, 1990–2022

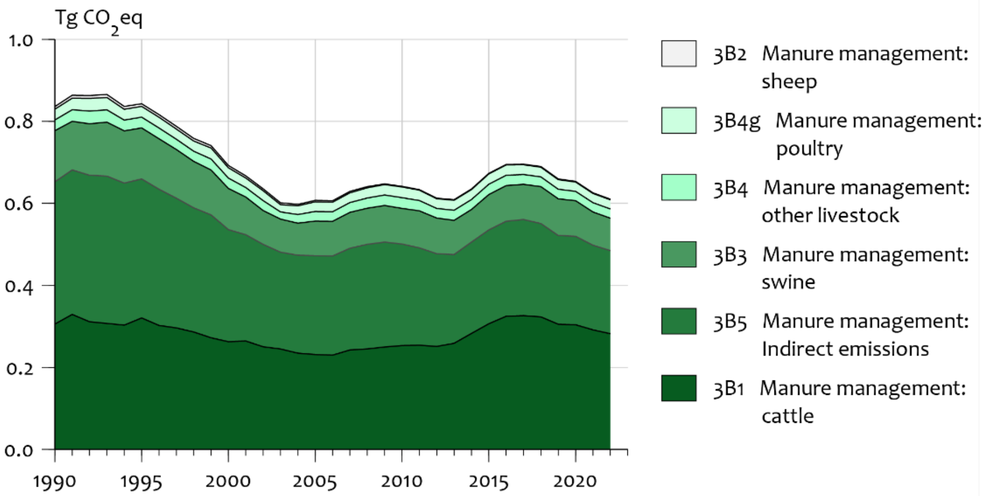


Figure 5.3 Category 3B Manure management – trend and emissions levels of source categories for N_2O, 1990–2022

Four different manure management systems are used in the Netherlands and included in the calculations:

- Liquid manure management systems;
- Solid manure management systems;
- Manure treatment;
- Manure excreted during grazing on pasture.

Animal numbers were distributed across the various manure management systems using information from the Agricultural census. In accordance with the IPCC 2006 Guidelines, N_2O emissions from manure excreted during grazing are not considered in source category 3B Manure management, but in source category 3D Agricultural soils (see section 5.4). The methods for calculating N excretion for the various livestock categories are described in Statistics Netherlands (2010).

CH_4 from manure management
Between 1990 and 2022, emissions of CH_4 from manure management decreased by 34.5% (Figure 5.2). Emissions from cattle increased by 22.9%, while swine and poultry emissions decreased by 55.5% and 85.2%, respectively (Table 5.5). With an increasing percentage of cattle kept indoors, a larger proportion of the manure is excreted inside animal housing facilities. This results in higher emissions (Annex 4 of Van Bruggen et al. 2024). For growing cattle, emissions decreased due to lower livestock numbers; this outweighs the increase in EF (Annex 2 and Annex 29 of Van Bruggen et al. 2024). An increase in emissions was seen between 2013 and 2017. This is due to an increase in cattle number combined with higher feed intake, resulting in a higher VS excretion (Annex 2 and Annex 28 of Van Bruggen et al. 2024). In anticipation of the end of the milk quota (2015), farmers increased their herd size. However, due to new policies, farmers subsequently had to decrease their herd size in order to comply with the phosphate quota (Van der Zee et al., 2024).

For poultry, the large decrease in emissions is associated with the change from battery cage systems with liquid manure, to floor housing systems or aviary systems with solid manure (Annex 8 of Van Bruggen et al., 2024). This lowered the CH_4 emissions as the solid manure systems have a lower EF. Moreover, the increase of manure treatment had an effect by shortening the manure's storage time (Annex 14 of Van Bruggen et al., 2024).

The decreasing trend in CH_4 emissions from swine is directly related to the decrease in volatile solids (VS) excretions by swine (Statistics Netherlands, 2023). This decreased due to changes in the feed composition (Zom and Groenestein, 2015). The decrease in CH_4 emissions was somewhat counteracted by an increase in livestock numbers in the first part of the time series (up to 1997). For the years 2017-2019, an increase in emissions can be seen as the VS excretion increased. In 2020-2022, VS excretion decreased again (Annex 28 of van Bruggen et al., 2024).

N_2O from manure management
Nitrous oxide emissions are calculated using an N-flow model (Van der Zee et al., 2024). Figure 5.4 is a schematic representation of N flows and the resulting emissions from agriculture. The amount of N in the manure is used throughout the model and corrected for the N emissions that have already taken place. For example, with N excretion in animal housing, losses in the form of NH_3, NO_x, N_2 and N_2O are all relative to the amount of N excreted. Only at the end of the calculation is the combined loss subtracted to yield the remaining N available for application.

The direct N_2O emissions from cattle decreased by 7.6% between 1990 and 2022. Sheep, swine and poultry emissions decreased by 76.8%, 36.7% and 14.3%, respectively (Table 5.5). Decreasing livestock numbers and N excretions per animal influenced this trend. Between 1990 and 2022, emissions from other livestock increased by 134.9% (Table 5.5); this increase was mainly caused by the increase in the number of goats. Between 1990 and 2013, the N excretion decreased due to an optimisation of animal production, resulting in higher production rates with lower dietary crude protein for all animal categories. From 2014 onwards, the amount of dietary crude protein has stabilised. In 2017, the N excretion for cattle increased again, which can be explained by a decrease in fed maize and an increase of fed grass; grass has a higher N content than maize. Apart from the increased share of grass in the feed, nutrient requirements increased through a higher average milk production and body weight per cow (Statistics Netherlands, 2023). In 2022, the N excretion of cattle decreased as the roughages contained less nitrogen (Statistics Netherlands, 2022).

The Netherlands' manure and fertiliser policy, aimed at reducing N leaching and run-off, regulates the amount of manure production and its application by the introduction of measures such as restrictions on the numbers of swine and poultry per farm (so called 'manure production rights') and maximum application limits for manure and inorganic N fertiliser, all part of the Dutch 'Manure and Fertilisers Act' in accordance with the Nitrates Directive. This has also resulted in a decrease in manure management emissions over the past two decades.

Indirect N_2O emissions following atmospheric deposition of NH_3, and NO_x emitted during the handling of animal manure decreased by 41.6% from 1990 to 2022 (Table 5.5). This decrease is explained by reduction measures for NH_3 and NO_x emissions from animal housing systems and manure storages for the period.

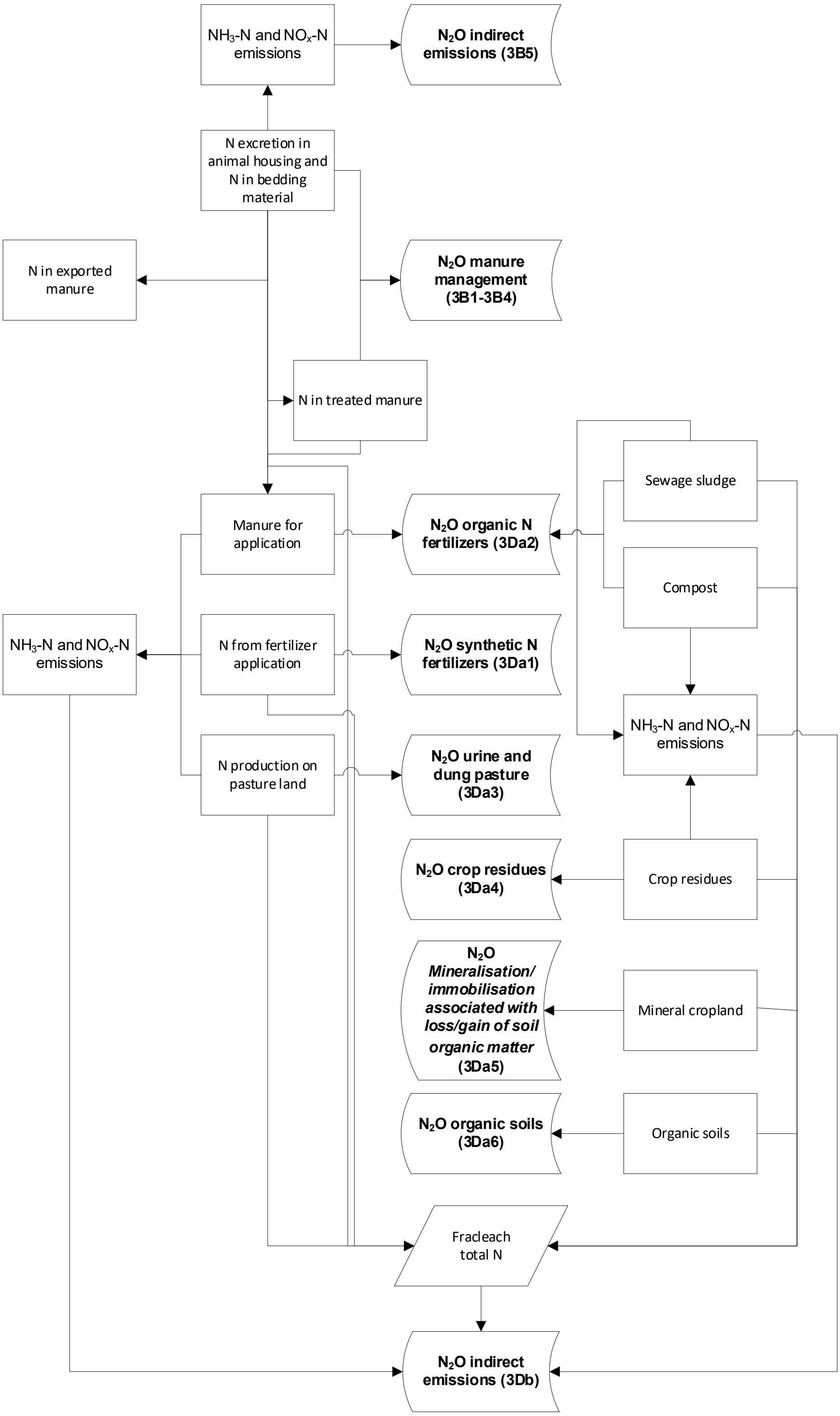


Figure 5.4 Schematic representation of N flows in agriculture and the allocation of emissions to source categories

5.3.2 *Methodological issues*

For all sub-source categories, the methodologies used to estimate emissions follow the 2006 IPCC Guidelines. Detailed information on calculation methods and EFs can be found in Chapters 4 and 7 of Van der Zee et al. (2024). An overview of the activity data can be found in Statistics Netherlands (2019 through 2023); Van Bruggen et al. (2024). More information on housing systems used in the Netherlands can be found at https://www.infomil.nl/onderwerpen/landbouw/stalsystemen/stalbeschrijvingen/ (in Dutch only).

Emissions from manure treatment are calculated using a Tier 2 method. Five manure treatment systems can be found in the Netherlands: Manure separation, the production of mineral concentrates, manure digestion, manure pelleting and incineration. A description of the EFs for the various types of manure treatment used in the Netherlands can be found in Melse and Groenestein, (2016). Emissions from manure digestion are reported under 5B. Biological treatment of solid waste. Emissions from the incineration of manure are reported under 1A1a other fuels.

CH_4 from manure management

Methane emissions from manure management are calculated using Tier 1 and Tier 2 methods. For horses, goats, mules and asses, sheep, rabbits and fur animals, a Tier 1 method is used. For cattle, swine, and poultry, a country-specific Tier 2 approach is used to calculate CH_4 EFs for manure management annually as they constitute key sources. The EFs are calculated for liquid and solid manure management systems within the key animal categories cattle, swine, and poultry and, where applicable, for the manure produced on pasture during grazing. These calculations are based on country-specific data on:

- Manure characteristics: volatile solids excretion (VS, in kg VS/animal/year) and maximum CH_4 producing potential (B0, in m^3 CH_4/kg VS);
- Manure management system conditions (storage temperature and period) for liquid manure systems, which determine the Methane Conversion Factor (MCF).

In the Netherlands, liquid animal manure is stored in pits underneath the slatted floors of animal housing facilities. This manure is regularly pumped into outside storage facilities or applied on the land. Given this practice, country-specific MCF values have been calculated for liquid manure since the manure management systems are different from the circumstances on which the default is based, as demonstrated in Groenestein et al. (2016). For solid manure management systems and manure produced on pasture while grazing, IPCC default values are used. The time that animals spend on pasture is calculated annually by the Working group on Uniformity of calculations of Manure and mineral data (Statistics Netherlands, 2011-2023). A time series with the emission factors for liquid manure, solid manure and manure in pasture can be found in Annex 29 of Van Bruggen et al. (2024). If the manure is treated, it is assumed that the storage time is short as it is beneficial for the farmer to treat the manure as soon as possible. In practice, it is possible that manure is stored for a longer period before treatment.

However, to account for this, complex calculations have to be made for all N species, with a high chance of overestimating the emissions. Methane emissions from manure treatment are based on the amount of manure in kg VS treated; emission factors are based on Melse and Groenestein (2016).

Table 5.6 presents the IEFs for manure management per animal category. These are expressed in kg CH_4 per animal per year and are calculated by dividing total emissions by livestock numbers in each category.

Table 5.6 CH_4 implied emission factors (kg/animal/year) for manure management specified by animal category, 1990–2022

Animal category	1990	1995	2000	2005	2010	2015	2020	2021	2022
Cattle									
Mature dairy cattle	23.07	24.10	27.97	31.07	34.87	36.72	37.57	37.85	39.00
Other mature cattle	7.42	7.53	7.50	7.84	8.04	8.01	6.80	6.75	6.74
Growing cattle	6.87	7.04	6.62	6.30	7.05	7.88	7.84	8.09	8.15
Sheep*	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19
Goats*	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
Horses	1.56	1.56	1.56	1.56	1.56	1.56	1.56	1.56	1.56
Mules and asses	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76
Swine*	9.68	8.77	8.05	7.19	6.07	5.31	5.66	5.42	5.34
Swine excl. piglets	15.44	14.34	13.18	12.06	10.43	9.55	10.36	9.88	11.19
Fattening pigs	12.87	11.81	10.76	9.70	8.40	7.53	8.35	8.00	7.93
Breeding swine	26.09	25.08	23.60	22.47	20.18	19.27	20.57	19.75	19.39
Poultry	0.19	0.13	0.08	0.05	0.03	0.03	0.03	0.03	0.03
Rabbits	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
Fur-bearing animals	0.68	0.68	0.68	0.68	0.68	0.68	0.68	NO	NO

** The IEF is calculated for total animal numbers, including young stock. Manure production by young stock is accounted for in manure production by the mother animal.*

Cattle (3B1)
The IEF for the manure management of mature dairy cattle increased between 1990 and 2022 as higher feed intake resulted in an increased VS production per cow. The shift in the proportion of the two main manure management systems used in dairy farming (liquid manure in the animal house and manure production on pasture) also contributed to the increased IEF as cows spend less time grazing: between 1990 and 2022, the share of manure produced in liquid manure management systems increased in comparison with the amount of manure produced on pasture (Statistics Netherlands, 2023).

Swine (3B3)
Between 1990 and 2022, the IEF for swine manure management (based on total swine numbers, including piglets) decreased due to a lower VS excretion per animal. The decrease in VS excretion per animal counteracts the increase in animal numbers in earlier years of the time series. The VS excretion decreased because the feed composition changed over the years, increasing the overall digestibility. The IEF also

decreased as the productivity of the sows increased between 1990-2022, thus distributing the emissions across more animals.

Poultry (3B4)
For poultry, the substantial decrease in CH_4 emissions is explained by a shift in the proportion of the two poultry manure management systems (solid and liquid manure) between 1990 and 2013, when the liquid manure system was fully replaced by the solid manure system (Van der Hoek and Van Schijndel, 2006). The decrease in poultry numbers by 2% since 1990 further decreases CH_4 emissions from poultry.

Sheep, goats, horses, mules and asses (3B2 and 3B4)
Sheep, goats, horses, and mules and asses only produce solid manure, which has a low EF. Therefore, the IEFs are also small. These represent the IPCC Tier 1 defaults.

Rabbits and fur-bearing animals
The IPCC Tier 1 default emission factors have been used for rabbits (solid manure) and for fur-bearing animals (liquid manure)(minks and foxes). Keeping fur-bearing animals in the Netherlands was banned in 2021.

Comparison with IPCC default EF for CH_4
The methods applied by the Netherlands for CH_4 calculations are in accordance with the 2006 IPCC Guidelines. Detailed descriptions of the methods are provided in Van der Zee et al. (2024). More detailed data on manure management, based on statistical information on manure management systems, is documented in Van der Hoek and Van Schijndel (2006) for the 1990–2006 period and in Statistics Netherlands, (2023) for the period from 2006 onwards.

N_2O from manure management
Direct emissions of N_2O from manure management are calculated using the Tier 1 method. As manure management does not constitute a key category for N_2O emissions, no higher Tier is required. Indirect N_2O emissions from manure management are calculated using a Tier 2 method. Emissions of NH_3 and NO_x are calculated using Tier 2 and Tier 3 methods. The default EF for indirect N_2O emissions from manure management has been used. An increase in IEF between 2010 and 2022 is the result of increased N excretion combined with a decrease in animal numbers (Table 5.7). This is caused by increased feed intake as a result of a higher average weight of mature dairy cattle (Statistics Netherlands, 2019; Van Bruggen et al., 2019) and a higher average milk production. As a result of new insights into the feed intake of horses and ponies, the N excretion increased in 2018 (Bikker et al., 2019).

Table 5.7 N_2O IEFs for manure management per animal category, 1990–2022 (mln kg/year and kg N_2O/kg manure-N)

Animal category	1990	1995	2000	2005	2010	2015	2020	2021	2022
Cattle									
Mature dairy cattle	0.34	0.36	0.32	0.34	0.34	0.35	0.40	0.39	0.38
Other mature cattle	0.19	0.22	0.20	0.18	0.17	0.18	0.22	0.21	0.19
Growing cattle	0.14	0.15	0.13	0.11	0.11	0.12	0.12	0.11	0.11
Sheep*	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01
Goats*	0.19	0.19	0.17	0.16	0.17	0.18	0.22	0.21	0.21
Horses	0.21	0.21	0.21	0.21	0.19	0.19	0.26	0.25	0.25
Mules and asses	0.11	0.11	0.11	0.11	0.10	0.10	0.13	0.13	0.13
Swine*	0.03	0.035	0.03	0.03	0.03	0.02	0.01	0.01	0.01
Poultry	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rabbits*	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Fur-bearing animals	0.01	0.01	0.01	0.01	0.01	0.01	0.01	NO	NO

* The IEF is calculated on total animal numbers, including young stock. Manure production by young stock is accounted for in manure production by the mother animal.

For indirect emissions from manure management, the atmospheric N deposition is calculated as described in section 7.4.1 of Van der Zee et al. (2024). The IPCC Guidelines also calculate leaching and run-off from manure storage. In the Netherlands, all slurry manure is stored underneath animal houses or in fully closed external storage tanks (this is an obligation ensuing from the EU Nitrates Directive). Solid manure must be stored on concrete plates with run-off directed into a slurry pit or separate tank.

Comparison with IPCC default EF for N_2O
For the relevant manure management systems and animal categories, the total N content of the manure is calculated by multiplying N excretion (kg/year/head) by livestock numbers. Activity data is collected in compliance with a Tier 2 method. The N_2O EFs used for liquid and solid manure management systems are IPCC defaults. The used method complies with the 2006 IPCC Guidelines.

5.3.3 *Uncertainty and time series consistency*

Uncertainty
The uncertainty analysis detailed in Annex 2 provides estimates of uncertainty according to IPCC source categories. The uncertainty for CH_4 from manure management ranges between 18% and c. 40% and is mostly determined by the estimated uncertainties in the EF (18% for 3B1 Growing cattle; 38% for 3A4 Other). Uncertainties in activity data range between 1% and c. 39%.

The uncertainty in the annual N_2O emissions from manure management is much higher; it is estimated at 64–100%, and it is attributable to the uncertainties in the EFs. A complete overview of the uncertainties can be found in section 4.4./ annex 10 of Van der Zee et al. (2024).

Time series consistency
A consistent methodology is used throughout the time series; see section 5.3.2. Emissions are calculated from animal population data and

EFs. The animal population data is collected both through the Identification and Registration system and in an annual census published by Statistics Netherlands. Consistent methods are used in compiling the census to ensure continuity in the collected data. EFs are either constant (default IPCC) or calculated/modelled from feed intake data collected through an annual survey by Statistics Netherlands (2019 through 2023).

5.3.4 *Category-specific QA/QC*

This source category is covered by the general QA/QC procedures discussed in Chapter 1.

5.3.5 *Category-specific recalculations*

Three category-specific recalculations have been performed. The TAN content of treated veal manure has been based on the TAN excretion instead of on a default value. The effect of this change on N_2O emissions from veal manure treatment ranges between -1% and +9%.
The N content of manure sent to treatment facilities has been based on the mandatory transport certificates instead of on defaults for the years 2018-2022. This affects N_2O and CH_4 emissions from manure treatment. The effect ranges between -4% and 2% (N_2O) and -3% and +4% (CH_4), respectively.
The indirect N_2O emissions from manure management (3Ba5) have been recalculated as the emissions of NH_3 and NO_x are affected by the two previous recalculations as well as by the inclusion of bedding material for the calculation of NH_3 emissions from manure management. More information on the calculation of indirect emissions can be found in sections 12.9 and 12.10 of Van der Zee et al. (2024). More information on the emissions from bedding material can be found in Annex 11 of Van der Zee et al. (2024).

5.3.6 *Category-specific planned improvements*

Investigations will be made into whether enough information is available to include the emissions from more manure treatment techniques, namely manure hygienisation and the composting of manure.
The time series consistency of the amount of treated manure will be assessed in 2024. The amount of manure has been based on transport certificates from 2018 onwards. Prior to 2018, default values were used for the N content of the treated manure.

5.4 Agricultural soils (3D)

5.4.1 *Source category description*

In 2022, agricultural soils were responsible for 23.0% of total GHG emissions in the Agriculture sector. Total N_2O emissions from agricultural soils decreased by 46.7% between 1990 and 2022 (Table 5.8). In 2022, N_2O emissions from grazing increased by 0.2% compared to 2021. Emissions from organic N fertilisers increased by 1.5% in 2022 due to an increase in application compared to 2021. Emissions from inorganic N fertilisers decreased by 6.4% in 2022 compared to 2021. In 2022, emissions from crop residues increased by 1% compared to 2021.

Table 5.8 Overview of the sector agricultural soils (3D) in the base year and the last two years of the inventory

Sector/category	Gas	1990	2021	2022	2022 vs 1990	Contribution to total in 2022 (%) by		
		Emissions in Tg CO_2-eq			%	sector	total gas	total CO_2-eq
3D. Agriculture soils	N_2O	7.8	4.2	4.1	-46.7%	23.0%	62.6%	2.6%
3Da. Direct N_2O emissions from agricultural soils	N_2O	6.3	3.7	3.6	-42.7%	20.1%	54.8%	2.3%
3Da1. Inorganic fertilisers	N_2O	1.8	1.0	0.9	-46.7%	5.2%	14.2%	0.6%
3Da2. Organic N fertilisers	N_2O	0.7	1.0	1.0	51.6%	5.8%	15.8%	0.7%
3Da3. Urine and dung from grazing animals	N_2O	2.7	0.7	0.7	-72.3%	4.1%	11.2%	0.5%
3Da4. Crop residues	N_2O	0.4	0.3	0.3	-28.6%	1.7%	4.5%	0.2%
3Da5. Mineralisation/ immobilisation associated with loss/gain of soil organic matter	N_2O	0.05	0.03	0.02	-59.2%	0.1%	0.3%	0.0%
3Da6. Cultivation of organic soils	N_2O	0.7	0.6	0.6	-20.7%	3.2%	8.8%	0.4%
3Db. Indirect N_2O Emissions from managed soils	N_2O	1.4	0.5	0.5	-64.1%	2.9%	7.8%	0.3%

This sector comprises the following key categories:

3Da	Direct emissions from agricultural soils	N_2O
3Db	Indirect emissions from managed soils	N_2O

The decrease in total N_2O emissions from 1990 onwards has been caused by a relatively large decrease in N inputs into soil (from inorganic fertiliser and organic N fertiliser applications and from production of animal manure on pasture during grazing; Figure 5.5). This was partly counteracted by a shift from applying manure on top of the soil (surface spreading) towards incorporating it into the soil, initiated by the Dutch ammonia policy. Incorporating manure into the soil reduces emissions of ammonia but increases direct emissions of N_2O, counteracted in part by lower indirect N_2O emission following the atmospheric deposition of NH_3 and NO_x.

Methane emissions from agricultural soils are regarded as natural, non-anthropogenic emissions and are therefore not estimated.

The source category Agricultural soils includes emissions from:
- Inorganic fertilisers (3Da1);
- Organic N fertilisers (mainly animal manure, 3Da2);

- Urine and dung from grazing animals (3Da3);
- Crop residues (3Da4);
- Mineralisation/immobilisation associated with losses/gains of soil organic matter (3Da5)
- Cultivation of organic soils (3Da6);
- Indirect N_2O emissions from managed soils (3Db).

Figure 5.5 shows the trend in total agricultural soils emissions.

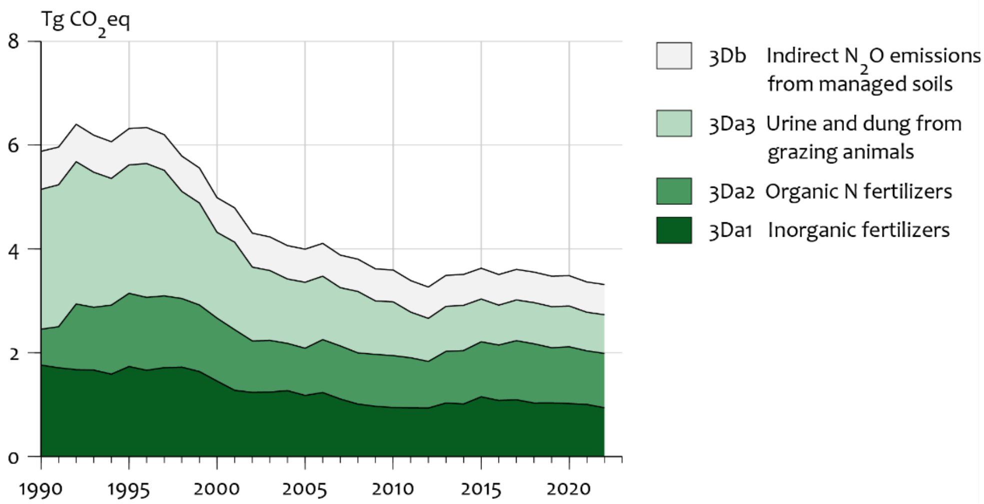


Figure 5.5 Category 3D Agricultural soils – trend and emission levels of source categories, 1990–2022

Between 70% and 80% of the N excreted in animal housing is available for application to soils. The remainder is lost during storage or exported. The export of manure increased in the last decade, but stagnated in recent years. The method to calculate manure export is explained in section 2.2.5 of Van der Zee et al. (2024). Approximately 10% to 16% of the N excreted in housing is emitted as NH_3 or NO_x oxide during storage. In addition, part of the N stored in manure is lost as N_2 and N_2O.

The total N supply to the soil was considered to calculate leaching and run-off. This supply consists of N from manure production in animal housing and on pasture (including treated manure, corrected for manure export), as well as the application of inorganic N fertiliser, sewage sludge and compost. In accordance with the IPCC 2006 Guidelines, the calculation includes atmospheric N deposition because the N deposited to soil is also subject to leaching and run-off. Total N supply to the soil decreased by 39% between 1990 and 2022. This can be explained by the Netherlands' manure and fertiliser policy aimed at reducing N leaching and run-off. This policy regulates the amount of manure production and its application to soils by introducing measures, such as restrictions on the numbers of swine and poultry per farm (so-called 'manure production rights') and maximum application limits for manure and inorganic N fertiliser, all part of the Dutch 'Manure and Fertilisers Act' in accordance with the Nitrates Directive. Because the leaching fraction has also decreased over time, the amount of N leached or run off has been reduced by 47% since 1990.

Between 1990 and 2022, the emissions of crop residues decreased by 28.6% (Table 5.8). The same decreasing trend can be seen in the amount of crop residues left on the field. This is mainly due to a decrease in grassland renewal. The rate of grassland renewal decreased as a result of policy changes that encouraged permanent grassland (RVO, 2021). The methodology to calculate N_2O emissions from crop residues is provided in section 12.7 of Van der Zee et al. (2024). Activity data can be found in Annex 21 of Van Bruggen et al. (2024).

5.4.2 *Methodological issues*

Direct and indirect N_2O emissions from agricultural soils are estimated using country-specific activity data on N input to soil and NH_3 volatilisation during grazing, manure management, and manure application. Most of this data is estimated at Tier 2 or Tier 3 level. The present methodologies follow the 2006 IPCC Guidelines. A description of the methodologies used and the data sources is presented in Chapter 12 of Van der Zee et al. (2024). More information can be found in the background document by Van der Hoek et al. (2007). The activity data and characteristics for crops are presented in Van Bruggen et al. (2024).

Direct N_2O emissions (3Da)

An IPCC Tier 2 methodology is used to estimate direct N_2O emissions from agricultural soils.

The EF of inorganic N fertiliser application for direct N_2O emissions between 1990 and 1999 is based on a weighted mean of various inorganic N fertiliser types applied to both mineral and organic soils. The EFs for animal manure applied to or produced on pastureland during grazing between 1990 and 1999 are also based on weighted means of the EF for mineral and organic soils.

For the years from 2000 to 2022, separate EFs have been quantified for organic soils and mineral soils. A distinction has also been made between arable land and grassland. This results in three different EFs each for inorganic fertiliser application, surface spreading of manure, and manure incorporation into soil. The EFs of grassland and arable land on organic soils are the same, as the carbon content (and thus the potential for N_2O emissions) in these soils is hardly affected by the type of agriculture practiced. For the years 2000–2022, two separate EFs have also been quantified for organic and mineral soils used for grazing. An overview of the EFs used is presented in Table 5.9, with default IPCC EFs included for comparison.

Table 5.9 EFs for direct N_2O emissions from agricultural soils (kg N_2O-N per kg N supplied, except Mineralisation/immobilisation associated with losses/gains of soil organic matter, which is expressed in kg N_2O-N per kg CO_2)

Source	Default IPCC	EF used	Reference
Inorganic N fertiliser	**0.01**	**0.013**	**1**
Mineral soils grassland		0.008	1
Organic soils grassland		0.030	1
Mineral soils arable land		0.007	1
Organic soils arable land		0.030	1
Animal manure application	**0.01**		
Surface spreading average		**0.004**	**1**
Mineral soils grassland		0.001	1
Organic soils grassland		0.005	1
Mineral soils arable land		0.006	1
Organic soils arable land		0.005	1
Incorporation into soil average		**0.009**	**1**
Mineral soils grassland		0.003	1
Organic soils grassland		0.010	1
Mineral soils arable land		0.013	1
Organic soils arable land		0.010	1
Sewage sludge	**0.01**		
Surface spreading		0.004	1
Incorporation into soil		0.009	1
Compost	**0.01**	**0.004**	**2**
Animal manure during grazing (cattle/swine/poultry)	**0.02**	**0.033**	**1**
Mineral soils		0.025	1
Organic soils		0.060	1
Animal manure during grazing (sheep/other animals)	**0.01**	**0.033**	**1**
Mineral soils		0.025	1
Organic soils		0.060	1
Crop residues	**0.01**	**0.01**	**3**
Grassland renewal		**5.5***	**5**
Mineralisation/immobilisation associated with losses/gains of soil organic matter	**0.01**		
Cultivation of organic soils		**0.02**	**3, 4**

*kg N_2O-N per ha grassland renewed
References: 1 = Velthof et al. (2010), Velthof and Mosquera (2011), Van Schijndel and Van der Sluis (2011); 2 = equal to that of surface-applied manure (Velthof and Mosquera, 2011); 3 = Van der Hoek *et al.* (2007); 4 = Kuikman *et al.* (2005); 5 = Velthof et al. 2010b.

Emissions from animal manure application are estimated for two manure application methods: surface spreading (which has a lower EF) and incorporation into soil (which has a higher EF). The higher value for incorporation is explained by two mechanisms. Incorporation of animal

manure into the soil produces less NH_3; therefore, more reactive N enters the soil available for N_2O emission. Furthermore, the manure is more concentrated (i.e. hot spots/anaerobic) than with surface spreading, generally creating improved conditions for N_2O production during nitrification and denitrification processes.
The different EFs for mineral soils and organic soils and mineral soil - arable land and mineral soil – grassland are caused by the difference in organic matter content. The organic matter content of the soil influences the N_2O emission. The difference in organic matter content between organic soil – grassland and organic soil – arable is negligible (Velthof and Rietra, 2018).

The IEF of direct N_2O emissions from the application of animal manure on agricultural soils increased by 101% in the 1990–2022 period (Table 5.10). This was caused by an ammonia policy-driven shift from the surface spreading of manure to the incorporation of manure into the soil.

Table 5.10 N_2O implied emission factor (kg N_2O-N per kg N supplied) from animal manure applied (excl. manure on pasture) to agricultural soils, 1990–2022

	'90	**'95**	**'00**	**'05**	**'10**	**'15**	**'21**	**'22**
Nitrogen input from manure applied to soils	0.004	0.008	0.009	0.007	0.008	0.008	0.008	0.008

The net decrease in direct N_2O emissions can be explained by the decrease in the direct N input to the soil by manure and inorganic N fertiliser application, partly countered by an increase in IEF because of the manure incorporation into the soil.

No experimental data on compost emissions is available. On the basis of expert judgement, the emission factor for compost was set equal to that of surface-applied manure, because compost is also applied to the surface. The IPCC guidelines contain one emission factor for all N additions to the soil. The emission factor used is within the uncertainty range provided by the IPCC (0.003-0.03). The EF used for urine and dung deposited by grazing animals is based on Velthof et al. (1996) who conducted a field study on N_2O emissions resulting from grazing in the Netherlands. Annex 9 of Van der Zee et al. (2024) describes how the results of this paper were used to calculate the emission factors used in the inventory of the Netherlands. As arable farming on organic soils is a relatively small compared to arable farming on mineral soils in the Netherlands, the EF for crop residues is based on mineral soils only. The EF of grassland renewal is based on the average of grassland renewal with and without ploughing up the land (Velthof et al. 2010b).

Emissions from mineralisation/immobilisation associated with losses/gains of soil organic matter are calculated using the Tier 1 method. The losses of soil organic matter are calculated by the LULUCF sector and discussed in Chapter 6. A constant C/N ratio of 10 is used throughout the time series. More information can be found in section 12.9 of Van der Zee et al. (2024).

Indirect N_2O emissions (3Db)
An IPCC Tier 2 method is used to estimate indirect N_2O emissions from atmospheric deposition. Country-specific data on NH_3 and NO_x emissions (estimated at Tier 3 level using NEMA) is multiplied by the IPCC default N_2O EF. The emissions can be found in Chapter 9 of Van Bruggen *et al.* (2024).

Indirect N_2O emissions resulting from leaching and run-off are estimated using country-specific data on total N input to soil and leaching fraction (estimated at Tier 3 level). The leaching fraction can be found in section 4.2 of Van Bruggen et al. (2024). The leaching fraction applied in the model reflects the specific characteristics of the Dutch agricultural soils, with relatively high water tables. A model (STONE) was adopted to assess this fraction, as described in Velthof and Mosquera (2011), while IPCC default values were used for the N_2O EF.

5.4.3 Uncertainty and time series consistency

Uncertainty
The uncertainty analysis outlined in Annex 2 provides estimates of uncertainty per IPCC source category. The uncertainty in direct N_2O emissions from inorganic N fertiliser, organic N fertiliser, and manure and dung deposited by grazing animals is estimated at 42%, 69%, and 68%, respectively. The uncertainty in indirect N_2O emissions from N used in agriculture is estimated to be more than 200%; primarily relating to the emission factor uncertainties.

Time series consistency
A consistent methodology is used throughout the time series; see section 5.4.2. Emissions are calculated as the product of livestock numbers and EFs. Livestock numbers are collected through the Identification and Registration system and in an annual census as published by Statistics Netherlands (CBS). Consistent methods are used in compiling the census to ensure consistency in the collected data.

5.4.4 Category-specific QA/QC

This source category is covered by the general QA/QC procedures discussed in Chapter 1.

5.4.5 Category-specific recalculations

As the amount of available animal manure has changed due to the inclusion of straw in the model, the INITIATOR model distributed the inorganic fertiliser differently across the various land types between 2000 and 2021. N_2O emissions from the application of inorganic fertiliser (3Da1) changed by between -0.2% and +1.1%. The Initiator model does not account for the years prior to 2000. In 2024, it will be assessed whether a time series correction can be implemented for the years 1990-1999.

Moreover, there were a few recalculations relating to the N_2O emissions from losses/gains in soil organic matter content. Final data on the use of inorganic fertilisers and compost in 2021 differs from the preliminary numbers. This decreases N_2O emissions in 2021.The N_2O emissions from crop residues (3Da4) have been recalculated for the entire time series. The area of mown grasslands changed due to the inclusion of mown

natural grasslands (used primarily for agricultural production) as well as the shift to the agricultural census instead of the grassland survey. As a result of these two changes, N_2O emissions from crop residues increased by 0%-2%. Mown natural grasslands were previously not accounted for in the calculations. The agricultural census provides the total mown area as well as the frequency of mowing per year, whereas the grassland survey only provided the grassland area.
Lastly, N_2O emissions from mineralisation/immobilisation associated with loss/gain of soil organic matter (3Da5) have been added to the time series. CO_2 emissions from this pool were included in the LULUCF sector in the NIR 2023, which made it possible to subsequently calculate the N_2O emissions. The N_2O emissions have been calculated using the Tier 1 method from the guidebook. More information on the calculation can be found in section 12.8 of Van der Zee et al. (2024).

5.4.6 Category-specific planned improvements

There are currently no planned improvements.

5.5 Liming (3G)

5.5.1 Source category description

The source category Liming includes emissions of CO_2 from the application of limestone (calcium carbonate) and dolomite (calcium-magnesium carbonate) to agricultural soils. Limestone and dolomite are applied to maintain a suitable pH range for crop and grass production. CO_2 emissions from liming decreased by 82.4% between 1990 and 2022 as a result of a decrease in limestone and dolomite use (Table 5.11).

Table 5.11 Overview of the sector Liming (3G) in the base year and the last two years of the inventory

Sector/category	Gas	1990	2021	2022	2022 vs 1990	Contribution to total in 2022 (%) by		
		Emissions in Tg CO_2-eq			%	sector	total gas	total CO_2-eq
3G. Liming	CO_2	0.183	0.025	0.032	-82.4%	0.2%	0.0%	0.0%

Category 3G Liming is not a key category.

Limestone and dolomite make up 40–60% of the calcium-containing fertilisers used in agriculture. The remaining percentage (30%–55% of the total) consists mainly of sugar beet factory lime. CO_2 emissions related to the latter are balanced by the CO_2 sink in sugar production and are therefore not accounted for. More information can be found in section 2.2.3.1 of Honig et al. (2024).

5.5.2 Methodological issues

Data on liming is derived from annually updated statistics on fertiliser use. The annual amounts of applied limestone and dolomite are converted into CO_2 emissions, in line with the calculations in the 2006 IPCC Guidelines.

Limestone and dolomite amounts reported in CaO (calcium oxide) equivalents are multiplied by the EFs for limestone (440 kg CO_2/ton pure limestone) and for dolomite (477 kg CO_2/ton pure dolomite). This method complies with IPCC Tier 1 methodology. More detailed descriptions of the methodologies and EFs used can be found in Chapter 15 of Van der Zee et al. (2024).

5.5.3 Uncertainty and time series consistency

Uncertainty

The analysis outlined in Annex 2 provides estimates of uncertainties by IPCC source category. The uncertainty in CO_2 emissions from liming of soils is calculated at c. 25%. The uncertainty in the activity data is estimated to be 25% and the uncertainty in the EFs is 1%. When considered over a longer time span, all carbon applied through liming is emitted.

Time series consistency

The methodology used to calculate CO_2 emissions from limestone and dolomite application for the 1990–2022 period is consistent over time. Statistics on calcium-containing fertiliser use are collected by Wageningen Economic Research and published on the website agrimatie.nl (direct link: http://agrimatie.nl/KunstMest.aspx?ID=16927).

5.5.4 Category-specific QA/QC and verification

The source categories are covered by the general QA/QC procedures discussed in Chapter 1.

5.5.5 Category-specific recalculations

Every year, preliminary numbers of limestone and dolomite application are used for the last year in the inventory. The final usage of limestone and dolomite in 2021 differs from the preliminary numbers, resulting in a 6% increase of CO_2 emissions in 2021.

5.5.6 Category-specific planned improvements

The preliminary application rates of the liming products in 2022 will be replaced with the final application rates.

5.6 Urea application (3H)

5.6.1 Source category description

During the production of urea, CO_2 is trapped from the atmosphere. This CO_2 is subsequently released during the application of urea. The entrapment is attributed to the production. The CO_2 emissions resulting from the application of urea on Dutch farmland are attributed to the Agriculture sector. The use of urea increased from 2003 to 2015, after which it decreased again. Carbon dioxide emissions from urea application increased by 3662% from 1990 to 2022 (Table 5.12).

Table 5.12 Overview of the sector Urea application (3H) in the base year and the last two years of the inventory

Sector/category	Gas	1990	2021	2022	2022 vs 1990	Contribution to total in 2022 (%) by		
		Emissions in Tg CO_2-eq			%	sector	total gas	total CO_2-eq
3H. Urea Application	CO_2	0.002	0.062	0.057	3662.0%	0.3%	0.0%	0.0%

Category 3H urea application is not a key category.

5.6.2 *Methodological issues*

Data on urea application are derived from annually updated statistics on fertiliser use. Urea fertilisers often contain other N compounds. As there is no information on the percentage of urea in urea fertilisers the calculations assume that urea fertilisers only consist of urea. The amounts of annually applied urea are converted into CO_2 emissions in line with the calculations in the 2006 IPCC Guidelines.

The amount of urea is multiplied by the EF for urea (0.2 kg CO_2/kg urea). This method follows the IPCC Tier 1 methodology. More detailed descriptions of the methodology and EF used can be found in Chapter 16 of Van der Zee et al. (2023).

5.6.3 *Uncertainty and time series consistency*

Uncertainty

The analysis outlined in Annex 2 provides estimates of uncertainties by IPCC source category. The uncertainty in CO_2 emissions from urea application is calculated at 25%. The uncertainty in the activity data is estimated to be 25% and the uncertainty in the EFs is 1%. When considered over a longer time span, all carbon applied through liming is emitted.

Time series consistency

The methodology used to calculate CO2 emissions from urea application is consistent over time. Statistics on urea application are collected by the agricultural census.

5.6.4 *Category-specific QA/QC and verification*

The source categories are covered by the general QA/QC procedures discussed in Chapter 1.

5.6.5 *Category-specific recalculations*

Every year, preliminary numbers of urea application are used for the last year in the inventory. The final usage of urea in 2021 differs from the preliminary numbers, resulting in a 6% decrease of CO_2 emissions in 2021.

5.6.6 *Category-specific planned improvements*

The preliminary application rate of urea in 2022 will be replaced by the final application rate.

6 Land use, land use change and forestry (CRF sector 4)

Major changes in the LULUCF sector compared to the National Inventory Report 2023

Emissions:	In 2022, total reported LULUCF emissions increased by 15% compared to 2021. Compared to the base year, emissions in 2022 were 5.8% lower. As a result of methodological changes described in this NIR 2024, emissions in the LULUCF sector for the year 1990 decreased by 12.9% compared to the NIR 2023. For 2021, they increased by 2.3% compared to the NIR 2023.
New Key categories:	No changes in key categories compared to the NIR 2023
Methodologies:	In the NIR 2024, four methodological changes have been implemented. All four result in recalculations for the whole time series. The methodological changes are as follows: 1) spatially explicit input data on soil management for the years 1990-2004 is introduced in the Tier 3 model (RothC) to calculate carbon stock changes in mineral soils in Cropland (CRF 4.B.1) and agricultural grasslands (CRF 4.C.1). This data was previously missing. Furthermore, the way in which the moving average of mineral soil emissions was calculated (to take into consideration weather extremes), was revised. The moving average used to be based on the period two years prior to and two years following the reporting year; this has now been adjusted to four years prior to the reporting year and the reporting year itself; 2) New data for carbon stocks in Forest land has been incorporated. Since the National Forest Inventory (NFI) 7 (2017-2021), the NFI is implemented as a continuous inventory with a five-year cycle and with permanent sample plots. 2022 was the first year of the 8th NFI cycle and is the first year for which new plot remeasurements are available. The new data is used to update the data for the measurements performed in 2017, resulting in a new average for the 2018-2022 period. As a result of this improvement in the collected data, the actual changes in carbon stocks can now be incorporated without the need

	for additional model extrapolations for the years beyond the last NFI data. For consistency reasons, however, this also requires an updated approach to the reference years used for the previous NFIs. Every National Forest Inventory prior to NFI-7 produced data for a different time period. In previous NIRs, the middle year of each inventory was chosen as the reference year to include in the NIR reports. For example, NFI–5 was conducted from 2001 to 2005, and so the reference year was 2003. With the changed approach in the NIR 2024, we aim to harmonise the years attributed to the NFI data and make this consistent with the approach for NFI–7 and NFI–8, which produce data every year. Therefore, we will now use the end year of each inventory, e.g. for NFI-5, (1 January) 2006 will be used as the reference year that we will report in the NIR. As a result, the period between the earlier NFI reference years becomes longer, while between NFI–5 and NFI–6 this becomes shorter. Because net carbon stock changes, as calculated on the basis of the consecutive NFIs, remain the same, this means that, whereas annual removals between the NFI's change, total removals over the whole time period remain equal. 3) Changes were implemented regarding the build-up of carbon stock in litter on Land converted to Forest land (CRF 4.A.2). This has been adjusted to a gradual increase through interpolation. The method is similar to the method for carbon stock gains in living biomass for Land converted to Forest land (using a thirty-year period until full build-up of the stock); 4) a Tier 1 methodology was implemented to calculate CH_4 and CO_2 emissions from all canals and ditches (>3m wide) and for reservoirs and fresh-water ponds created since 1900 (CRF 4(II).D.3). Additionally, new country-specific data on carbon content in litter in forest land were applied to convert litter thickness – as measured during the NFIs – to litter carbon stocks. These new data were used to calculate carbon stock changes in litter in land converted to forest land and for deforestation (Forest land converted to other land uses).

6.1 Overview of the sector

6.1.1 General overview of shares and trends in sources and sinks

This chapter describes the 2024 GHG inventory for the Land use, land use change and forestry (LULUCF) sector. It covers both the sources and sinks of CO_2 from land use, land use change, and forestry. Emissions of nitrous oxide (N_2O) from the cultivation of organic soils are included in the Agriculture sector (category 3D), except for N_2O emissions from Forest land, which are reported in CRF Table 4(II). Direct N_2O emissions from nitrogen mineralisation associated with loss/gain of soil organic matter in all land categories (CRF table 4III) are included here, except those from Cropland remaining cropland, which are also included in the Agriculture sector. Methane (CH_4) emissions from drainage ditches in drained Forest land, Cropland and agricultural grasslands on organic soils are reported in CRF Table 4(II) as a specific category under organic soils for these land use categories. Emissions of CH_4 from open water are reported under Wetlands in CRF Table 4(II).

Land use in the Netherlands is dominated by agriculture (approximately 54%), followed by settlements (15%) and forestry (9%); 3% comprises dunes, nature reserves, wildlife areas, heather, and reed swamp. The remaining area (19%) is open water (information based on the 2021 land use maps used for LULUCF reporting, see Van Baren et al., 2024).

The soils in the Netherlands are dominated by mineral soils, mainly sandy soils, and clay soils (of fluvial or marine origin). Organic soils, used mainly as meadowland, cover about 11% of the land area, one third of them being peaty soils.

The Netherlands has an intensive agricultural system with high inputs of nutrients and organic matter. The majority of agricultural land is grassland (54%) or arable farming land (28%). The remaining land is fallow or used for horticulture, fruit trees, etcetera. In 2020, 79% of grassland was permanent grassland (of which 10% is high nature value grassland); the remaining 21% is temporary grassland, on which grass and fodder maize are cultivated in rotation (Statistics Netherlands, 2022[7]). Since 1990, the agricultural land area has decreased by about 5%, mainly because of conversion to settlements/infrastructure and nature.

Table 6.1 presents the sources and sinks in the LULUCF sector in 1990, 2021 and 2022. For 1990 and 2022, total net emissions are 5.4 Tg CO_2-eq and 5.1 Tg CO_2-eq, respectively. The results for 2021 have been added to give insight into annual changes.

Sector 4 (LULUCF) accounted for about 3.2% of net national total CO_2 equivalent emissions in 2022.

CO_2 emissions from the drainage of peat soils and peaty soils were the major source in the LULUCF sector and total 6.0 Tg CO_2 in 2022 (7.2 Tg CO_2 in 1990). This drainage results in peat oxidation and is due to

[7] CBS Statline Landbouwtelling; oppervlakte gewassen, aantal dieren, arbeidskrachten en bijbehorend aantal bedrijven. https://opendata.cbs.nl/portal.html?_la=nl&_catalog=CBS&tableId=81302ned&_theme=203. Accessed 10 January 2022.

agricultural and urban water management; it is the chief contributor to the net emissions of Cropland (4B), Grassland (4C) and Settlements (4E). Additionally, drainage ditches on organic soils added 8.7 Gg CH_4 (0.24 Tg CO_2-eq) in 2022, compared to 10.9 Gg CH_4 (0.31 Tg CO_2-eq) in 1990.

Forests constitute the major net CO_2 sink with -1.4 Tg CO_2 in 2022, which includes Forest land remaining Forest land (4A1) and Land converted to Forest land (4A2). Compared to 2021 the net CO_2 sink sharply decreased, which is the result of a change in methodology but is also due to the real observed decrease in forest carbon sink based on the most recent National Forest Inventory (NFI) data, see section 6.1.3. for an explanation of the methodology change. At this time, the reason for this decrease has not yet been analysed. This will be done once more data from the 8th NFI becomes available in the coming years.

Table 6.1 Overview of the Land use, land use change and forestry (LULUCF) sector in the base year and the last two years of the inventory

Sector/category	Gas	1990	2021	2022	2022 vs 1990	Contribution to total in 2022 (%) by		
		Emissions in Tg CO_2-eq			%	sector	total gas	total CO_2-eq
4. Total Land use categories	CO_2	4.7	3.7	4.4	-6.3%	86.6%	3.3%	2.8%
	CH_4	0.6	0.6	0.6	-0.8%	11.7%	0.4%	0.4%
	N_2O	0.1	0.1	0.1	-13.1%	1.7%	0.1%	0.1%
	All	5.4	4.4	5.1	-5.8%	100.0%		3.2%
4A. Forest land	CO_2	-2.2	-2.3	-1.4	34.3%	-28.2%	-1.1%	-0.9%
4A1. Forest land remaining forest land	CO_2	-1.4	-1.6	-0.8	43.5%	-15.6%	-0.6%	-0.5%
4A2. Land converted to forest land	CO_2	-0.8	-0.7	-0.6	17.6%	-12.5%	-0.5%	-0.4%
	All	-2.2	-2.3	-1.4	34.3%	-28.2%	-1.1%	-0.9%
4B. Cropland	CO_2	2.9	2.0	1.9	-33.3%	37.9%	1.5%	1.2%
4B1. Cropland remaining cropland	CO_2	1.5	0.8	0.7	-55.3%	13.1%	0.5%	0.4%
4B2. Land converted to cropland	CO_2	1.4	1.2	1.3	-10.1%	24.9%	1.0%	0.8%
	All	2.9	2.0	1.9	-33.3%	37.9%	1.5%	1.2%
4C. Grassland	CO_2	2.9	2.5	2.4	-17.0%	48.0%	1.8%	1.5%
4C1. Grassland remaining grassland	CO_2	3.3	2.7	2.6	-20.9%	50.9%	2.0%	1.6%
4C2. Land converted to grassland	CO_2	-0.3	-0.1	-0.1	56.0%	-2.9%	-0.1%	-0.1%
	All	2.9	2.5	2.4	-17.0%	48.0%	1.8%	1.5%
4D. Wetlands	CO_2	0.01	-0.04	-0.05	-536.7%	-1.0%	0.0%	0.0%
	CH_4	0.3	0.4	0.3	19.8%	6.9%	0.2%	0.2%
4D1. Wetlands remaining wetlands	CO_2	NO,IE,NA	NO,IE,NA	NO,IE,NA		0.0%	0.0%	0.0%
	CH_4	0.2	0.3	0.3	28.8%	6.0%	0.2%	0.2%
4D2. Land converted to wetlands	CO_2	0.01	-0.04	-0.05	-536.7%	-1.0%	0.0%	0.0%
	CH_4	0.1	0.0	0.0	-20.3%	0.8%	0,0%	0,0%

Sector/category	Gas	1990	2021	2022	2022 vs 1990	Contribution to total in 2022 (%) by		
		Emissions in Tg CO_2-eq			%	sector	total gas	total CO_2-eq
	All	0.3	0.3	0.3	-536.7%	5.9%	0.0%	0.0%
4E. Settlements	CO_2	1.0	1.2	1.2	18.7%	23.5%	0.9%	0.8%
4E1. Settlements remaining settlements	CO_2	0.2	0.5	0.5	112.8%	9.2%	0.4%	0.3%
4E2. Land converted to settlements	CO_2	0.8	0.7	0.7	-7.5%	14.4%	0.6%	0.5%
	All	1.0	1.2	1.2	18.7%	23.5%	0.9%	0.8%
4F. Other land	CO_2	0.1	0.2	0.2	99.0%	3.7%	0.1%	0.1%
4F1. Other land remaining other land	CO_2		0.0	0.0				
4F2. Land converted to other land	CO_2	0.1	0.2	0.2	99.0%	3.7%	0.1%	0.1%
	All	0.1	0.2	0.2	99.0%	3.7%	0.1%	0.1%
4G. Harvested wood products	CO_2	-0.1	0.1	0.1	289.5%	2.6%	0.1%	0.1%
National total GHG emissions (incl. CO_2 LULUCF)	CO_2	168.4	143.9	132.1	-21.6%			
	CH_4	36.3	19.1	18.5	-49.0%			
	N_2O	16.1	7.1	6.6	-58.7%			
	Total	228.1	171.5	158.4	-30.5%			

Emissions of CH_4 are only presented explicitly for open water under wetlands. Other emissions of CH_4 and emissions of N_2O are only presented for the total as the subdivision into the separate land use categories will mostly result in emissions that are smaller than 0.1 Tg CO_2-eq.

Key categories
When taking LULUCF categories into account in the key category analysis, the inventory comprises the following key categories:

4A	Forest land	CO_2
4B	Cropland	CO_2
4B	Cropland	N_2O
4C	Grassland	CO_2
4C	Grasslands	CH_4
4E	Settlements	CO_2
4F	Other land	CO_2

6.1.2 *Methodology and coverage*

Details of the methodologies applied to estimating CO_2 emissions and removals in the LULUCF sector in the Netherlands are given in a methodological background document (Van Baren et al., 2024).

The methodology of the Netherlands for assessing emissions from LULUCF is primarily based on the 2006 IPCC Guidelines (IPCC, 2006), and the 2019 refinement to the 2006 IPCC guidelines (IPCC, 2019). It follows a carbon stock change approach that is based on inventory data subdivided into appropriate pools and land use types, and a wall-to-wall approach for the estimation of area per category of land use. For the calculation of CH_4 emissions from open water under the Wetland category and from drainage ditches in peat meadows and Cropland on organic soils, the guidelines from the 2013 IPCC Wetlands supplement (IPCC, 2014) were applied.

The information on the activities and land use categories covers the entire territorial (land and water) surface area of the Netherlands. The inventory includes six land use categories: Forest land (4A); Cropland (4B); Grassland (4C); Wetlands (4D) (including open water); Settlements (4E) and Other land (4F). Category (4G) Harvested wood products (HWP) (4G), provides information on carbon gains and losses from the HWP carbon pool.

Spatially explicit land use and land-use conversion data (‘remaining’ or ‘land converted to’) is presented in a matrix (see section 6.3) in accordance with the geographically explicit Approach 3 described in Chapter 3 of Volume 4 of the 2006 IPCC Guidelines.

The land use category Grassland is subdivided in two sub-categories: Grassland (non-TOF) and Trees outside forests (TOF) (see section 6.2 and Van Baren et al., 2024). The sub-category Grassland (non-TOF) is the aggregation of the main sub-categories Grassland (i.e. predominantly grass vegetation), Nature (mainly heathland and peat moors) and Orchards. All IPCC categories are applicable to the Netherlands.

TOF are units of land that do not meet the minimum area requirement for the forest definition, but otherwise fulfil those requirements in terms of tree cover and tree height. This category is included under Grassland. In terms of carbon stocks and their changes, the TOF category, however, is similar to Forest land.

Conversions of land use from, to, and between Grassland (non-TOF) and TOF are monitored separately, and subsequent calculations of carbon stock changes differ from one another (see Van Baren et al., 2024).

An overview of the completeness of reporting by the Netherlands is provided in Table 6.2. In this table, pools for which carbon stock changes are reported are indicated in bold type, with the appropriate tier level in brackets. 'NO' is used for pools for which there are no carbon stock changes. 'IE' indicates that carbon stock changes are included elsewhere. Pools for which carbon stock changes are not estimated are marked 'NE', with an indication of the significance of the respective source or sink ('s' = significant, 'n.s.' = not significant) and a reference to the section where this is justified in this NIR.

The notation key NA is used in cases with a Tier 1 assumption of carbon stock equilibrium.

CH_4 emissions from flooded lands under Wetlands are reported using a Tier 1 methodology and default emission factors (see section 6.7.2).

Table 6.2 Carbon stock changes reported in the national inventory per land use (conversion) category

From **To↓**	**FL**	**CL**	**GL**	**WL**	**Sett**	**OL**
FL	BG (T2) BL (T2) DD (T2) DW (T2) Litt (T2) MS (NA) OS (T2) FF (T1)	BG (T2) BL (T2) DD (T2) DW (T2) Litt (T2) MS (T2) OS (T2) FF (IE)	BG (T2) BL (T2) DD (T2) DW (T2) Litt (T2) MS (T2) OS (T2) FF (IE)	BG (T2) BL (T2) DD (T2) DW (T2) Litt (T2) MS (T2) OS (T2) FF (IE)	BG (T2) BL (T2) DD (T2) DW (T2) Litt (T2) MS (T2) OS (T2) FF (IE)	BG (T2) BL (T2) DD (T2) DW (T2) Litt (T2) MS (T2) OS (T2) FF (IE)
CL	BG (T1) BL (T2) DD (T2) DM (T2) MS (T2) OS (T2) WF (IE)	BG (NA, n.s. 6.5.1) BL (NA, n.s., 6.5.1) DD (T2) DM (NA, n.s., 6.5.1) MS (T3) OS (T2) WF (IE)	BG (T1) BL (T1) DD (T2) DM (NA, n.s., 6.5.1, 6.6.1) MS (T2) OS (T2) WF (IE)	BG (T1) BL (NO) DD (T2) DM (NA, n.s., 6.5.1, 6.7.1) MS (T2) OS (T2) WF (IE)	BG (T1) BL (NO) DD (T2) DM (NA, n.s. 6.5.1, 6.8.1) MS (T2) OS (T2) WF (IE)	BG (T1) BL (NO) DD (T2) DM (NA, n.s. 6.5.1, 6.9.1) MS (T2) OS (T2) WF (IE)
GL	BG (T1, T2) BL (T2) DD (T2) DM (T2) MS (T2) OS (T2) WF (IE)	BG (T1, T2) BL (T1, T2) DD (T2) DM (NA, 6.5.1, 6.6.1) MS (T2) OS (T2) WF (IE)	BG (T2) BL (T1, T2) DD (T2) DM (NO, NA, n.s 6.6.1) MS (T3) OS (T2) WF (T1)	BG (T1, T2) BL (NO) DD (T2) DM (NA, n.s 6.6.1, 6.7.1) MS (T2) OS (T2) WF (IE)	BG (T1, T2) BL (NO) DD (T2) DM (NA, n.s 6.6.1, 6.8.1) MS (T2) OS (T2) WF (IE)	BG (T1, T2) BL (NO) DD (T2) DM (NA, n.s. 6.6.1, 6.9.1) MS (T2) OS (T2) WF (IE)

From To↓	FL	CL	GL	WL	Sett	OL
WL	BG (NE, n.s. 6.7.1) BL (T2) DM (T2) MS (T2) OS (T2) WF (IE)	BG (NE, n.s. 6.7.1) BL (T1) DM (NE, 6.5.1, 6.7.1) MS (T2) OS (T2) WF (IE)	BG (NE, n.s. 6.7.1) BL (T1, T2) DM (NE, 6.6.1, 6.7.1) MS (T2) OS (T2) WF (IE)	BG (NE, n.s. 6.7.1) BL (NE, n.s. 6.7.1) DM (NE, n.s. 6.7.1) MS (NA) OS (NO) WF (IE)	BG (NE, n.s. 6.7.1) BL (NO) DM (NE, n.s 6.7.1, 6.8.1) MS (T2) OS (NO) WF (IE)	BG (NE, n.s. 6.7.1) BL (NO) DM (NE, n.s 6.7.1, 6.9.1) MS (T2) OS (NO) WF (IE)
Sett	BG (NE, n.s. 6.8.1) BL (T2) DM (T2) MS (T2) OS (T2) WF (NO)	BG (NE, n.s. 6.8.1) BL (T1) DM (NA, 6.5.1, 6.8.1) MS (T2) OS (T2) WF (NO)	BG (NE, n.s. 6.8.1) BL (T1, T2) DM (NA, 6.6.1, 6.8.1) MS (T2) OS (T2) WF (NO)	BG (NE, n.s. 6.8.1) BL (NO) DM (NA, 6.7.1, 6.8.1) MS (T2) OS (T2) WF (NO)	BG (NA, n.s. 6.8.1) BL (NA, n.s. 6.8.1) DM (NA, 6.8.1) MS (NA) OS (T2) WF (NO)	BG (NE, n.s. 6.8.1) BL (NO) DM (NA, 6.8.1, 6.9.1) MS (T2) OS (T2) WF (NO)
OL	BG (NO, n.s. 6.9.1) BL (T2) DM (T2) MS (T2) OS (NO) WF (NO)	BG (NO, n.s. 6.9.1) BL (T1) DM (NA, 6.5.1, 6.9.1) MS (T2) OS (T2) WF (NO)	BG (NO, n.s. 6.9.1) BL (T1, T2) DM (NA, 6.6.1, 6.9.1) MS (T2) OS (T2) WF (NO)	BG (NO, n.s. 6.9.1) BL (NO) DM (NA, 6.7.1, 6.9.1) MS (T2) OS (NO) WF (NO)	BG (NO, n.s. 6.9.1) BL (NO) DM (NA, 6.8.1, 6.9.1) MS (T2) OS (T2) WF (NO)	NA

Carbon stock changes included are BG: Biomass Gain; BL: Biomass Loss; DD: Drainage Ditches (<3 m) on organic soils with methane emissions; DW: Dead Wood; Litt: Litter; DM: Dead organic Matter; MS: Mineral Soils; OS: Organic Soils; FF: Forest Fires; WF: Other Wildfires. Land use types are: FL: Forest Land; CL: Cropland; GL: Grassland; TOF: Trees Outside Forests; WL: Wetland; Sett: Settlements; OL: Other Land.
Pools for which carbon stock changes are reported are indicated in bold type, with the appropriate tier level in brackets. See the indicated sections for further justification for the use of the notation key 'NA' in the case of non-significant (n.s.) pools

Forest land, Cropland, Grassland and Settlements are key categories; grassland is so due to the significant CH_4 emissions from peat soils (see sections 6.5.1, 6.6.1 and 6.8.1).

Carbon stock changes in biomass and dead organic matter
The specific methodologies applied to calculating carbon stock changes in living biomass and dead organic matter are provided in the sub-chapters dealing with the land use categories: Forest land (6.4), Cropland (6.5), Grassland (6.6), Wetlands (6.7), Settlements (6.8) and Other land (6.9). Methodologies for harvested wood products are provided in section 6.10.

Carbon stock changes in mineral soils
The Netherlands uses a Tier 3 approach to assessing carbon stock changes in mineral soils for Cropland remaining cropland and Grassland remaining grassland under agricultural use. For mineral soils under the other 'remaining' land use categories a Tier 1 assumption of dynamic equilibrium is assumed, which is reported as NA in the CRF tables. A Tier 2 approach is used for calculating carbon stock changes in land use conversions on mineral soils.

Cropland remaining cropland and Grassland remaining grassland
Changes in carbon stocks in mineral soils for Cropland remaining cropland and Grassland remaining grassland are calculated by means of the RothC model (version 26.3, Coleman and Jenkinson 2014) that is applied on a national scale, as described in Lesschen et al. (2021). For more details on the methodology, see section 11.2.2 in Van Baren et al. (2024). The model provides dynamic carbon stock changes over time that depend on a number of input variables. The most important input data are crop areas, input of organic fertilisers, use of cover crops, removal of straw and soil carbon content. A consistent time series of the input data has been made for the 1990-2022 period. Calculations are performed at 4-digit zip code level, comprising about 3,400 units with agricultural land. Further details on the input data can be found below.

- Climate data: Monthly data for the 1990-2021 period is available per KNMI zone (14 zones) in the Netherlands.
- Crop areas are based on 'Basisregistratie landbouwpercelen' (BRP, base layer for the Land Parcel Information System (LPIS) in the Netherlands) and aggregated to 40 crop categories. Detailed data has been available from 2005 onwards, while for the 1990-2004 period, national data was downscaled on the basis of the crop distribution data from 2005.
- Crop yield is based on harvest statistics from Statistics Netherlands (CBS), for the most common crops at provincial level and other crops at national level.
- Organic fertiliser supply is based on data from the Initiator model, which is also used in the National Emission Model for Agriculture (NEMA) for reporting on the Agriculture sector. A distinction is made between grazing and fertiliser application on grassland and cropland. This data has been available from 2000 onwards, while for the 1990-1999 period, data from Statistics Netherlands was used. This data is based on nitrogen applications and converted using average C/N ratios to carbon.

- Compost inputs are derived from data from the Agriculture Sector, which includes data on the nitrogen inputs from compost. This is only a small supply source of carbon compared to manure.
- For cover crops (green manures and catch crops), detailed data from LPIS has been available from 2017 onwards, while for the period before, only national total areas are available, which were obtained from NEMA.
- Straw removal is based on national average data from the 'Bedrijven Informatie Netwerk' (BIN, the Dutch data for the EU Farm Accountancy Data Network (FADN)[8]) for wheat and barley straw. This information has been available from 2005 onwards, while the 2005-2007 average was used for the 1990-2004 period. For other straw crops, a fixed percentage was applied, as described in Lesschen et al. (2021)

Lesschen et al. (2021) used soil carbon data from the 2018 Soil Sampling Programme (Knotters et al., 2022), but this only considers spatial variation in soil carbon to a limited extent. Therefore, a new soil carbon map was created on the basis of digital soil mapping, in which the data from the Soil Sampling Programme is used and linked to a wide range of other data, such as land use and topography. A pH map of the Netherlands has previously been made, using this same digital soil mapping method, see Helfenstein et al. (2022). This new organic carbon map is now available, and the average C content under mineral grassland and arable soils has been calculated per 4-digit zip code area. In the last step, the results of the model are aggregated per main soil type (sand, clay, loess, and soils with human-induced organic rich topsoil (*eerdgrond*)) to annual average carbon stock changes per ha Cropland or Grassland.

The soil organic carbon (SOC) balance calculations with RothC have been performed on the basis of the actual monthly climate data from the Royal Netherlands Meteorological Institute (KNMI). As the model is quite sensitive to the climate parameters, the annual variability of the SOC balance was considerable (-0.41 to +0.25 ton C/ha). Therefore, we opted to use the five-year average SOC balance for C fluxes in the Cropland remaining cropland and Grassland remaining grassland categories. This five-year period is in line with the five-year accounting periods of the EU LULUCF regulation and also with the national forest inventory, which is based on a five-year cycle. The five-year average SOC balance is calculated using the actual year and the four preceding years, e.g. the value for 2022 is based on the average of the 2018-2022 period.

Land use conversions on mineral soils

For land use conversions on mineral soils, the approach is based on the overlay of the land use maps with the 2014 update of the Dutch soil map, combined with the soil carbon stocks quantified for each land-use and soil type combination (see section 3.5 in Van Baren et al., 2024).

For the Netherlands, the LSK national sample survey of soil map units (Finke et al., 2001) is the basis for quantifying carbon emissions from

[8] https://agriculture.ec.europa.eu/data-and-analysis/farm-structures-and-economics/fadn_en

land use changes on mineral soils, which covers about 1,400 locations at five different depths. The carbon stock in the upper 30 cm was measured by De Groot et al. (2005). The data was classified into eleven soil types and four land use categories at the time of sampling (Lesschen et al., 2012).

Samples were taken on Forest land, Cropland and Grassland. For conversions involving other land uses, estimates were made using the 2006 IPCC Guidelines. The assumptions were:

- For conversion to settlements: 50% is paved and has a soil carbon stock of 80% of that of the former land use, 50% consists of grassland or wooded land with corresponding soil carbon stock.
- For Wetlands converted to or from forest, there is no change in carbon stock.
- For Other land, the carbon stock is zero (conservative assumption).

The 2006 IPCC Guidelines prescribe a twenty-year transition period in which carbon stock changes take place. This transition period in mineral soils means that land use changes in 1971 will still have a small effect on reported carbon stock changes in 1990. These pre-1990 land use changes are represented by the use of a 1970 land use map. This also means that the twenty-year transition period is included in land that was converted to another land use before 1990.

Carbon stock changes in organic soils
On the basis of the definition of organic soils in the 2006 IPCC Guidelines, two types of organic soils are considered. First, peat soils with a peat layer of at least 40 cm within the first 120 cm, and second, peaty soils (Dutch: *moerige gronden*) with a peat layer of 5–40 cm within the first 80 cm. The development of organic soil area between 1990 and 2014 and between 2014 and 2040 was assessed using overlays of three soil maps: the initial map with the average year of sampling dated 1977; a 2014 update on the spatial extent of organic soils; and a forecast map with projected spatial extent of organic soils in 2040 (see Van Baren et al., 2024 for details). Drainage of cultivated organic soils results in oxidation and thus loss of peat. As a result, the reported total area of organic soils decreased from 528 kha in 1977 to 500 kha in 1990, and to 437 kha in 2014. The total area of organic soils for the intermediate years was interpolated between 1977 and 2014. To assess the (loss of) extent of organic soils after 2014, an updated forecast map of the extent of peat and peaty soils by 2040 was used (Erkens et al., 2021; for more details, see Van Baren et al. 2024). For intermediate years, the total area of organic soils was interpolated from the two maps of 2014 and 2040.

Overlays with the land use maps provide information on areas of organic soils under the various land use categories. Carbon stock losses resulting from drainage of peat and peaty soils are determined for areas of Cropland, Grassland under agricultural use (excluding nature grasslands), Settlements and part of the Forest land (see specification below). For the areas of land of Cropland, Grassland and Forest land, 5% of the total area is considered to consist of drainage ditches. For these ditches, CH_4 emissions are calculated instead of CO_2 emissions (see section on 'emissions and removals from drainage and rewetting and other management of organic soils' below. More detailed information is provided in Van Baren et al. (2024).

On the basis of the available datasets, two different approaches for calculating the emission factors for peat soils and peaty soils have been developed (see Van Baren et al., 2024). For CO_2 emissions from cultivated peat soils, the methodology is described in Kuikman et al. (2005). This method is based on subsidence resulting from the oxidation of organic matter. Estimated total annual emissions from cultivated soils are converted to an annual EF per ha peat soil to report emissions from peat soils for the land use (change) categories Grassland, Cropland and Settlements. Using an intermediary peat map from 2004, this resulted in an average EF for peat of 19 tons CO_2 ha^{-1} both in 1990 and 2004, indicating that no EF changes occurred over time.

For peaty soils, another approach was used on the basis of a large dataset of soil profile descriptions over time (De Vries et al., in press). From this dataset, the average loss rate of peat was derived from the change in peat layer thickness over time. Also in this case, two EFs were assessed on the basis of the areas of peaty soils present on the 2004 map or the 2014 map. On the basis of both these maps, the EF for peaty soils was determined to be 13 tons CO_2 ha^{-1}, which remained stable over time

Drainage of organic soils is not usually applied in forestry in the Netherlands. However, since afforestation usually occurs on land with previous agricultural land use, the possibility that the old drainage systems from the agricultural sites are still active cannot be completely excluded. Therefore, to account for possible emissions, the area of forest planted on organic soils that were previously in agricultural use, and where drainage systems may still be (partially) functioning was estimated at 24.2% of the total forest area on peat soils and 22.0% of the total forest area on peaty soils (see section 11.3 in Van Baren et al. (2024)). The same country-specific EFs are then applied to these areas as those used for drained peat and peaty soils under Grassland, Cropland and Settlements. Additionally, the associated emissions of N_2O were calculated using a Tier 1 approach with the Tier 1 EF for boreal and temperate organic nutrient-rich (0.6 kg N_2O-N ha^{-1}) and nutrient-poor (0.1 kg N_2O-N ha^{-1}) forest soils. For the 1990–2017 period, an average of 79% of the forests on peat soil was on nutrient-rich peat soils and 21% on nutrient-poor peat soils (see Van Baren et al., 2024); 100% of the forests on peaty soils were on nutrient-rich peaty soils. These ratios were subsequently applied to the Tier 1 EFs resulting in average EFs of 0.495 kg N_2O-N ha^{-1} for N_2O emissions from drained peat soils under Forest land, and 0.6 kg N_2O-N ha^{-1} for peaty soils.

Detailed information on calculations for peat and peaty soils is provided in Van Baren et al. (2024).

Emissions and removals from drainage and rewetting and other management of organic soils (CRF Table 4(II))
CO_2 emissions resulting from drainage are included as carbon stock changes in organic soils under the various land use categories.

Methane (CH_4) emissions from drainage ditches in drained Forest land, Cropland and agricultural grasslands on organic soils are reported in CRF Table 4(II) using the Tier 1 approach from the 2013 IPCC wetland supplement (IPCC 2014). It applies the default ditch fraction of 5%, meaning that 5% of the land areas designated as drained Forest land, Cropland or Grasslands consists of drainage ditches. A country-specific emission factor of 518 kg CH_4 ha^{-1} yr^{-1} is applied to these areas on the basis of a case study for the Netherlands by Peacock et al. (2021). This value is similar to the default emission factor for drainage ditches in shallow drained temperate grassland (i.e. 527 kg CH_4 ha^{-1} yr^{-1}) in Table 2.3 of the 2013 IPCC wetland supplement (IPCC 2014).

Rewetting and other management does not occur on a large scale in the Netherlands.

Direct nitrous oxide emissions from disturbance associated with land use conversions (CRF Table 4(III))
Nitrous oxide (N_2O) emissions from soils resulting from disturbance associated with land use conversions were calculated for all land use conversions using a Tier 2 methodology (Van Baren et al., 2024). The default EF of 0.01 kg N_2O-N/kg N was used. Average C:N ratios for three aggregated soil types based on measurements by Van Baren et al. (2024), were used. For all other aggregated soil types, the default C:N ratio of 15 (IPCC, 2006: section 11.16) was used. For aggregated soil types where conversion of land use resulted in a net gain of carbon, N_2O emissions were set to zero.

Biomass burning (CRF Table 4(V))
For *Controlled biomass burning* in all land use categories, the emissions of CO_2, CH_4 and N_2O are reported as 'IE' and 'NO'. The area of and emissions from the occasional burning carried out in the interest of nature management are included under wildfires. Other controlled burning, such as the burning of harvest residues, is not allowed in the Netherlands (see Article 10.2 of 'Wet Milieubeheer', the Environmental Protection Act).

Wildfires are rare in the Netherlands and only recently, limited information of extent and intensity of fires has become available. Therefore, the emissions of CO_2, CH_4 and N_2O from wildfires are reported using a Tier 1 methodology. The area of wildfires is based on a historical series from 1980 to 1992. Emissions from forest fires are reported under Forest land remaining Forest land even though some of it may be on Land converted to forest land. Emissions from other wildfires are reported under Grassland remaining grassland, even though they may be occurring on other land use categories. Under the other land use categories, wildfires are reported as IE.

6.1.3 *Changes in this year and recalculations for years previously reported*

This year, four methodological changes have been implemented, resulting in modifications to the carbon stock changes and associated emissions and removals along (part of) the time series:

1) Changes to the calculation of carbon fluxes in mineral soils under managed croplands and grasslands remaining in these land use categories.
2) Implementing a methodology to include continuous updates of forest carbon stocks from national forest inventories.
3) Tier 2 method for assessing carbon stock changes in litter in the Land converted to forest land category.
4) New Tier 1 methodology to calculate CH_4 and CO_2 emissions from all canals and ditches (>3m wide) and for reservoirs and freshwater ponds created since 1900 in the Wetlands category.

Additionally, new data has been included for Forest land, which interacts with the Tier 2 methodology for carbon stock changes in litter in Land converted to forest land. Because of this interaction, the implications of these changes are included below under the description of the methodological change in litter.

Changes to the calculation of carbon fluxes in mineral soils under Cropland remaining cropland and Grassland remaining grassland

For Cropland remaining cropland and Grassland remaining grassland under agricultural use, changes in carbon stocks in mineral soils have been calculated dynamically since the NIR of 2023, following a Tier 3 approach that is based on the RothC model. For the NIR 2024, two changes have been made:

1) Additional calculations were performed for the 1990-2004 period. In the NIR 2023, the soil organic carbon stock (SOC) changes were only calculated for the 2005-2021 period, while for the 1990-2004 period, the result of 2005 was used due to lack of data. For the NIR 2024, additional data was collected, which allowed calculations by RothC for the entire period (1990-2022). This resulted in lower emissions and higher removals from mineral soils in the 1990-2004 period, when the SOC balance was higher as a result of higher carbon inputs from manure and a higher share of permanent grassland.
2) Due to the high variability of the modelled changes in SOC stocks due to changes in weather, it was decided to use five-year average values of the modelled SOC balance. For the NIR 2023, this moving average was calculated as the average of the period spanning two years before and after the specific year. However, this resulted in the same value for the three most recent years. It was therefore decided to calculate the moving average over the past 4 years and target year instead, which better reflects more recent changes due to the uptake of mitigation practices.

These two changes imply recalculations for mineral soils in Cropland remaining cropland and Grassland remaining grassland for the whole time series (see Figure 6.1).

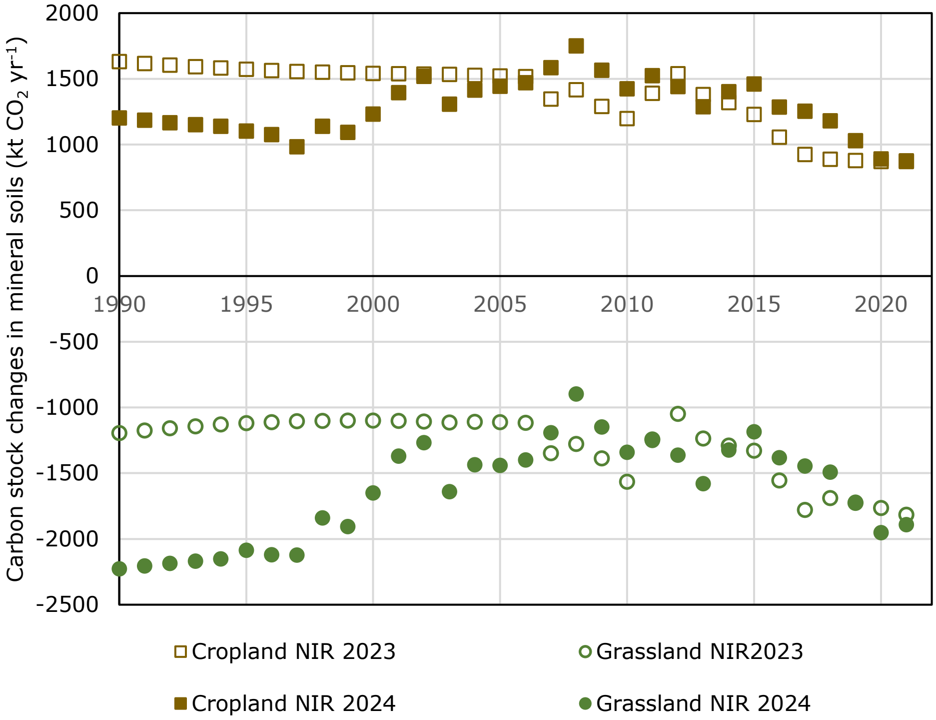


Figure 6.1 Effect (kt CO_2) of methodological change in mineral soils for Cropland remaining cropland and Grassland remaining grassland. These are the differences compared to the 2023 submission where the soil organic carbon (SOC) balance calculations were not performed for the 1990-2004 period and the moving average was calculated differently for the entire period

Approach to including continuous updates of forest carbon stocks from forest inventories

Since the NFI-7 (2017-2021) the NFI has been implemented as a continuous inventory with a five-year cycle and with permanent sample plots. 2022 was the first year of the 8th NFI cycle and is the first year for which new plot remeasurements are available. As a result, annual updates of forest carbon stocks can now be included. This provides data on the actual changes in carbon stocks and removes the need for model extrapolations for the years beyond the last NFI data. For consistency in the time series, however, this also requires an updated approach for the reference years used for the previous NFIs. In order to have consistent time series, the assigned reference years in the previous NFIs had to be changed from the inventory mid-year to the inventory end-year (see Table 6.3). As a result, the time periods between the earlier NFIs become longer, while the period between NFI–5 and 6 has become shorter. Because net carbon stock changes, as calculated on the basis of the consecutive NFIs, remain the same, this means that, while annual removals between the NFIs change, total gain/loss over the whole time period remains the same.

Table 6.3 Period the National Forest Inventories (NFI) were measured and the reference years the measured forest carbon stocks were attributed to in the NIR 2023 and NIR 2024

		Reference year (1st January year X)	
NFI	**Period measured**	**NIR23**	**NIR24**
HOSPextra		-	1990
HOSP	1988-1991	1990	1992
NFI–5	2001-2005	2003	2006
NFI–6	2012-2013	2013	2014
NFI–7	2017-2021	2021	2022
NFI–8-I	2022	-	2023

Table 6.3 presents the measurement periods for the forest inventories (more information on the inventories is provided in Van Baren et al. (2024). The 1st of January following the last measuring year is used as the refence date for the bookkeeping calculations. The first datapoint (HOSP) moved from 1990 to 1992; to get a datapoint for 1990, the trend between HOSP and NFI–5 was interpolated backwards to 1990 to create the HOSPextra datapoint. The first measurement year 2022 of the NFI–8 was incorporated to update the 2017 measurements in the NFI-7 as the same plots were remeasured. The data used for reference year 2023 now includes the NFI measurement from the years 2018-2022: i.e. using a five-year moving average.
Recalculation of coniferous ratios is now based on individual trees in the individual NFI plots for NFI–5 through NFI–8-I. Previously, this ratio was based on the dominant tree species in a plot.

Table 6.4 Coniferous ratios used in the NIR 2023 and NIR 2024

Coniferous ratio		
NFI	**NIR23**	**NIR24**
HOSP	0.51	0.51
NFI–5	0.50	0.41
NFI–6	0.45	0.38
NFI–7	0.41	0.34
NFI–8-I	0.41	0.34

For the NIR 2024, CRs were calculated on the basis of individual trees in the individual plots, compared to the dominant tree species in previous submissions. NFI–5 through NFI–8-I were updated.

In Tables 6.5 and 6.6, the parameters used per NFI are presented for the NIR 2023 and the current NIR 2024.

Table 6.5 Data used for the NIR 2023

NFI	Year	GS	AGB	BCEF	BGB	R	Share	DW Biomass	
							Conifers	DWs	DWl
HOSP	1990	158	112.7	0.713	24.3	0.22	0.51	0.84	
NFI-5	2003	199	143.2	0.721	30.6	0.21	0.50	1.35	1.49
NFI-6	2012	217	161.9	0.744	33.8	0.21	0.45	1.93	1.89
NFI-7	2021	229	176.6	0.773	36.3	0.21	0.41	2.99	2.66
EFISCEN-space	2022	230	178.1	0.772	37.4	0.21	0.43	3.05	2.70

Per NFI inventory, its reference year, average Growing stock (GS; m^3 ha^{-1}), aboveground biomass (AGB; tonnes ha^{-1}), BCEF (tonne d.m. per m^3 stemwood volume), belowground biomass (BGB; tonnes ha^{-1}), root to Iot ratio (R), share of conifer biomass in the total forest biomass, mass (tonnes ha^{-1}) of standing deadwood (DWs) and lying deadwood (DWl). See also table 4.1 in Van Baren et al., 2023.

Table 6.6 Data used for the NIR 2024

NFI	Year	GS	AGB	BCEF	BGB	R	Share	DW Biomass	
							Conifers	DWs	DWl
HOSPextra	1990	152	108.3	0.712	23.8	0.22	0.53	0.76	
HOSP	1992	158	112.7	0.713	24.3	0.22	0.51	0.84	
NFI-5	2006	199	143.2	0.721	30.6	0.21	0.41	1.35	1.49
NFI-6	2014	217	161.9	0.744	33.8	0.21	0.38	1.93	1.89
NFI-7	2022	229	176.6	0.773	36.3	0.21	0.34	2.99	2.66
NFI–8-I	2023	229	177.4	0.775	37.26	0.21	0.34	2.89	2.86

Per NFI inventory, its reference year, average Growing stock (GS; m^3 ha^{-1}), aboveground biomass (AGB; tonnes ha^{-1}), BCEF (tonne d.m. per m^3 stemwood volume), belowground biomass (BGB; tonnes ha^{-1}), root-to-shoot ratio (R), share of conifer biomass in the total forest biomass, mass (tonnes ha^{-1}) of standing deadwood (DWs) and lying deadwood (DWl). See also table 4.1 in Van Baren et al., 2024.

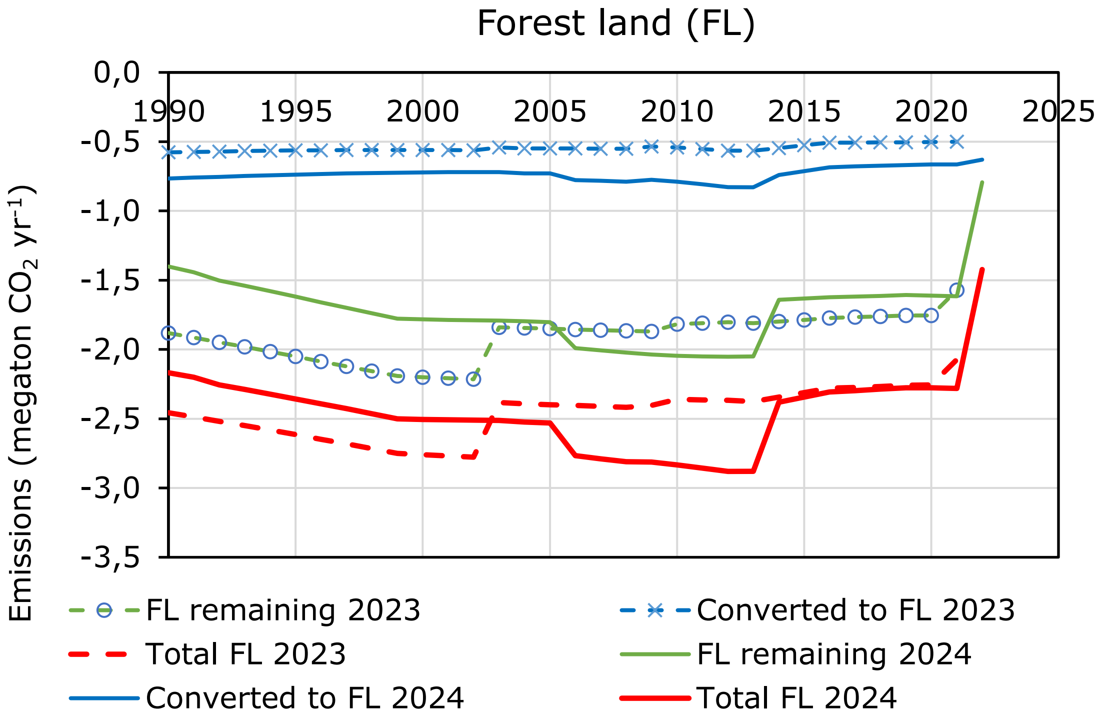


Figure 6.2 Change in the CO_2 emissions from Forest land between the NIR 2023 and 2024

Tier 2 method for assessing carbon stock changes in litter in the Land converted to forest land category and new NFI data on Forest land

In the NIR 2023, a new approach was implemented to include the full carbon stock gains in litter in Forest land at the moment that units of land would transition from Land converted to Forest land to Forest land remaining forest land. This created a spike in the reporting of gains in the litter pool in the year this conversion took place from converted to remaining. No build-up of carbon in the litter pool was reported for Forest land remaining forest land during the remaining years. When Forest land remaining was converted to another land use, the total litter carbon pool was considered to be lost and reported in the land use it converted to.

In the NIR 2024, this approach is further developed to include gradual increases in carbon stock in forest litter starting from 0 in the year of conversion to Forest land, to reach the average carbon stock in litter in Forest land remaining forest land after thirty years. This methodology is similar to the methodology applied for net carbon stock gains in living biomass for land converted to Forest land (twenty years) and Forest land remaining forest land (twenty to thirty years after conversion). The methodology for carbon stock changes in litter in Forest land remaining forest land (>thirty years after conversion) has not changed and still assumes that these constitute an uncertain net sink that is conservatively reported at zero.

In addition to the change in methodology, new data has become available on carbon content in litter (De Jong et al., 2023). Using these data on carbon content per cm litter depth and the data on litter thickness from the National Forest Inventories (NFIs), improved carbon stocks for litter could be quantified (Van Baren et al., 2024) for NFI-5 through NFI-7.

Table 6.7 Values for litter carbon stock per hectare (ha) for the various forest inventories used in the NIR 2023 and 2024

Litter		**ton C/ha**		**ton C/ha**
NFI	**Year**	**NIR23**	**Year**	**NIR24**
HOSPextra			1990	28.54
HOSP	1990	28.66	1992	28.66
NFI–5	2003	35.95	2006	29.5
NFI–6	2013	32.78	2014	35.4
NFI–7	2021	30.24	2022	34.2
NFI–8-I	2022	30.24	2023	34.2

New Tier 1 methodology to calculate CH_4 and CO_2 emissions from all canals and ditches (>3 m) and for reservoirs and freshwater ponds created since 1900 in the Wetlands category

The Wetlands category in the Netherlands is predominantly open water for which currently no default methodologies are provided in the 2006 IPCC guidelines. While the 2019 refinement to the IPCC guidelines provides new Tier 1 methods for open water, these are not always applicable to the situation in the Netherlands. In many cases, open water in the Netherlands that could be classified as reservoirs has already existed for a long time and has a natural origin, but are now managed with regulated water tables. There are large water surfaces that, as a result of sea defence measures over the past century, changed from saltwater/sea to freshwater lakes. Examples are the IJsselmeer and Markermeer, which together form a closed off inland bay, and the Oosterschelde and Grevelingenmeer in the river estuary in the south-west of the country. In a first step, Tier 1 methodologies are now applied to the part of the open water that is human-made (i.e. all canals and ditches and for reservoirs and freshwater ponds created since 1900). For these waters, it is clear the emissions have an anthropogenic cause. Further description of the method is given in Van Baren et al. (2024). The emission factors listed in Table 6.8 are applied to the various Wetland types. The CO_2 emissions are included as net carbon stock losses under mineral soils or organic soils in CRF Table 4.D, the CH_4 emissions are reported in CRF Table 4(II). The emissions for all the new Wetland types are currently included in the Wetland category Open water. In the CRF tables, no distinction is made between the various Wetland types. With the upcoming change to the common reporting tables (CRT), for reasons of efficiency it was decided not to make these changes in the CRF, but wait for the CRT to implement this distinction in Wetland types in the reporting tables. Areas for all Wetland categories are now reported under section 6.7.2 of this NIR submission.

In the meantime, Tier 2 and Tier 3 methodologies are being developed for use in future submissions.

Table 6.8 Tier 1 emission factors per hectare (ha) per year (yr) used for land converted to and remaining flooded land categories

Wetlands category	**Emission factor**			**Source**
Reservoirs	Converted to	3.74	ton CO_2/ha/yr	Table 7.13, 2019 refinements
		0.0847	ton CH_4/ha/yr	Table 7.15, 2019 refinements
	Remaining	0.054	ton CH_4/ha/yr	Table 7.9, 2019 refinements
Freshwater ponds	Converted to and Remaining	0.183	ton CH_4/ha/yr	Table 7.12, 2019 refinements
Canals + ditches (>3m)[1]	Converted to and Remaining (mineral)	0.416	ton CH_4/ha/yr	Table 7.12, 2019 refinements
Canals + ditches (>3m)[1]	Converted to and Remaining (organic)	0.518	ton CH_4/ha/yr	Peacock et al. (2021)

1) Since the NIR 2023, CH_4 emissions from drainage ditches <3 m are reported under the land use these drainage ditches are part of (forest land, cropland or grassland).
'Source' refers to the table from the 2019 refinements to the 2006 IPCC guidelines (IPCC 2019).

6.2 Land use definitions and the classification systems

This section provides an overview of land use definitions and the classification systems used in the Netherlands, and how they correspond to the land use, land use change, and forestry categories that need to be covered. The Netherlands has defined the various land use categories in line with the descriptions provided in the 2006 IPCC Guidelines. For more detailed information, see Van Baren et al. (2024).

Forest land (4A)
The Netherlands has chosen to define the land use category Forest land as 'all land with woody vegetation, now or expected in the near future (e.g. clear-cut areas to be replanted, young afforestation areas)'. The following criteria define this category:

- Forests are patches of land exceeding 0.5 ha, with:
    - a minimum width of 30 m;
    - a tree crown cover of at least 20%; and
    - a tree height of at least 5 m, or, if this is not the case, these thresholds are likely to be achieved at the particular site.

This definition conforms to FAO reporting standards and was within the ranges set by the Kyoto Protocol.

Cropland (4B)
The Netherlands has chosen to define Cropland as 'arable land and nurseries (including tree nurseries)'. Intensively managed grasslands

are not included in this category; they are reported under Grassland. For part of the Netherlands' agricultural land, rotation between Cropland and Grassland is frequent, but data on where exactly this occurs is not available. Currently, the situation on the topographical map is used as a guideline, with lands under agricultural crops and classified as arable lands at the time of recording reported under Cropland, and lands with grass vegetation at the time of recording classified as Grassland.

Grassland (4C)
From the NIR 2018 onwards, two distinct sub-categories have been identified within the Grassland category, and these are spatially explicitly assessed. These are (1) Trees outside forests (TOF) and (2) Grassland (non-TOF). Both are explained below.

Trees outside forests (TOF)
Trees outside forests (TOF) are wooded areas that comply with the Forest land definition except for their surface area (<0.5 ha or less than 30 m width). These represent fragmented forest plots as well as groups of trees in parks and natural terrains, and most woody vegetation lining roads and fields.

Grassland (non-TOF)
Any type of terrain that is predominantly covered by grass vegetation is reported under Grassland (non-TOF). The category also includes vegetation that falls below, and is not expected to reach, the thresholds used in the Forest land category. It is further split into the following sub-categories:

- Grassland vegetation, i.e. all areas predominantly covered by grass vegetation (whether natural, recreational, or cultivated);
- Nature, i.e. all natural areas not covered by grassland vegetation. This mainly consists of heathland and peat moors and may have the occasional tree as part of the typical vegetation structure.
- Orchards, i.e. areas with standard fruit trees, dwarf varieties or shrubs. These do not conform to the Forest land definition and, while agro-forestry systems are mentioned in the definition of Cropland, the main undergrowth of orchards in the Netherlands is grass. Therefore, orchards are reported under Grassland (non-TOF). A separate carbon stock for orchards is being estimated as part of an area-weighted averaged carbon stock in grasslands (see section 6.6 and Van Baren et al. (2024)).
  In the calculations, orchards are not explicitly spatially included. Instead, statistics on areas of orchards are used. See Van Baren et al. (2024) for details.

Wetlands (4D)
The Netherlands is characterised by wet areas. Many of these areas are covered by grassy vegetation and those are included under Grassland. Some wetlands are covered by rougher vegetation, consisting of wild grasses or shrubs, and those are reported in the sub-category Nature, under Grassland. Forested wetlands (e.g. willow coppices) are included in Forest land.
As a result, only reed marshes and open water bodies in the Netherlands are included in the Wetland land use category. This includes natural

open water in rivers, but also man-made open water in canals, ditches, and artificial lakes. It includes bare areas that are under water only part of the time as a result of tidal influences, and very wet areas without vegetation. It also includes 'wet' infrastructure for boats, i.e. waterways as well as the water in harbours and docks.

Since the submission of the NIR 2024, the Wetlands land use category has been further stratified with the 'Flooded Land' category containing the sub-categories: reservoirs, freshwater ponds, and canals and ditches. These Wetlands categories used to be reported as Open water, therefore the total area of Wetlands has not changed compared to previous submissions.

- Reservoirs: inland sweet water lakes larger than 8 ha. Excludes the IJsselmeer and Markermeer.
- Freshwater ponds: inland sweet water ponds smaller than 8 ha.
- Canals and ditches (> 3 m): constructed linear waterbodies.

Reservoirs and freshwater ponds have only been included when they were created after 1900. All canals and ditches are included. See Van Baren et al. (2024) sections 2.5 and 3.2 for details.

Settlements (4E)
In the Netherlands, the main categories included under the Settlements category are (1) built-up areas and (2) urban areas and transport infrastructure. Built-up areas include any constructed item, independent of the type of construction material, that is (expected to be) permanent, is fixed to the soil surface, and serves as a place of residence or location for trade, traffic and/or work. It includes houses, blocks of houses, and apartments, office buildings, shops and warehouses, as well as filling stations and greenhouses.

Urban areas and transport infrastructure includes all roads, whether paved or not – with the exception of forest roads – these are included in the official forest definition. They also include train tracks, (paved) open spaces in urban areas, car parks, and graveyards. Though some of the latter categories are covered by grass, the distinction cannot be made from a study of maps. As grass graveyards are not managed as grassland, their inclusion in the land use category Settlements conforms better to the rationale of the land use classification.

Other land (4F)
The Netherlands uses this land use category to report surfaces of bare soil not included in any other category. This mostly includes almost bare sands and the earliest stages of succession on sand in coastal areas (beaches, dunes and sandy roads), or uncultivated land alongside rivers. It does not include bare areas that emerge from shrinking and expanding water surfaces; these are included in Wetland. In general, the amount of carbon in Other land is limited.

6.3 Information on approaches to representing land areas and land use databases used for the inventory preparation

One consistent approach has been used for all land use categories. The Netherlands applies full and spatially explicit land use mapping that allows geographical stratification at 25 m x 25 m (0.0625 ha) pixel resolution (Kramer et al., 2009; Van den Wyngaert et al., 2012). This corresponds to the wall-to-wall approach used for reporting under the UNFCCC (approach 3 in Chapter 3 of IPCC, 2006).

Harmonised and validated digital topographical maps representing land use on 1 January 1970, 1990, 2004, 2009, 2013, 2017 and 2021 were used for wall-to-wall map overlays (Van Baren et al., 2024; Kramer and Clement, 2015; Kramer et al. 2007, 2009a,b; Van den Wyngaert et al., 2012; Kramer & Clement, 2022; Kramer & Los, 2022), resulting in six national-scale land use and land use change matrices covering the following periods: 1970-1990 (Table 6.9), 1990–2004 (Table 6.10), 2004–2009 (Table 6.11), 2009–2013 (Table 6.12), 2013–2017 (Table 6.13) and 2017-2021 (Table 6.14). In order to create change matrices beyond the availability of the land use maps, an extrapolation of the trend between the land use maps of 2017 and 2021 is conducted. Here, the change rate per land use, soil type and whether a land use trajectory is stable is taken into account to extrapolate towards a desired reporting year. When a new land use map comes available, this is used instead of the extrapolation. The information on the activities and land use categories covers the entire territorial (land and water) surface area of the Netherlands. The sum of all land use categories is constant over time. For more details, see Van Baren et al. (2024).

The land use maps used for 1970 and 1990 are based on maps of historic land use in the Netherlands (‘Historisch grondgebruik Nederland, HGN), while later maps are based on the Nature Base maps originally used for monitoring nature development in the Netherlands. After 2009, these maps were no longer used for monitoring nature development, but in order to guarantee consistency in the land use change matrix for LULUCF reporting, they are still produced on request as a basis for the LULUCF land use change monitoring (see Van Baren et al. (2024) for more details).

The classification of forest areas on the underlying topographical maps that is used to compile the LULUCF maps accounts for management interventions to prevent harvested areas from being classified under Deforestation (D). Additional information on (planned) destinations of areas and subsidy schemes is used to support the classification.

An overlay was produced with all land-use and soil maps, resulting in an array of trajectories showing land use in the maps (1970, 1990, 2009, 2013, 2017, 2021), and soil in the maps (1977, 2014), plus the area on which this sequence occurred. For trajectories that changed from one mineral soil type to another, we assumed the 1977 value to be the same as the 2014 value, as the new map is considered to be more accurate than the old one. Subsequently, the resulting array of trajectories was aggregated, so that only unique trajectories remained. For all trajectories with an area smaller than 10 ha that changed land use from 1970 to 1990, the 1970 land use was reclassified to the 1990 land use. In this way, the inaccuracies in the 1970 map are ignored, while maintaining the overall land use transition trend for the 1970-1990 period. This procedure concerned 2.0% of the total land area.

Subsequently, the resulting array of trajectories was aggregated, so that only unique trajectories remained.
Please note that for comparison purposes with CRF tables, map dates are always 1 January of the year indicated and hence reflect the situation at the end of the previous inventory year.

Table 6.9 Land use and land use change matrix aggregated to the six UNFCCC land use categories for the 1970-1990 period (ha) with Grassland (GL) divided into GL (non-TOF) and GL (TOF)

	BN 1990							
HGN 1970	**FL**	**CL**	**GL (non-TOF)**	**G (TOF)**	**WL**	**Sett**	**OL**	***Total***
FL	300,044	4,313	15,753	1,274	1,079	6,144	726	329,333
CL	22,133	687,295	182,415	2,094	11,176	50,894	195	956,202
GL-non TOF	28,182	297,694	1,243,850	4,896	21,533	86,068	1,174	1,683,396
GL-TOF	1,697	1,249	4,039	10,361	175	2,207	107	19,836
WL	1,350	4,762	15,077	156	753,597	4,527	3,648	783,118
Sett	7,734	24,237	44,055	1,943	3,659	259,450	485	341,564
OL	1,109	132	2,774	77	3,117	312	33,227	40,747
Total	*362,249*	*1,019,682*	*1,507,962*	*20,801*	*794,336*	*409,602*	*39,563*	*4,154,195*

Table 6.10 Land use and land use change matrix aggregated to the six UNFCCC land use categories for the 1990–2004 period (ha) with Grassland (GL) divided into GL (non-TOF) and GL (TOF)

	BN 2004							
BN 1990	**FL**	**CL**	**GL (non-TOF)**	**G (TOF)**	**WL**	**Sett**	**OL**	***Total***
FL	334,348	1,220	14,592	2,852	1,503	7,035	699	362,249
CL	12,527	739,425	176,854	2,039	6,823	81,813	201	1,019,682
GL-non TOF	18,075	196,624	1,190,957	4,474	18,642	78,283	907	1,507,962
GL-TOF	2,350	386	3,314	11,335	318	2,988	110	20,801
WL	888	596	9,094	328	777,801	2,837	2,791	794,336
Sett	1,456	1,626	10,993	1,078	1,391	392,936	122	409,602
OL	552	8	2,547	98	2,583	630	33,144	39,563
Total	*370,196*	*939,885*	*1,408,352*	*22,206*	*809,061*	*566,522*	*37,974*	*4,154,195*

Table 6.11 Land use and land use change matrix aggregated to the six UNFCCC land use categories for the 2004–2009 period (ha) with Grassland (GL) divided into GL (non-TOF) and GL (TOF)

	BN 2013							
BN2009	**FL**	**CL**	**GL (non-TOF)**	**GL (TOF)**	**WL**	**Sett**	**OL**	***Total***
FL	360,356	1,319	6,257	1,483	699	3,327	204	*373,645*
CL	2,484	794,119	116,032	311	1,410	10,743	28	*925,126*
GL-non TOF	8,095	145,435	1,194,348	1,590	10,850	30,922	516	1,391,756
GL-TOF	1,346	219	1,532	17,212	164	1,582	31	22,086
WL	651	305	6,183	112	803,194	1,353	1,948	813,746
Sett	2,535	3,199	20,664	815	4,477	557,496	135	589,323
OL	444	1	970	49	1,825	328	34,897	38,512
Total	*375,912*	*944,597*	*1,345,986*	*21,572*	*822,619*	*605,751*	*37,759*	*4,154,195*

Table 6.12 Land use and land use change matrix aggregated to the six UNFCCC land use categories for the 2009–2013 period (ha) with Grassland (GL) divided into GL (non-TOF) and GL (TOF)

	BN 2009							
BN 2004	**FL**	**CL**	**GL (non-TOF)**	**GL (TOF)**	**WL**	**Sett**	**OL**	***Total***
FL	357,622	352	5,223	1,514	703	4,575	208	370,196
CL	2,012	813,514	108,507	296	1,796	13,732	27	939,885
GL-non TOF	7,129	106,576	1,243,564	1,706	10,615	37,714	1,047	1,408,352
GL-TOF	1,701	137	1,198	16,892	126	2,122	30	22,206
WL	374	177	9,633	92	796,581	1,441	762	809,061
Sett	4,598	4,368	23,125	1,556	3,035	529,603	237	566,522
OL	209	2	506	29	890	137	36,201	37,974
Total	*373,645*	*925,126*	*1,391,756*	*22,086*	*813,746*	*589,323*	*38,512*	*4,154,195*

Table 6.13 Land use and land use change matrix aggregated to the six UNFCCC land use categories for the 2013–2017 period (ha) with Grassland (GL) divided into GL (non-TOF) and GL (TOF)

	BN 2017							
BN 2013	**FL**	**CL**	**GL (non-TOF)**	**GL (TOF)**	**WL**	**Sett**	**OL**	***Total***
FL	356,773	1,665	9,353	2,022	804	4,890	404	375,912
CL	903	762,661	170,219	246	1,676	8,868	24	944,597
GL-non TOF	4,822	103,147	1,197,260	1,504	9,191	28,670	1,394	1,345,986
GL-TOF	1,141	205	1,658	16,548	146	1,834	41	21,572
WL	837	291	6,717	192	807,543	4,340	2,700	822,619
Sett	1,036	2,583	21,378	711	1,571	578,275	196	605,751
OL	215	7	735	34	1,415	484	34,869	37,759
Total	*365,726*	*870,559*	*1,407,320*	*21,256*	*822,346*	*627,360*	*39,628*	*4,154,195*

Table 6.14 Land use and land use change matrix aggregated to the six UNFCCC land use categories for the 2017–2021 period (ha) with Grassland (GL) divided into GL (non-TOF) and GL (TOF)

	BN 2021							
BN 2017	**FL**	**CL**	**GL (non-TOF)**	**GL (TOF)**	**WL**	**Sett**	**OL**	***Total***
FL	356,579	675	5,115	1,157	263	1,578	359	365,726
CL	762	707,797	154,279	130	1,023	6,541	27	870,559
GL-non TOF	4,398	125,580	1,251,360	870	5,473	18,691	948	1,407,320
GL-TOF	693	218	1,502	17,928	82	739	96	21,256
WL	301	332	4,394	65	812,759	1,471	3,024	822,346
Sett	707	2,103	18,554	371	1,545	603,850	229	627,360
OL	361	5	2,967	42	2,258	166	33,828	39,628
Total	*363,801*	*836,710*	*1,438,171*	*20,563*	*823,403*	*633,037*	*38,511*	*4,154,195*

Subsequently, the annual land use changes have been derived from these land use change matrices (see Van Baren et al. (2024) for these matrices).

As can be observed from the land use change matrices above, land use is dynamic in a densely populated country like the Netherlands. For example, conversion of Grassland to Cropland and Cropland to Grassland is especially common. Temporary rotations of this sort are frequent, but the total areas of Grassland and Cropland remain relatively stable.

When comparing the five land use change matrices, the different lengths of time between the available land use maps should be considered, as this has an effect on the annualised land use changes. The long period between 1990 and 2004 means that some interannual changes, such as Cropland–Grassland rotations are not captured. For instance, Cropland might be converted to Grassland in 1992, and converted back to Cropland in 1995, but these changes will not be visible using the 1990 and 2004 land use maps. The more recent maps are closer together timewise and thus are better able to capture short-term rotations between Grassland and Cropland.

Between 1970 and 2013, forest area steadily increased, followed by a sharp decline between 2013 and 2017. In the 2017-2021 period, there was also a net loss of forest area, but the gross changes make clear that deforestation rates more than halved in comparison to the 2013-2017 period.

More detailed analyses of the land use maps (see Schelhaas et al., 2021) make clear that between 2004 and 2017, deforestation rates increased for two principal reasons. First, deforestation took place as part of nature development, and specifically Natura 2000 development, under which areas of heathland and shifting sand have increased at the cost of Forest land. Second, farmers' contracts under the set-aside forest regulation and other national regulations from the 1980s aimed at temporarily increasing forest production capacity and addressing the perceived over-production in agriculture, came to an end in 1995, with the result that forests established in the 1980s and early 1990s are now being converted back into agricultural land use.

Despite the relatively high deforestation rates in earlier periods, until 2013 the rate of afforestation exceeded the deforestation rate. From the 2013–2017 matrix, it can be inferred, however, that afforestation rates have decreased considerably, resulting in a net decrease in forest area since 2013. In principle, deforestation needs to be compensated by afforestation of an equal area elsewhere. An exception to this rule was for conversion to priority nature on the basis of ecological arguments, e.g. through Natura 2000 development or management plans. In such cases, forest conversion could take place without compensation. There were also signs that there is a lack of monitoring and enforcement of the compensation rule at local government level. In the meantime, the latest land use change matrix indicates that in the years between 2017 and 2021, net deforestation occurred, but at a considerably lower rate than between 2013-2017. As a result of increased policy attention, in 2020 a new forest strategy was implemented with the aim to increase forest area in the Netherlands by 10% compared to the 2017 level. It now also ensures compensation in cases where forest is converted to other priority nature types. This effect will be visible in future land use changes.

6.4 Forest land (4A)

6.4.1 Source category description

Reported in this category of land use are CO_2 emissions and sinks caused by changes in forests. All forests in the Netherlands are classified as temperate: 19.5% coniferous, 44.8% broadleaved, with the remainder a mixture of the two. The share of mixed and broadleaved forests has grown strongly in recent decades (Schelhaas et al., 2022[9]). In the Netherlands, with its high population density and strong pressure on land, all forests are managed. Consequently, no sub-division is applied between managed and unmanaged forest land. Where such a sub-division is asked for in the CRF, the notation key NO is used in the tables for unmanaged forests.

Units of land that meet all the requirements for Forest land except the minimum area (0.5 ha) or width (30 m) are reported as Trees outside forests (TOF) under the Grassland category.

The Forest land category includes three sub-categories:

- Forest land remaining forest land (4A1): includes estimates of changes to the carbon stock in various carbon pools in Forest land;
- Land converted to Forest land (4A2): includes estimates of changes in land use to Forest land during the twenty-year transition period, since 1970;
- Forest land converted to other land use categories (4B2, 4C2, 4E2, 4F2): includes emissions related to the conversion of Forest land to all other land use categories (deforestation).

6.4.2 Methodological issues

Removals and emissions of CO_2 from forestry and changes in woody biomass stock are estimated using a country-specific Tier 2 methodology. The chosen approach follows the 2006 IPCC Guidelines, which suggest a stock difference approach. The basic assumption is that the net flux can be derived by converting the change in growing stock volumes in the forest into volumes of carbon. Detailed descriptions of the methods and EFs used can be found in the methodological background report for the LULUCF sector (Van Baren et al., 2024). The Netherlands' national inventory follows the carbon cycle of a managed forest and wood products system. Changes in carbon stock are calculated for above-ground biomass (AGB), below-ground biomass (BGB) and dead wood and litter in forests.

National Forest Inventories

Data on forests is based on four National Forest Inventories (NFI) carried out in 1988–1991 (HOSP: Schoonderwoerd and Daamen, 1999), 2001–2005 (NFI-5: Daamen and Dirkse, 2005), 2012–2013 (NFI-6: Schelhaas et al., 2014), 2017-2021 (NFI-7: Schelhaas et al, 2022) and 2022 being the first year of five from the NFI-8. As these most accurately describe

[9] Report on the 7th Forest Inventory with results in Dutch only. For an English summary of the results and an English summary flyer 'State of the Forests in the Netherlands', see: https://edepot.wur.nl/576640

the state of Dutch forests, they were applied in the calculations for Forest land remaining forest land, Land converted to forest land, and Forest land converted to other land use. Thus, they represent the state of the forest at five moments in time; 1992 (HOSP), 2006 (NFI-5), 2014 (NFI-6), 2022 (NFI-7) and 2023 (NFI-8).

Changes in carbon stocks in living biomass in forests were calculated using plot-level data from the HOSP, NFI-5 NFI-6,NFI-7 and the first year of NFI-8 inventories. From the NFI-7 onwards, a continuous forest inventory with permanent sample plots will be carried out. This means that the calculations for the carbon stock will change from the NFI-8 onwards. NFI-7 contains data measured from 2017-2021 covering the whole Dutch forest; the first year of the NFI-8 measured the same plots in 2022 as were measured in 2017. The data used for the carbon stock calculations with date 2023 contains forest measurements from 2018-2022 to represent the whole Dutch forest. In addition, changes in activity data were assessed using several databases of tree biomass information, with allometric equations to calculate AGB, BGB and forest litter.

More detailed descriptions of the methods and EFs used can be found in Van Baren et al. (2024).

6.4.2.1 Forest land remaining forest land

The net change in carbon stocks for Forest land remaining forest land is calculated as the difference in carbon contained in the forest between two points in time. Carbon in the forest is derived from the growing stock volume, making use of other forest traits routinely determined in forest inventories. With the repeated measures, changes in biomass and carbon stocks were assessed for the 1992–2006, 2006–2014 and 2014-2022 periods and annually from 2022, with the continuous forest inventory using a five-year moving average. The annual changes during the years in between these periods were determined using linear interpolation.

An exception was made for units of Forest land remaining forest land that were afforested between twenty and thirty years ago. These are reported under Forest land remaining forest land, but the calculation of living biomass, dead wood and litter carbon stock changes in these units follows the approach for Land converted to forest land (see section 6.4.2.2).

Living biomass
For each plot measured during the NFIs, information is available on the tree species, their standing stock (stem volumes), and the forest area they represent. Based on this, the biomass is estimated directly for each tree measured using the following calculation steps (for more details see Van Baren et al., 2024):

1) Using the species-specific wood density, based on IPCC default values, the stem volume is converted to stem biomass. The other biomass compartments (foliage, branches and roots) are estimated using the allometric equations that include only diameter at breast height (DBH) as independent variable, provided in a study by Forrester et al. (2017) based on a Europe-wide dataset of biomass observations. Total tree biomass is calculated as the sum of all compartments, and totals per ha are calculated from the individual biomasses and the plot size. For the HOSP

dataset (1990; see Van Baren et al. (2024) for details), individual tree observations are not available. A species-specific BCEF at the plot level was derived from the NFI-5 data (average year 2006), using the reported main species, and applied it to the plot-level volume estimations for the HOSP.

2) Average growing stocks (in m^3 ha^{-1}), average BCEFs (tonnes biomass m^{-3}), and average root-to-shoot ratios are calculated (see Table 6.15 and Van Baren et al. (2024)). These are weighted for the representative area of each of the NFI plots for each NFI.
3) On the basis of the distribution of total biomass per hectare between coniferous and broadleaved trees, the relative share of coniferous and broadleaved forest is determined.
4) The average growing stock, average BCEFs, average root-to-shoot ratios, and shares of coniferous and broadleaved forests are linearly interpolated between the NFIs to estimate these parameters for all the intermediate years.
5) The average annual above-ground and below-ground biomasses (tonnes dry matter ha^{-1}) are estimated by combining annual average growing stock, BCEF, and root-to-shoot ratios.
6) Using the relative share of coniferous and broadleaved forests and the differentiated T1 carbon fractions for conifers and broad-leaved species, aboveground and belowground biomass is converted to carbon amounts.

The result of this assessment provides the average net carbon stock changes in living (aboveground and belowground) biomass for an average ha of forest in the Netherlands. This is multiplied by the area of Forest land remaining forest land in a given year to assess the total net carbon stock changes in living biomass for Forest land remaining forest land in that year.
Losses from wood harvesting are not taken into account separately, as these are already included in the differences in the average carbon stocks between the forest inventories. However, since the harvested wood is part of the gross changes in carbon stocks, it is added to the net changes as calculated in the steps above to assess gross carbon stock gains in living biomass and, simultaneously, it is considered under the gross carbon stock losses in living biomass for reporting gains and losses (see section 4.2.1 in Van Baren et al. (2024) for details). The net effect remains the same as assessed in the steps above.

In several review reports, the ERT referred to the apparent high growth rates of biomass in Dutch forests indicating that it is among the highest in Annex I countries. Dutch experts consider this a misinterpretation of the results. Although the increase in growing stock in Dutch forests appears to be higher than in other countries, the volume growth rates are not. However, the low harvest intensities in the Netherlands, with only about 55% of the increment being harvested, and the specific age class structure of Dutch forests (see Schelhaas et al. (2022)[10], and

[10] Available at: https://edepot.wur.nl/571720) providing information on age class distribution (Chapter 7, "Kiemjaar"), harvesting (Chapter 15, "Velling") and growing stock (Chapter 16, "Mutaties houtvoorraad"). A flyer with key figures explained in English is available at https://edepot.wur.nl/576640, including information on age, growing stock and harvests.

annex 5 in Van Baren et al. (2024)), result in a strong net increase in growing stock over time.

Table 6.15 Average growing stock (GS; m^3 ha^{-1}), BCEF (tonnes d.m. per m^3 stemwood volume) aboveground biomass (AGB; tonnes dry matter ha^{-1}), belowground biomass (BGB; tonnes d.m. ha^{-1})

Year	Growing stock (m^3 ha^{-1})	BCEF (tonnes d.m. m^{-3})	AGB (tonnes d.m. ha^{-1})	BGB (tonnes d.m. ha^{-1})
1990	152	0.712	108	24
1991	155	0.713	110	24
1992	158	0.713	113	25
1993	161	0.714	115	25
1994	164	0.714	117	26
1995	167	0.715	119	26
1996	170	0.715	121	26
1997	172	0.716	123	27
1998	175	0.716	126	27
1999	178	0.717	128	27
2000	181	0.718	130	28
2001	184	0.718	132	28
2002	187	0.719	134	29
2003	190	0.719	137	29
2004	193	0.720	139	29
2005	196	0.720	141	30
2006	199	0.721	143	30
2007	201	0.724	145	31
2008	203	0.727	148	31
2009	206	0.730	150	32
2010	208	0.733	152	32
2011	210	0.735	155	32
2012	213	0.738	157	33
2013	215	0.741	159	33
2014	217	0.744	162	34
2015	219	0.748	164	34
2016	220	0.751	165	35
2017	222	0.755	167	35
2018	223	0.759	169	36
2019	224	0.762	171	36
2020	226	0.766	173	36
2021	227	0.769	175	37
2022	229	0.773	177	37
2023	229	0.775	177	37

All values are dated the 1st of January of the specified year. Values in between the years are linearly interpolated

Dead wood
Dead wood volume is available from the forest inventory datasets. The calculation of carbon stock changes in dead wood in forests follows the approach for the calculation of carbon emissions from living biomass, i.e. using a thirty-year transition period from the moment of land use change towards Forest land, and is conducted for lying and standing deadwood (see Van Baren et al. (2024)). For deadwood, a wood density was used equal to 60% of the values for fresh wood.

Litter
As of the NIR 2024, the carbon stock changes in litter in forests follow the same approach as the calculation of carbon emissions from living biomass with one difference. The build-up period to full carbon stock is the same for litter, thirty years after the land use change, but after these thirty years, no change in carbon stock is reported. For Forest land remaining forest land, this means that after ten years of being in the remaining category, no carbon stock changes are reported anymore.

Data for the carbon stock of litter is a combination of litter thickness measurements from the NFIs and carbon content measurements from De Jong et al. (2023). For the full method description, see section 4.2.1 in Van Baren et al. (2024).

Effects of wood harvests on biomass gains and losses
Net carbon stock changes in biomass in Forest land remaining forest land are based on the information from the forest inventories. As a result, the effect of harvesting wood on carbon in the remaining forest biomass is already implicitly included in the carbon stock differences between the various forest inventories. Thus, the gross gains in biomass between the inventories were higher than calculated from the inventories' stock differences. Therefore, the carbon in the biomass of the harvested wood in a given year was added to the carbon stock changes in living biomass. At the same time, this identical amount of carbon was reported under carbon stock losses from living biomass, resulting in the net change as determined from the carbon stock differences between the forest inventories. As a consequence, the net stock change is gradual, but the gains and losses are more erratic. See Van Baren et al. (2024) for more details.

Forest fires
In the Netherlands, no recent statistics are available on the occurrence and intensity of wildfires in forests (forest fires). The area of burned forest is based on a historical series from 1980 to 1992 for which the annual number of forest fires and the total area burned is available (Wijdeven et al., 2006). The average annual area (37.8 ha) from the 1980–1992 period has been used for all years from 1990 onwards (Van Baren et al., 2024).

Emissions of CO_2, CH_4 and N_2O from forest fires are reported at Tier 2 level according to the method described in the 2006 IPCC Guidelines (IPCC, 2006: equation 2.27). The mass of fuel for forest fires is based on the average annual carbon stock in living biomass, litter, and dead wood (Tables 6.15 and 6.16). These values change annually, depending on forest growth and harvesting. Because burned sites are also part of the NFI, the loss of carbon due to forest fires is covered in the carbon stock changes derived from the NFI. Yet forest fires are very infrequent, mostly cover small areas, and have a relatively mild impact on biomass. As a result, it is not clear if the NFI fully covers information on forest fires and their emissions. The approach followed may thus include some double counting of these emissions, and is therefore considered conservative.

With the available data, it is not possible to distinguish between forest fires in Forests remaining forests and Land converted to forest land. Therefore, total emissions from forest fires are reported in CRF Table 4(V) under 'wildfires for forests remaining forests'.

The UNFCCC reviewer of the NIR 2019 suggested available geospatial techniques for the identification of forest fires such as the European Forest Fire Information System (EFFIS) as a possible data source to improve fire activity data after 1992. An earlier attempt to improve wildfire activity data by testing various remote sensors and geospatial techniques showed that the potential for remote sensing is limited in the case of the Netherlands (see Roerink and Arets, 2016). Because forest fires are infrequent, usually have a low intensity, and cover relatively small areas, none of the geospatial approaches was very effective in detecting the relevant forest fires and wildfires. Moreover, the cost of monitoring and analysis was considered to be disproportionate to the potential quality improvement for the GHG inventory (see Roerink and Arets, (2016), and Van Baren et al. (2024) for more details).

We have investigated other possible improvements in wildfire statistics in the Netherlands using the EFFIS data reported in its annual fire reports from 2000. Until 2017, the Netherlands did not submit a report to EFFIS, but the EFFIS reports also include independent rapid damage assessments to provide reliable and harmonised estimates of the areas affected by forest fires in collaborating countries. Although the Netherlands is included in these assessments, EFFIS's resolution of fire detection of 50 ha (older years), or, more recently, 30 ha, is larger than the area of most forest and wildfires in the Netherlands. As a result, they remain largely undetected in the EFFIS system. Since 2004, only seven wildfires have been included in the EFFIS data for the Netherlands (see section 12.3 in Van Baren et al. (2024), for more details). We will further explore possible sources of improved wildfire activity data by combining geospatial analyses with the information registered by the Netherlands Fire Service. Given the currently small extent of wildfires in the Netherlands, an important prerequisite will be that such approaches should be cost-effective and proportionate to the expected emissions from wildfires.

Emissions from fertiliser use in forests
Fertilisers are minimally applied in forestry in the Netherlands. Therefore, in CRF Table 4(I) direct nitrous oxide (N_2O) emissions from nitrogen (N) inputs for Forest land remaining forest land are reported as NO.

6.4.2.2 Land converted to forest land

Removals and emissions of CO_2 from forestry and changes in woody biomass stock are estimated using a country-specific Tier 2 methodology. The approach chosen follows the 2006 IPCC Guidelines.

Living biomass

Changes in carbon stocks in AGB and BGB in Land converted to forest land are estimated using the following set of assumptions and calculation steps:

1. The EF is calculated for each annual set of newly established units of Forest land separately. Thus, the specific age of the reforested/afforested units of land is taken into account.
2. At the time of afforestation, carbon stocks in AGB and BGB are zero.
3. The specific growth curve of new forests is unknown, but analyses of NFI plot data make clear that carbon stocks in newly planted forests reach the carbon stock of average forests in thirty years. Consequently, carbon stocks in AGB or BGB on units of newly established Forest land increase annually by the difference between the carbon stock in AGB or BGB at that time and the carbon stock in AGB or BGB of the average forest under Forest land remaining forest land, divided by the number of years left to reach an age of thirty years. This will result in twenty years of this build-up of carbon being reported in Land converted to Forest land and ten years in Forest land remaining Forest land.

For Cropland and Grassland converted to forest land, biomass loss in the year of conversion is calculated using Tier 1 default values. Conversion from Grassland (TOF) to Forest land may occur when areas surrounding units of Trees outside forests are converted to Forest land and the total forested area becomes larger than the lower limit of the forest definition (i.e. 0.5 ha). For these conversions from Trees outside forests to Forest land, it is assumed that the biomass remains and the forest continues to grow as in Forest land remaining forest land.

Litter and dead wood

The specific accumulation of dead wood and litter in newly established forest plots is unknown, but from NFI measurements, the litter thickness and presence of deadwood is known. Therefore, the carbon build-up in litter and dead wood follows the approach for the calculation of carbon emissions from living biomass (see Van Baren et al. (2024)).

Emissions from forest fires

All emissions from forest fires are included under Forest land remaining forest land and are reported here as IE.

Emissions from fertiliser use in forests

Fertilisers are minimally applied in forestry in the Netherlands. Therefore, in CRF Table 4(I), direct N_2O emissions from N inputs for Land converted to forest land are reported as NO.

6.4.2.3 Forest land converted to other land use categories

Living biomass

It is assumed that with the change from Forest land to other land use categories, all carbon stored in aboveground and belowground biomass, as well as in dead wood and litter is lost. For living biomass, the amount of carbon lost depends on the accumulated carbon since the forest was established, whereas for units of land in the Land converted to forest land category and in Forest land remaining forest land established less than thirty years ago, the carbon stocks are determined by the young forest approach as explained above in sections 6.4.2.1 and 6.4.2.2 (see also section 4.2.2 in Van Baren et al. (2024).

Conversion from Forest land to Grassland (TOF) occurs when surrounding forest is converted to other land uses and the remaining forest area becomes smaller than the lower limit of the forest definition (i.e. 0.5 ha). For these conversions from Forest land to Trees outside forests, it is assumed that no loss of biomass occurs.

Table 6.16 Emission factors (EF) for dead organic matter carbon stocks in mature (> 30 year) Forest land (Mg C ha^{-1})

Year	EF dead wood (Mg C/ha)	EF litter (Mg C/ha)
1990	0.38	28.5
1991	0.40	28.6
1992	0.41	28.7
1993	0.49	28.7
1994	0.56	28.8
1995	0.63	28.8
1996	0.70	28.9
1997	0.77	29.0
1998	0.84	29.0
1999	0.91	29.1
2000	0.98	29.1
2001	1.05	29.2
2002	1.12	29.3
2003	1.19	29.3
2004	1.26	29.4
2005	1.33	29.4
2006	1.40	29.5
2007	1.46	30.2
2008	1.52	31.0
2009	1.58	31.7
2010	1.64	32.5
2011	1.70	33.2
2012	1.76	33.9
2013	1.82	34.7
2014	1.88	35.4
2015	1.99	35.3

Year	EF dead wood (Mg C/ha)	EF litter (Mg C/ha)
2016	2.10	35.1
2017	2.21	35.0
2018	2.33	34.8
2019	2.44	34.7
2020	2.55	34.5
2021	2.66	34.4
2022	2.77	34.2
2023	2.82	34.2

All values represent the stock on the 1st of January for the specified year

Dead wood
Total emissions from the dead wood component following deforestation are calculated by multiplying the total area deforested by the average carbon stock in dead wood, as estimated by the calculations for Forest land remaining forest land. Thus, it is assumed that, with deforestation, all carbon stored in dead wood is lost to the atmosphere. National averages are used as there is no record of the spatial occurrence of specific forest types. This loss is also applied to Grassland (TOF) (see section 4.2.3 in Van Baren al. (2024) and resulting emission factors in Table 6.16), which includes both standing and lying dead wood.

Litter
Total emissions from the litter component following deforestation are calculated by multiplying the total area deforested by the average carbon stock in litter, as estimated by the calculations for Forest land remaining forest land. National averages are used for the EFs as there is no record of the spatial occurrence of specific forest types.

The average carbon stock in the litter layer has been estimated at the national level (De Jong et al., 2023). Litter thickness data from the NFIs and carbon content estimates from De Jong et al. (2023) are combined to calculate carbon content for litter. See Van Baren et al. (2024) for the full methodology.

The assessment of carbon stocks and related changes in litter in Dutch forests was based on extensive datasets on litter thickness and carbon content in litter (see Van Baren et al. (2024): section 4.2.1). Carbon stock changes per area of litter pool of the area of deforestation is high compared to those reported by other parties. These high values are related to the large share of the forest area that is on poor Pleistocene soils characterised by relatively thick litter layers. Additional information on geomorphological aspects is provided in Schulp et al. (2008) and De Waal et al. (2012) (see section 4.2.3 in Van Baren et al. (2024) and resulting emission factors in Table 6.16).

6.4.3 *Uncertainty and time series consistency*

Uncertainties
The analysis in Annex 2 presented in Table A2.3 provides estimates of uncertainty by IPCC source category that are based on error propagation. This analysis combines uncertainty estimates of forest

statistics, land use and land use change data (topographical data), and the uncertainties in the method used to calculate the annual growth in carbon increase and removals. The uncertainty range in CO_2 emissions from 4A (Forest land) is calculated at +10% to -12%. For N_2O and CH_4 uncertainties are much higher, up to 400% for N2O, due to large uncertainties in emission factors. See Van Baren et al. (2024) for details.
The Netherlands also applies an improved uncertainty assessment to the LULUCF sector as a whole with better representation of uncertainties in the land use matrix, using Monte Carlo simulations for combining different types of uncertainties (see Chapter 14 of Van Baren et al. (2024) for details).

Time series consistency
To ensure time series consistency in Forest land remaining forest land, the same approach to activity data, land use area, and emissions calculation is used for all years up to 2021. More detailed information is provided in section 6.4.2.1.

To ensure time series consistency in Land converted to forest land, the same approach to activity data, land use area, and emissions calculation is used for all years. More detailed information is provided in section 6.4.2.2.

6.4.4 Category-specific QA/QC and verification

The source categories are covered by the general QA/QC procedures discussed in Chapter 1. Additional Forest land-specific QA/QC includes:

- During the measurements of the four forest inventories, specific QA/QC measures were implemented to prevent errors in measurements and reporting (see Arets et al., 2023).

6.4.5 Category-specific recalculations

The addition of the NFI–8 and the methodology change for assigning the reference year to the NFIs resulted in recalculations of all carbon stocks for Forest land. The new methodology for litter and new data on carbon content of litter stocks resulted in recalculations of the carbon stock for litter in Forest land.

6.4.6 Category-specific planned improvements

No category-specific improvements have been planned.

6.5 Cropland (4B)

6.5.1 Source category description

Emissions resulting from the disturbance of mineral soils due to land use changes to Cropland and emissions resulting from the lowering of the ground water table in organic soils under Cropland are significant, and are calculated separately for areas of Cropland remaining cropland and Land converted to cropland (see Arets et al., 2023). As a result of these high emissions from mineral soils and drained organic soils, the Cropland category is a key source. The carbon stock gains and losses in living biomass in Grassland converted to Cropland also strongly contribute to the emissions and removals in the Cropland category, but this contribution remains below the threshold of 25% of gains/losses in the category for it to be a significant pool under the Cropland category.

Because Cropland in the Netherlands mainly consists of annual cropland where annual biomass gains are harvested each year, no net accumulation of carbon stocks in biomass over time is expected in Cropland (IPCC, 2006). On the basis of estimates using the Tier 1 EFs, the carbon pool biomass gains and dead organic matter (DOM) in Cropland remaining cropland and Land converted to cropland can be considered not significant. Therefore, following the Tier 1 method in the 2006 IPCC Guidelines, carbon stock changes in living biomass are not estimated for Cropland remaining cropland.

Even if we apply the unrealistically high average EF for biomass gains and losses of Land converted to cropland to the area of Cropland remaining cropland, the resulting carbon stock changes remain well below the significance level (i.e. 25% of gains/losses in the category). Therefore, in CRF Table 4.B, these carbon stock changes are reported with the notation key NA.

There are significant carbon stock changes in biomass in orchards, which in the Netherlands predominantly consist of fruit trees. Because of the mainly grassy vegetation between trees, orchards are included under Grassland (see section 6.6).

Dead organic matter in annual cropland is expected to be negligible and, applying a Tier 1 method, it is assumed that dead wood and litter stocks (DOM) are not present in Cropland (IPCC, 2016). Therefore, carbon stock gains in DOM are not estimated in land use conversions to Cropland, nor are carbon stock losses in conversions from Cropland to other land uses.

Carbon stock losses for conversions to Cropland depend on the carbon stocks in DOM in the ‘converted from’ land use category. Currently, carbon stocks in DOM are only included under Forest land.

6.5.2 *Methodological issues*

With regard to soil emissions, a twenty-year transition period starting in 1990 is included, while carbon stock changes in biomass are considered to be instantaneous on conversion. In CRF Table 4.B, the area associated with the transition period for soil is reported.

Living biomass

The value of emissions and removals of CO_2 from carbon stock changes in living biomass for Land converted to cropland is calculated using a Tier 1 approach. This value is also used for determining emissions for Cropland converted to other land use categories (4A2, 4C2, 4D2, 4E2, 4F2).

Soils

Carbon stock changes in mineral soils for Cropland remaining cropland are calculated using a Tier 3 methodology, applying the RothC model. Carbon stock changes in mineral soils for land use changes involving Cropland and emissions from drained organic soils under Cropland are calculated using Tier 2 methodologies. More information on the methodologies is provided in section 6.1.2 and more details are provided in Chapter 11 of Van Baren et al. (2024).

6.5.3 *Uncertainty and time series consistency*

Uncertainties

The analysis in Annex 2 Table A2.3 provides estimates of uncertainties for each IPCC source category that are based on error propagation. The uncertainties in the Dutch analysis of carbon levels depend on the factors that feed into the calculations (calculation of the organic substances in the soil profile and conversion to a national level) and data on land use and land use change (topographical data). The uncertainty range in the CO_2 emissions for 4B Cropland) is calculated at 45%. For N_2O and CH_4, uncertainties are much higher, due to uncertainties in emission factors (see Van Baren et al. (2024) for details).
The Netherlands also applies an improved uncertainty assessment to the LULUCF sector as a whole with better representation of uncertainties in the land use matrix, using Monte Carlo simulations for combining different types of uncertainties (see Chapter 13 in Van Baren et al. (2024) for details).

Time series consistency

To ensure time series consistency, the same approach to activity data and land use area is used for all the years up to 2021.

6.5.4 *Category-specific QA/QC and verification*

The source categories are covered by the general QA/QC procedures discussed in Chapter 1.

6.5.5 *Category-specific recalculations*

Further improvement of the Tier 3 method for estimating carbon stock changes due to land management of mineral soils in the remaining category for Cropland and Grassland have resulted in recalculations of this pool for the whole time series.

6.5.6 *Category-specific planned improvements*

No category-specific improvements have been planned.

6.6 Grassland (4C)

6.6.1 *Source category description*

Under the Grassland category, two main sub-categories are identified: (1) Trees outside forests (TOF) and (2) Grassland (non-TOF); see section 6.2. Conversions of land use to, from, and between Grassland (non-TOF) and TOF are separately monitored, and each takes a different approach to calculating the carbon stock changes.

Trees outside forests (TOF)

The Trees Outside Forests (TOF) category is determined in a spatially explicit way and experiences carbon stock changes similar to those of Forest land (see section 6.4.2 and Arets et al., 2023). For land use conversion to TOF, the same biomass increase and associated changes in carbon stocks are assumed as for Land converted to forest land.

For conversions from TOF to other land uses, however, no losses of dead wood or litter are assumed. As the patches are smaller and any edge effects thus larger than in forests, the uncertainty regarding dead wood and litter accumulation is even higher for TOF than for Forest land. Moreover, for small patches and linear woody vegetation, the chance of dead wood removal is high, and disturbance effects on litter may prevent accumulation. Therefore, the conservative estimate of no carbon accumulation in these pools has been applied.

Conversion from Forest land to TOF may occur if connected surrounding units of Forest land are converted to other land uses and the remaining area no longer complies with the forest definition. Such units of land are considered to remain with tree cover, but losses of carbon in dead wood and litter will occur.

Grassland (non-TOF)
As described for Cropland, emissions resulting from the lowering of the ground water table in organic soils under Grassland (non-TOF) are significant. Therefore, these are explicitly calculated for areas of Grassland remaining grassland (non-TOF) and Land converted to grassland (non-TOF) (see Arets et al., 2023).

For carbon stock changes in living biomass in grassland vegetation and nature remaining in these categories, a Tier 1 method is applied, assuming no change in carbon stocks (IPCC, 2006; for details see Arets et al., 2023). In orchards, an increase in carbon stocks can be expected as the fruit trees age (see section 6.6.2 below). As a result of changing areas of grassland vegetation and orchards, the average carbon stocks in Grassland remaining grassland (non-TOF) change between years, reflected in the carbon stock changes in biomass in Grassland remaining grassland (non-TOF).

Carbon stock gains in living biomass for Land converted to grassland (non-TOF) are calculated using a Tier 1 approach (see section 6.6.2). Carbon stocks in Grassland (non-TOF) depend on carbon stocks per unit of area of grassland vegetation, nature and orchards and the relative contribution made by these categories to the Grassland (non-TOF) area. This value is also used to determine carbon stock losses in biomass for Grassland converted to other land use categories.

Dead organic matter (DOM) in grassland and orchards is expected to be negligible. While dead wood and litter may be formed in orchards, common orchard management that includes pruning and the removal of dead wood and litter will prevent build-up of large amounts of DOM. Even if we applied a value of 10% of annual carbon stock gains in biomass as an estimate of carbon stock gains in DOM in the same sub-category for which NE is currently used, this would make up only 1% of the carbon stock gains and losses in the Grassland category. Therefore, the Tier 1 approach is used (IPCC, 2006), assuming no build-up of DOM, which is reported as ‘NE’.

This means that the carbon stock gains in DOM are not included in land use conversions to Grassland (non-TOF), nor are the carbon stock losses included in conversions from Grassland (non-TOF) to other land use categories. Carbon stock losses for conversions to Grassland (non-TOF) will depend on the carbon stocks in DOM in the 'converted from' land use category. Currently, carbon stocks in DOM are only included under Forest land.

Land converted to grassland that changes from one Grassland (non-TOF) category to another within the twenty-year transition period (i.e. from grassland vegetation to nature or the other way around, see Arets et al., 2023) is still reported in the land converted to Grassland (non-TOF) category until the end of the twenty-year transition period.

Conversions between Grassland (non-TOF) and TOF
Whereas conversions between Grassland (non-TOF) and TOF are reported under Grassland remaining grassland, the two categories are considered separately in the calculations.

Conversions from Grassland (non-TOF) to TOF will result in the loss of Grassland (non-TOF) biomass in the year of conversion and subsequent growth of biomass in TOF. Conversion from TOF to Grassland (non-TOF) will involve a loss of carbon stocks in biomass from TOF and an increase in carbon stocks in Grassland (non-TOF), as applies to conversions from other land use categories. The changes in carbon stocks in mineral soils will also be included using a twenty-year transition period, similar to conversions between Forest land and Grassland (non-TOF).

6.6.2 *Methodological issues*

With regard to soil emissions, a twenty-year transition period is included starting from 1990, while carbon stock changes in biomass are considered to be instantaneous on conversion. In the CRF, the area associated with the transition period for soil is reported.

Living biomass
Grassland non-TOF
Carbon stock changes due to changes in biomass in land use conversions to and from Grassland (non-TOF) are calculated using Tier 1 default carbon stocks. For the whole Grasslands (non-TOF) category, including grassland vegetation, nature and orchards, an average carbon stock per unit of land is calculated from the carbon stocks per unit area of grassland vegetation, nature and orchards, weighted for their relative contribution to the Grassland (non-TOF) category. Therefore, average carbon stocks for Grassland (non-TOF) will vary over time as a result of varying relative contributions of the various vegetation types to the total Grassland (non-TOF) area (see Table 6.17).

Default values for dry matter and carbon factors are used to determine carbon stocks in living biomass in grassland vegetation and nature. Combined, these amount to 6.4 ton C per ha (see Arets et al., 2023). Carbon stocks in living biomass in orchards are based on an average age of trees in orchards[11] and a Tier 1 biomass accumulation rate of 2.1 ton C ha^{-1} yr^{-1} (IPCC, 2006). The average age of fruit orchards changed over time from 10.4 years in 1997 to 13 years in 2017[12].

[11] https://opendata.cbs.nl/statline/#/CBS/nl/dataset/81735NED/table?ts=1517993072950
[12] https://opendata.cbs.nl/statline/#/CBS/nl/dataset/81735NED/table?ts=1517993072950

Between the measurement years (1997, 2002, 2007, 2012 and 2017), the age developments were interpolated and linearly extrapolated before and after on the basis of the two adjacent measured ages. Subsequently, the average ages of fruit orchard trees are multiplied by the Tier 1 biomass accumulation of 2.1 tonnes ha^{-1} yr^{-1} to calculate the average carbon stock in orchard biomass (tC ha^{-1}) (Table 6.17). Areas of orchards published by Statistics Netherlands (CBS) between 1992 and 2016[13] and from 2017 onwards[14] are used to assess the area-weighted average carbon stocks in Grassland non-TOF (Table 6.17). The two Statistics Netherlands time series used include mostly the same fruit tree categories. Only in the case of other stone fruit trees ('overige steenvruchtbomen'), the more recent time series also include, on average, 700 ha of high-standard fruit trees, which were not recorded separately before. Because of the relatively small effect, this is estimated to have no net emissions (around -4 kt CO_2), it was decided not to correct for it at this moment in time.

Net carbon stock changes in both mineral and organic soils for land use changes involving Grassland are calculated using the methodology provided in Van Baren et al. (2024).

Table 6.17 Area and carbon stocks (CS) in living biomass for orchards and grass vegetation and combined average carbon stocks per area of Grassland (non-TOF)

	Orchard			Grass vegetation		Total		Average
Year	**Area (kha)**	**CS ha^{-1} (tC)**	**CS (tC)**	**Area (kha)**	**CS (tC)**	**Area (kha)**	**CS (tC)**	**CS (tC/ha)**
1990	25.0	22.7	566.9	1,426.4	9,117.7	1,451.4	9,684.5	6.67
1991	24.7	22.6	557.3	1,419.7	9,074.9	1,444.4	9,632.2	6.67
1992	24.4	22.5	548.3	1,413.0	9,032.0	1,437.4	9,580.3	6.67
1993	24.2	22.4	540.9	1,406.2	8,988.7	1,430.4	9,529.6	6.66
1994	24.1	22.3	537.3	1,399.3	8,944.3	1,423.4	9,481.6	6.66
1995	23.1	22.2	512.8	1,393.3	8,905.9	1,416.4	9,418.7	6.65
1996	22.9	22.1	506.5	1,386.5	8,862.4	1,409.4	9,368.8	6.65
1997	23.0	22.0	504.9	1,379.4	8,817.4	1,402.4	9,322.3	6.65
1998	22.4	21.9	489.7	1,373.0	8,776.4	1,395.4	9,266.1	6.64
1999	21.9	21.8	476.5	1,366.5	8,734.9	1,388.4	9,211.4	6.63
2000	20.5	21.7	444.4	1,360.9	8,699.0	1,381.4	9,143.4	6.62
2001	19.5	21.6	420.6	1,354.9	8,660.7	1,374.4	9,081.3	6.61
2002	19.2	21.5	413.3	1,348.2	8,617.6	1,367.4	9,030.9	6.60
2003	18.4	21.8	400.9	1,342.0	8,578.2	1,360.4	8,979.1	6.60
2004	18.3	22.1	405.0	1,338.5	8,555.8	1,356.9	8,960.9	6.60
2005	18.1	22.4	405.3	1,335.2	8,534.6	1,353.3	8,939.9	6.61
2006	18.2	22.7	412.6	1,331.6	8,511.3	1,349.7	8,923.9	6.61
2007	18.5	23.0	424.4	1,327.7	8,486.8	1,346.2	8,911.2	6.62
2008	18.6	23.3	432.8	1,324.0	8,463.2	1,342.6	8,896.0	6.63
2009	18.8	23.6	442.8	1,312.1	8,387.2	1,330.9	8,830.0	6.63

[13] https://opendata.cbs.nl/statline/#/CBS/nl/dataset/70671NED/table?fromstatweb
[14] https://opendata.cbs.nl/statline/#/CBS/nl/dataset/84470NED/table?ts=1582625476425

	Orchard			Grass vegetation		Total		Average
Year	Area (kha)	CS ha^{-1} (tC)	CS (tC)	Area (kha)	CS (tC)	Area (kha)	CS (tC)	CS (tC/ha)
2010	18.6	23.8	442.4	1,300.7	8,314.0	1,319.2	8,756.4	6.64
2011	18.3	24.1	441.4	1,289.3	8,241.0	1,307.6	8,682.4	6.64
2012	17.9	24.4	437.4	1,278.0	8,168.7	1,295.9	8,606.1	6.64
2013	18.2	25.0	455.4	1,292.5	8,261.4	1,310.7	8,716.8	6.65
2014	18.3	25.6	468.2	1,307.2	8,355.4	1,325.4	8,823.6	6.66
2015	18.5	26.2	485.2	1,321.7	8,448.4	1,340.2	8,933.6	6.67
2016	19.1	26.8	512.4	1,335.9	8,539.1	1,355.0	9,051.5	6.68
2017	18.6	27.4	508.5	1,344.5	8,593.9	1,363.0	9,102.4	6.68
2018	18.4	28.0	515.2	1,352.6	8,646.1	1,371.0	9,161.3	6.68
2019	18.4	28.6	525.0	1,360.7	8,697.5	1,379.1	9,222.5	6.69
2020	18.0	29.2	525.1	1,369.1	8,751.1	1,387.1	9,276.2	6.69
2021	17.9	29.8	531.9	1,377.4	8,804.0	1,395.2	9,335.9	6.69
2022	17.8	30.4	541.8	1,385.5	8,856.2	1,403.4	9,398.0	6.70

Trees outside forests
For Trees Outside Forests (TOF), no separate data on growth or increment is available. It is therefore assumed that TOF grow at the same rates as forests under Forest land (see section 6.4 and Arets et al., 2023). The only difference between the two categories is the size of the stand (<0.5 ha for TOF), so this seems a reasonable assumption. It is also assumed that no build-up of dead wood or litter occurs and that no harvesting takes place. Instead, all the wood included in the national harvest statistics is assumed to be harvested from Forest land.

Wildfires
There are no recent statistics available on the occurrence and intensity of wildfires in the Netherlands. Emissions of CO_2, CH_4 and N_2O from wildfires are reported according to the Tier 1 method described in the 2006 IPCC Guidelines.

The area of wildfires is based on a historical series from 1980 to 1992, for which the annual number of forest fires and the total burned area are available (Wijdeven et al., 2006). Forest fires are reported under Forest land (see section 6.4.2). The average annual area of other wildfires is 210 ha (Arets et al., 2023). This includes all land use categories. Most wildfires in the Netherlands, however, are associated with heath and grassland. All other emissions from wildfires, except forest fires, are therefore included under Grassland remaining grassland. CO_2, CH_4 and N_2O emissions from wildfires are based on the default carbon stock in living biomass on Grassland (non-TOF).

Area of cultivated organic soils
Only areas of cultivated organic soils under Grassland (non-TOF) are drained; areas of nature grasslands are not drained. In these areas of drained cultivated organic soils, the 5% reduction for drainage ditches is considered, as no carbon stock losses and associated CO_2 emissions are calculated for them. While in CRF Table 4.C the total area of organic soil

is included, the carbon stock changes are based only on the cultivated areas minus 5% for drainage ditches. This explains the differences between the areas of organic soils reported under Cropland and Grassland in the LULUCF sector on the one hand, and the areas reported in CRF Table 3.D in the Agriculture sector on the other. To improve transparency, a comparison between the various areas is presented in Table 6.18.

Table 6.18 Areas (kha) of peat and peaty soil in total Grassland (non-TOF) compared with the part considered to be drained cultivated grassland reported in CRF Table 3.D.

Year	Area grassland (non-TOF)			Area drained cultivated grassland		
	Peat	Peaty	Total	Peat	Peaty	Total
	kha					
1990	217,257	93,491	310,747	206,394	88,816	295,210
1991	215,710	92,933	308,643	204,924	88,286	293,211
1992	214,171	92,378	306,549	203,462	87,759	291,221
1993	212,639	91,825	304,465	202,007	87,234	289,241
1994	211,116	91,275	302,391	200,560	86,711	287,271
1995	209,601	90,727	300,327	199,121	86,191	285,311
1996	208,093	90,181	298,274	197,688	85,672	283,360
1997	206,593	89,638	296,231	196,264	85,156	281,420
1998	205,101	89,097	294,199	194,846	84,642	279,489
1999	203,617	88,559	292,176	193,437	84,131	277,567
2000	202,141	88,023	290,164	192,034	83,621	275,656
2001	200,673	87,489	288,162	190,639	83,114	273,754
2002	199,213	86,957	286,170	189,252	82,610	271,862
2003	197,760	86,428	284,189	187,872	82,107	269,979
2004	196,223	85,873	282,096	186,412	81,579	267,991
2005	194,693	85,317	280,010	184,959	81,051	266,010
2006	193,170	84,762	277,932	183,512	80,523	264,035
2007	191,655	84,206	275,861	182,072	79,996	262,068
2008	190,146	83,651	273,797	180,639	79,468	260,107
2009	189,186	83,036	272,223	179,727	78,885	258,612
2010	188,234	82,420	270,655	178,823	78,299	257,122
2011	187,291	81,803	269,094	177,926	77,713	255,639
2012	186,355	81,184	267,539	177,038	77,124	254,162
2013	185,876	81,850	267,726	176,582	77,758	254,340
2014	185,732	82,445	268,177	176,446	78,323	254,768
2015	185,578	83,041	268,619	176,299	78,889	255,188
2016	185,412	83,639	269,051	176,141	79,457	255,598
2017	185,294	83,666	268,960	176,029	79,483	255,512
2018	185,172	83,696	268,868	175,913	79,511	255,424
2019	185,046	83,729	268,775	175,794	79,542	255,336
2020	184,916	83,765	268,681	175,670	79,577	255,247
2021	184,781	83,812	268,593	175,542	79,621	255,164
2022	184,649	83,854	268,503	175,416	79,662	255,078

All areas are dated on 1 January of the years indicated.

6.6.3 *Uncertainty and time series consistency*

Uncertainties

The analysis in Annex 2 Table A2.3 provides estimates of uncertainties by IPCC source category, based on error propagation. The uncertainty range for CO_2 emissions in category 4C Grassland (non-TOF) is calculated at 75%. For CH_4 and N_2O uncertainties are much higher, mainly due to uncertainties in emission factors (see Van Baren et al. (2024) for details). The Netherlands also applies an improved uncertainty assessment to the LULUCF sector as a whole with better representation of uncertainties in the land use matrix, using Monte Carlo simulations for combining different types of uncertainties (see Chapter 14 of Van Baren et al. (2024) for details). There is currently no Monte Carlo uncertainty assessment that is based on the TOF category, but uncertainties are likely to be similar to those of Forest land – except that the uncertainty relating to the land use map may be larger as a result of the inherently small patches of TOF.

Time series consistency

To ensure time series consistency, the same approach to activity data, land use area and emissions calculation is used for all years. Removals in the later years are the result of carbon stock gains in mineral soil that are mainly due to the relatively large areas of Cropland converted to grassland since 2013. Interannual changes in implied EFs in mineral soils are the result of shifts in trends of land use changes. Carbon stock changes in mineral soils are based on combinations of land use change and soil type. Therefore, the mix of combinations of land use changes and soil types include changes over time. Moreover, actual annual land use changes, mixed with the timing of the twenty-year transition periods for carbon stock changes in soils, further affects the interannual changes in the implied EFs calculated on the basis of the total area in a certain conversion category (e.g. Cropland converted to grassland).

6.6.4 *Category-specific QA/QC and verification*

The source categories are covered by the general QA/QC procedures discussed in Chapter 1.

6.6.5 *Category-specific recalculations*

Further improvement of the Tier 3 method for estimating carbon stock changes due to land management of mineral soils in the remaining category for Cropland and Grassland have resulted in recalculations of this pool for the whole time series.

6.6.6 *Category-specific planned improvements*

No improvements have been planned at the moment.

6.7 Wetlands (4D)

6.7.1 *Source category description*

The Wetland land use category mainly consists of open water. Therefore for 4D1 (Wetland remaining wetland) no changes in carbon stocks in living biomass and soil have been estimated. For land use conversions from Wetland to other land uses, no carbon stock losses in living biomass are assumed to occur; these will be reported as not occurring (NO). For land use changes from Forest land, Cropland and Grassland to

Wetland (4D2), losses in carbon stocks in living biomass and net carbon stock changes in soils are included.

Because the Wetland category is mainly open water, dead organic matter (DOM) is assumed to be negligible. Therefore, no carbon stock gains in DOM are included in land use conversions to Wetland, nor are carbon stock losses included in conversions from Wetland to other land use categories. Carbon stock losses for conversions to Wetland will depend on the carbon stocks in DOM in the 'converted from' land use category. Currently, carbon stocks in DOM are only included under Forest land.

In the Netherlands, land use on peat areas is mainly Grassland, Cropland, or Settlements. Emissions from drainage in peat areas are included in carbon stock changes in organic soils for these land use categories.

6.7.2 *Methodological issues*

Living biomass

Carbon stocks in living biomass and DOM on flooded land and in open water are considered to be zero. For conversion from other land uses to Wetland, the Netherlands applies a stock difference method, assuming that all the carbon in biomass and organic matter that existed before conversion is emitted.

Emissions from fertiliser use in Wetland

The Wetland land use category mainly consists of open water, on which no direct nitrogen inputs occur. Therefore, in CRF Table 4(I), direct N_2O emissions from N inputs for Wetland are reported as NO.

Wetlands activity data

Starting with the submission of the NIR 2024, a Tier 1 approach for Wetlands is applied. To achieve this, a water type map (Clement & Puijenbroek,. 2010) was used to reclassify Wetlands, which in previous submissions used to be reported as Open water. Reservoirs, freshwater ponds, canals, and ditches were classified. In a first step, Tier 1 methodologies are now applied to that part of the open water that is human-made, i.e. all canals and ditches, and reservoirs and freshwater ponds created since 1900. For these water bodies, it is clear that the emissions have an anthropogenic cause. Further description of the method is provided in section 3.2 of Van Baren et al. (2024). In the current submission of 2024, the various areas are not specified in the CRF. With the upcoming change to the common reporting tables (CRT), it was deemed undesirable to make these changes in the CRF. Next year, when the CRT will be used, a distinction will be made. Therefore, emissions from flooded land (reservoirs, freshwater ponds, canals and ditches) are all reported under Open water at the moment. Areas for the various wetland categories per year are presented in Table 6.19.

Table 6.19 Areas (ha) of the different sub-categories for the land use category Wetlands

Year	Open water	Reed	Reser-voirs	Fresh-water ponds	Canals	Ditches	Total Wet-lands
1990	741,698	21,292	6,060	5,771	14,763	5,804	795,388
1991	741,942	21,740	6,063	5,787	14,891	6,016	796,439
1992	742,185	22,189	6,066	5,803	15,019	6,228	797,491
1993	742,429	22,638	6,070	5,819	15,147	6,440	798,543
1994	742,672	23,087	6,073	5,836	15,275	6,652	799,595
1995	742,916	23,536	6,076	5,852	15,403	6,865	800,646
1996	743,160	23,984	6,079	5,868	15,531	7,077	801,698
1997	743,403	24,433	6,082	5,884	15,658	7,289	802,750
1998	743,647	24,882	6,085	5,900	15,786	7,501	803,802
1999	743,891	25,331	6,088	5,916	15,914	7,713	804,854
2000	744,134	25,780	6,092	5,932	16,042	7,926	805,905
2001	744,378	26,228	6,095	5,948	16,170	8,138	806,957
2002	744,621	26,677	6,098	5,964	16,298	8,350	808,009
2003	744,865	27,126	6,101	5,980	16,426	8,562	809,061
2004	745,713	26,891	6,098	5,970	16,544	8,781	809,998
2005	746,562	26,656	6,096	5,960	16,661	9,000	810,934
2006	747,410	26,420	6,093	5,950	16,779	9,219	811,871
2007	748,258	26,185	6,091	5,940	16,896	9,438	812,808
2008	749,107	25,950	6,088	5,930	17,014	9,656	813,745
2009	751,274	26,027	6,086	5,913	17,000	9,664	815,964
2010	753,442	26,104	6,083	5,895	16,986	9,672	818,182
2011	755,609	26,181	6,081	5,878	16,973	9,679	820,400
2012	757,777	26,258	6,079	5,860	16,959	9,687	822,619
2013	757,731	26,369	6,075	5,846	16,937	9,594	822,551
2014	757,686	26,479	6,071	5,831	16,915	9,500	822,482
2015	757,640	26,590	6,067	5,817	16,893	9,407	822,414
2016	757,595	26,700	6,063	5,803	16,871	9,314	822,346
2017	758,084	26,638	6,054	5,795	16,833	9,205	822,610
2018	758,573	26,575	6,045	5,788	16,796	9,097	822,874
2019	759,062	26,512	6,036	5,781	16,758	8,988	823,138
2020	759,551	26,450	6,028	5,774	16,720	8,880	823,402
2021	760,023	26,404	6,019	5,762	16,679	8,777	823,663
2022	760,494	26,357	6,010	5,751	16,638	8,674	823,924

Methane and carbon dioxide emissions from Flooded Land
Methane and carbon dioxide emissions from all land uses converted to Flooded land and remaining Flooded land are calculated using a Tier 1 approach from the 2019 refinements to the 2006 IPCC guidelines (IPCC 2019). For the climate zone definition, Cool Temperate is used. Carbon dioxide emissions only occur on land converted to Reservoirs. Methane emissions from ditches and canals on organic soils are calculated using a country-specific emission factor from Peacock et al. (2021). For details on the method used, see Van Baren et al. (2024).

6.7.3 *Uncertainty and time series consistency*

Uncertainties

The analysis in Annex 2 Table A2.3 provides estimates of uncertainties according to IPCC source categories that are based on error propagation The uncertainty range in the CO_2 emissions for 4D Wetlands is calculated at 75% (see Van Baren et al. (2024) for details).
The Netherlands also applies an improved uncertainty assessment to the LULUCF sector as a whole, with better representation of uncertainties in the land use matrix, using Monte Carlo simulations for combining different types of uncertainties (see Chapter 14 of Van Baren et al. (2024) for details).

Time series consistency

To ensure time series consistency, the same approach to activity data, land use area and emissions calculation has been used for all years.

6.7.4 *Category-specific QA/QC and verification*

The source categories are covered by the general QA/QC procedures discussed in Chapter 1.

6.7.5 *Category-specific recalculations*

Implementation of the new Tier 1 method for methane and carbon dioxide emissions for Flooded land converted to and remaining resulted in new emissions for the land use Wetlands.

6.7.6 *Category-specific planned improvements*

Improved and higher-tier approaches for assessing emissions and removals from Wetlands are being assessed. This will result in improved methodologies to be included in future NIRs. This is expected to be a stepwise process with successive improvements in successive years.

6.8 Settlements (4E)

6.8.1 *Source category description*

In peat soils under Settlements, the lowering of the groundwater table also causes oxidation of peat that, in turn, results in high emissions. Together with loss of carbon stocks in biomass resulting from conversion of Forest land to settlement and Grassland to settlement, these are significant sources of CO_2.

Although Settlements also include areas with grass and trees, biomass gains and losses are expected to be in balance. Therefore, the Netherlands applies the Tier 1 method, assuming no change in carbon stocks in biomass in 4E1 (Settlements remaining settlements). Moreover, thanks to the high resolution of the land use grid, areas of land of 25 x 25 m or more within urban areas meeting the criteria for Forest land, Grassland or Trees outside forests, will be reported under those land use categories and not under Settlements (see Arets et al., 2023). In other words, the major pools of carbon in urban areas are covered by other land use categories.

As no additional data is available on carbon stocks in biomass and DOM in Settlements, and because conversions to Settlements are more frequent than conversions from Settlements to other land uses, it is more conservative not to report carbon stock gains and losses for biomass and DOM in Settlements resulting from conversions to and from Settlements.

It is also assumed that no carbon stock changes occur in mineral soils under Settlements remaining settlements. For conversions from other land uses to Settlements, the Netherlands applies a stock difference method, assuming that all the carbon in living biomass and organic matter that existed before conversion is emitted at once.

6.8.2 *Methodological issues*

The methodology for calculating carbon stock losses in biomass for Forest land converted to settlements is provided in section 6.4. Sections 6.5 (Cropland) and 6.6 (Grassland) describe the methodology for calculating carbon stock losses in biomass for conversions from Cropland and Grassland to Settlements. Land use conversions from Wetlands or Other land to Settlements will result in no changes in carbon stocks in living biomass.

Emissions from fertiliser use in Settlements

Under Settlements, direct N_2O emissions from the use of fertilisers and compost by private consumers and hobby farmers are reported under 3Da1 (Inorganic N fertilisers) and 3Da2 (Organic N fertilisers). 3Da1 and 3Da2 also include fertilisers used outside agriculture. Therefore, in CRF Table 4(I), N_2O emissions from N inputs for Settlements are reported as 'IE'.

6.8.3 *Uncertainty and time series consistency*

Uncertainties

The analysis in Annex 2 Table A2.3 provides estimates of uncertainties for each IPCC source category that are based on error propagation. The uncertainty range in CO_2 emissions for 4E Settlements is calculated at 70%. For N_2O, uncertainties are much higher, due to uncertainties in emission factors (see Van Baren et al. (2024) for details). The Netherlands also applies an improved uncertainty assessment to the LULUCF sector as a whole, providing a better representation of uncertainties in the land use matrix, using Monte Carlo simulations for combining different types of uncertainties (see Chapter 14 of Van Baren et al. (2024) for details).

Time series consistency

To ensure time series consistency, the same approach to activity data, land use area and emissions calculation is used for all years.

6.8.4 *Category-specific QA/QC and verification*

The source categories are covered by the general QA/QC procedures discussed in Chapter 1.

6.8.5 *Category-specific recalculations*

No recalculations have been performed this year.

6.8.6 *Category-specific planned improvements*

No improvements have been planned.

6.9 Other land (4F)

6.9.1 *Source category description*

In the Netherlands, the land use category 4F (Other land) is used to report areas of bare soil not included in any other category. These include coastal dunes and beaches with little or no vegetation, inland dunes and shifting sands, i.e. areas where the vegetation has been removed to create spaces for early succession species (and which are kept bare by the wind). Inland bare sand dunes have developed as a result of heavy overgrazing. For a long time, this was combatted by forest planting. These inland dunes and shifting sands, however, provided a habitat to some species that have now become rare. As a conservation measure in certain areas, these habitats have now been restored by removing vegetation and topsoil.

No carbon stock changes occur on Other land remaining other land. For units of land converted from other land uses to the Other land category, the Netherlands assumes that all the carbon in living biomass and DOM that existed before conversion is lost and no gains on Other land exist. Carbon stock changes in mineral and organic soils on land converted to Other land are calculated and reported.

Similarly, land use conversions from Other land to the other land use categories involve no carbon stock losses from biomass or DOM.

6.9.2 *Methodological issues*

The methodology for calculating carbon stock changes in biomass for Forest land converted to settlements is provided in section 6.4. Sections 6.5 (Cropland) and 6.6 (Grassland) provide the methodology for calculating carbon stock changes in biomass in conversions from Cropland and Grassland to Other land. Land use conversions from Wetland or Settlements to Other Land will result in no changes in carbon stocks in living biomass.

6.9.3 *Uncertainty and time series consistency*

Uncertainties

The analysis in Annex 2 Table A2.3 provides estimates of uncertainties for each IPCC source category that are based on error propagation The uncertainty in CO_2 emissions for 4F Other Land is calculated at 150%. Uncertainties for N_2O emission are even higher, due to the uncertainties in emission factors (see Van Baren et al. (2024) for details). The Netherlands also applies an improved uncertainty assessment to the LULUCF sector as a whole, providing a better representation of uncertainties in the land use matrix, using Monte Carlo simulations for combining different types of uncertainties (see Chapter 14 in Van Baren et al. (2024) for details).

Time series consistency

To ensure time series consistency, the same approach to activity data, land use area, and emissions calculation is used for all years.

6.9.4 *Category-specific QA/QC and verification*

The source categories are covered by the general QA/QC procedures discussed in Chapter 1.

6.9.5 *Category-specific recalculations*

No recalculations have been performed this year.

6.9.6 *Category-specific planned improvements*

No improvements have been planned.

6.10 Harvested wood products (4G)

6.10.1 *Source category description*

The Netherlands calculates sources and sinks from Harvested wood products (HWP) on the basis of the change in the pool, as suggested in the 2013 IPCC KP guidance (IPCC, 2014). These HWP emissions and removals are reported in the CRF using Approach B2.

6.10.2 *Methodological issues*

The approach taken to calculate the HWP pools and fluxes follows guidance in section 2.8 of the 2013 IPCC KP guidance (IPCC, 2014). Carbon from HWP allocated to Deforestation is reported using instantaneous oxidation (Tier 1) as the calculation method. The remainder of the carbon is added to the respective HWP pools. As no country-specific methodologies or half-life constants exist, the calculation for the HWP pools follows the Tier 2 approach outlined in the 2013 IPCC KP guidance (i.e. applying equations 2.8.1–2.8.6 in that guidance) (Arets et al., 2023).

Four categories of HWP are taken into account: Sawnwood, Wood panels, Other industrial round wood, and Paper and paperboard. Emissions from wood harvested for energy purposes are included in carbon stock losses in living biomass under Forest land remaining forest land, but are not used as an inflow to the HWP pool. As a result, these emissions are accounted for on the basis of instantaneous oxidation.

The distribution of material inflow into the various HWP pools is based on the data reported from 1961 onwards to the FAO for its statistics on imports, production, and exports of the various wood product categories (see CRF Table 4.Gs2), including those for industrial round wood and wood pulp as a whole.

To assess carbon amounts in the various HWP categories, the default carbon conversion factors for the aggregated HWP categories Sawnwood, Wood-based panels, and Paper and paperboard from the 2013 IPCC KP guidance (see Table 6.20) have been used. For the category Other industrial round wood, the values for Sawnwood have been used, as the latter category includes certain types of round wood use, such as the use of whole stems as piles in building foundations and road and waterworks, and as fences and poles. These are considered applications with a long to very long lifetime, for which the thirty-five-year half-life is considered appropriate.

To calculate the inflow of domestically produced paper, equation 2.8.2 from the 2013 IPCC KP guidance (IPCC, 2014) is applied to reported quantities of production, imports and exports of paper and paperboard. However, after 1993 the result give a negative value, indicating that there is no more production of pulp from domestic wood. In line with the instructions in the 2013 IPCC KP guidance (IPCC, 2014) these negative values are set to zero.

The paper and cardboard produced in the Netherlands is produced from imported cellulose (wood pulp) and recycled waste paper (Teeuwen et al., 2023). Therefore, using the production approach to HWP implies that no gains in paper and paperboard are expected.

Table 6.20 Tier 1 default carbon conversion factors and half-life factors for the HWP categories

HWP category	C conversion factor (Mg C per m^3 air dry volume)	Half-lives (years)
Sawn wood	0.229	35
Wood-based panels	0.269	25
Other industrial round wood	0.229	35
Paper and paperboard	0.386	2

6.10.3 *Uncertainty and time series consistency*

Uncertainties

The analysis in Annex 2 Table A2.3 provides estimates of uncertainties for each IPCC source category that are based on error propagation. As both activity data and emission factors have low uncertainty, the total uncertainty in the CO_2 emissions for 4G Harvested wood products is calculated at around 1% (see Van Baren et al. (2024) for details).

The Netherlands also includes HWP in the improved uncertainty assessment of the LULUCF sector as a whole, using Monte Carlo simulations to combine different types of uncertainties (see Chapter 14 of Van Baren et al. (2024) for details).

Time series consistency

Annual changes in carbon stocks in HWP are erratic by nature because they depend on highly variable inputs of wood production, imports, and exports. Net CO_2 emissions and removals in the 1990–2019 period range between -158 Gg CO_2 (removals) and 165 Gg CO_2.

6.10.4 *Category-specific QA/QC and verification*

The source categories are covered by the general QA/QC procedures discussed in Chapter 1.

6.10.5 *Category-specific recalculations*

No recalculations have been performed this year.

6.10.6 *Category-specific planned improvements*

No category-specific improvements are foreseen.

7 Waste (CRF sector 5)

Major changes in the Waste sector compared to the National Inventory Report 2023	
Emissions:	In 2022, total GHG emissions from the Waste sector further decreased by 6,0% compared to 2021; and by 82.0% compared to 1990.
New Key categories:	Compared to NIR 2023, there are no changes in key categories.
Methodologies:	In category 5A solid waste disposal on land, the 2019 methods of refinement are applied to the calculations. This results in the recalculation of CH_4 emissions from solid waste disposal.
	In Category 5D wastewater handling, N_2O emissions from Public WWTPs (category 5D1) and industrial aerobic biological WWTPs (category 5D2) have been recalculated by means of an improved emission factor**.**

7.1 Overview of the sector

The national inventory of the Netherlands comprises four source categories in the Waste sector:

- solid waste disposal on land (5A): CH_4 (methane) emissions;
- composting and digesting of biomass waste (including manure) (5B): CH_4 and N_2O (nitrous oxide) emissions;
- treatment of waste, including municipal waste incineration plants (5C): CO_2 and N_2O emissions (included in 1A1a);
- wastewater treatment and discharge (5D): CH_4 and N_2O emissions.

Table 7.1 Overview of the sector Waste (5) in the base year and the last two years of the inventory

Sector/category	Gas	1990	2021	2022	2022 vs 1990	Contribution to total in 2022 (%) by		
		Emissions in Tg CO_2-eq			%	sector	total gas	total CO_2-eq
5 Waste	CH_4	15.8	2.5	2.4	-84.9%	80.7%	12.8%	1.5%
	N_2O	0.5	0.6	0.6	3.6%	19.3%	8.6%	0.4%
	All	16.3	3.1	2.9	-82.0%	100.0%		1.9%
5A. Solid waste disposal on land	CH_4	15.3	2.2	2.0	-86.8%	68.9%	10.9%	1.3%
5A1. Managed waste disposal on land	CH_4	15.3	2.2	2.0	-86.8%	68.9%	10.9%	1.3%
5B. Biological treatment of solid waste	CH_4	0.0	0.1	0.1	2,589.6%	4.4%	0.7%	0.1%
	N_2O	0.0	0.1	0.1	1,130.0%	2.4%	1.1%	0.0%
	All	0.01	0.22	0.20	1,790.0%	6.8%		0.1%
5D. Wastewater treatment and discharge	N_2O	0.5	0.5	0.5	-8.4%	16.9%	7.5%	0.3%
	CH_4	0.4	0.2	0.2	-49.2%	7.3%	1.2%	0.1%
	All	1.0	0.7	0.7	-26.2%	24.1%		0.4%
Total national emissions (incl LULUCF)	CO_2	168.4	143.9	132.1	-21.6%			
	CH_4	36.3	19.1	18.5	-49.0%			
	N_2O	16.1	7.1	6.6	-58.7%			
	Total	228.1	171.5	158.4	-30.5%			

Table 7.1 presents the contribution made by the emissions from the Waste sector to total GHG emissions in the Netherlands, as well as the key sources in this sector by level, trend, or both. The list of all (key and non-key) sources in the Netherlands is included in Annex 1.

CO_2 emissions from the anaerobic decay of waste in landfill sites are not included as these are considered to be part of the carbon cycle rather than a net source. The Netherlands does not report emissions from waste incineration facilities for municipal waste in the Waste sector under category 5C, but under CRF 1A1a. These facilities also produce electricity and/or heat used for energy purposes (to comply with IPCC reporting guidelines). Methodological issues concerning this source category are briefly discussed in section 7.4. The methodology is described in detail in the methodology report (Honig et al., 2024), see also the reference in Annex 7.

In 2022, the Waste sector accounted for 1.9% of national total emissions (including LULUCF), compared to 7.1% in 1990. Emissions of CH_4 and N_2O accounted for about 81% and 19% of CO_2 equivalent emissions from the sector, respectively. Emissions of CH_4 from waste, of which approximately 69% originates from landfills (5A1 Managed waste disposal on land), accounted for 10.9% of total CH_4 emissions in 2022. N_2O emissions from the Waste sector originate from biological treatment of solid waste and from wastewater treatment. Fossil fuel-related emissions from waste incineration, mainly CO_2, are included in fuel combustion emissions from the Energy sector (1A1a).

Between 1990 and 2022, emissions from the Waste sector decreased by 82.0% (from 16.3 Tg CO_2-eq in 1990 to 2.9 Tg CO_2-eq in 2022; see Figure 7.1), mainly due to an 86.8% reduction in CH_4 from landfills. Between 2021 and 2022, CH_4 emissions from landfills decreased by 7.2%.

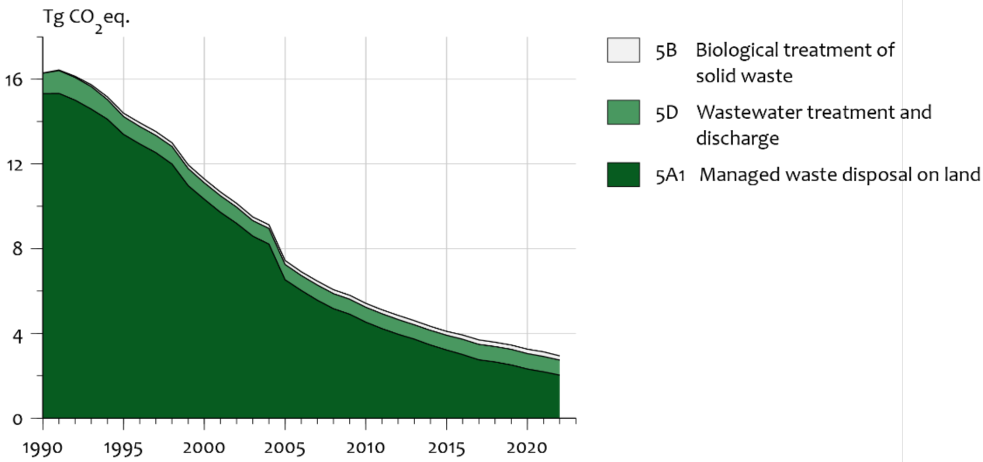


Figure 7.1 Sector 5 Waste – trend and emissions levels of source categories, 1990–2022

Decreased methane emissions from landfills since 1990 are the result of:
- increased recycling of waste;
- a considerable reduction in the amount of municipal solid waste (MSW) disposal at landfills;
- a decreasing organic waste fraction in the waste disposed;
- increased methane recovery from landfills (from 4% in 1990 to a source-specific 15% in 2022).

As indicated above, emissions from waste incineration (5C) are included in category 1A1a Other fossil fuels (see section 3.2.4.1). Emissions from municipal waste incineration accounted for c. 0.6 Tg CO_2-eq in 1990 (601 Gg CO_2 and 0.07 Gg N_2O emissions). In 2022, emissions accounted for approximately 2.8 Tg CO_2-eq (2,667 Gg CO_2 and 0.41 Gg N_2O).

7.2 Solid waste disposal on land (5A)

7.2.1 Category description

In 2022, there were eighteen operational landfill sites in the Netherlands. In the past, waste was landfilled on a few thousand sites; these older sites still contribute to the national emissions of methane. As a result of anaerobic degradation of organic material in the landfill body, all landfills produce CH_4 and CO_2. Landfill gas comprises about 50% (vol.) CH_4 and 50% (vol.) CO_2. Due to a light overpressure, landfill gas migrates into the atmosphere. CH_4 recovery currently occurs at 53 sites in the Netherlands. The gas is extracted before it is emitted into the atmosphere and is subsequently used as an energy source or flared off. In either case, the CH_4 in the extracted gas is not released into the atmosphere. The CH_4 may be degraded (oxidised) to some extent by bacteria when it passes through the landfill cover; this results in lower CH_4 emissions.

The anaerobic degradation of organic matter in landfills can take many decades. Not all factors influencing this process are known. Each landfill site has unique characteristics including concentration and type of organic matter, moisture, and temperature, among others. The chief factors determining the decrease in net CH_4 emissions are lower quantities of organic carbon deposited in landfills (organic carbon content multiplied by the total amount of landfilled waste) and higher methane recovery rates from landfills (see sections 7.2.2 and 7.2.3).

In 2022, solid waste disposal on land accounted for 68.9% of total emissions from the Waste sector and 1.3% of total national CO_2 equivalent emissions (see Table 7.1).

Dutch policies are directly aimed at reducing the amount of waste sent to landfill sites. As a result, many older and smaller sites were closed in the 1990s. This required enhanced prevention of waste production and increased recycling of waste, followed by incineration. As early as the 1990s, the government introduced bans on the landfilling of certain categories of waste; for example, the organic fraction of household waste. Another means of reducing landfilling was raising landfill taxes in line with the higher costs of incinerating waste.[15] As a result of this policy, the amount of waste sent to landfills decreased from 14 million tons in 1990 to 2.1 million tons in 2022, thus reducing emissions from this source category.
5A Solid waste disposal on land CH_4 is a key source in this category.

7.2.2 *Methodological issues*

A more detailed description of the method and EFs used can be found in section 2.3.2.2 of Honig et al. (2024).
Data on the amount of waste disposed at landfill sites derives mainly from the annual survey performed by the Working Group on Waste Registration (WAR) at all the landfill sites in the Netherlands. This data is documented in Rijkswaterstaat (2024), which also presents the annual amount of CH_4 recovered from landfill sites.

In order to calculate CH_4 emissions from all landfill sites, it is assumed for modelling purposes that all waste is disposed of at one landfill site. As stated above, however, characteristics of individual sites can vary substantially. CH_4 emissions from this 'national landfill' were then calculated using a first-order decomposition model (first-order decay function) with an annual input of the total amounts deposited, the characteristics of the landfilled waste, and the amount of landfill gas extracted. This is equivalent to the IPCC Tier 2 methodology. Since landfills are a key category of CH_4 emissions, the present methodology is in line with the 2006 IPCC Guidelines (IPCC, 2006).

The parameters used in the landfill emissions model are as follows:

- Total amount of landfilled waste;
- fraction of degradable organic carbon (DOC) (see Table 7.2 for a detailed time series);
- CH_4 generation (decomposition) rate constant (k-value): 0.094 up to and including 1989, decreasing to 0.0693 in 1995, further

[15] In extreme circumstances, e.g. an increase in demand for incineration capacity due to unprecedented supply, the regional government can grant an exemption from these 'obligations'.

decreasing to 0.05 in 2005 (IPCC parameter), and remaining constant thereafter; this corresponds to a half-life of 14.0 years;
- CH_4 oxidation factor for managed landfills (IPCC parameter): 10%;
- fraction of DOC actually dissimilated (DOCF): 0.58 until 2004 (see Oonk et al., 1994), annually determined from 2005 onwards on the basis of the composition of waste disposed. This is elaboration of the refinement points from the 2019 IPCC refinements;
- methane correction factor (MCF): 1.0 (IPCC parameter);
- fraction of methane in landfill gas produced: 57.4% for the years up to 2004 (see Oonk, 2016), decreasing by 50% in 2005 (IPCC parameter), and remaining constant thereafter;
- amount of recovered landfill gas, published in the annual report titled 'Waste processing in the Netherlands' (Rijkswaterstaat, 2024);
- time delay from deposit of waste to start production of methane gas: set at 6 months (IPCC parameter). On average, waste landfilled in year x starts to contribute to methane emissions in year x+1.

A selection of these parameters are discussed in the following sub-sections.

Amount of waste landfilled
Table 7.2 provides an overview of landfilled waste, its degradable organic carbon content (DOC) and the fraction of the degradable organic content that actually dissimilates.

Table 7.2 Amounts of waste landfilled, degradable organic carbon content and degradable organic carbon that dissimilates

Year	Amount landfilled (Mton)	Degradable organic carbon (kg/ton)	Degradable organic carbon that dissimilates (%)
1945	0.1	132	58
1950	1.2	132	58
1955	2.3	132	58
1960	3.5	132	58
1965	4.7	132	58
1970	5.9	132	58
1975	8.3	132	58
1980	10.6	132	58
1985	16.3	132	58
1990	13.9	131	58
1995	8.2	125	58
2000	4.8	110	58
2005	3.5	62	41
2010	2.1	33	34
2011	1.9	31	37
2012	3.3	32	29

Year	Amount landfilled (Mton)	Degradable organic carbon (kg/ton)	Degradable organic carbon that dissimilates (%)
2013	2.7	33	34
2014	2.2	34	35
2015	2.3	43	40
2016	2.8	52	40
2017	2.9	56	39
2018	3.2	51	38
2019	2.8	49	34
2020	2.4	43	32
2021	2.1	38	31
2022	2.1	37	31

Between 1945 and 1970, a number of municipalities kept detailed records of their waste collection. In addition, information was available about which municipalities had their waste incinerated or composted. All other municipal waste was landfilled.

This information, in combination with data on landfilling from various sources (SVA, 1973; Statistics Netherlands, 1988, 1989; Nagelhout, 1989) and data on the years 1950, 1955, 1960, 1965 and 1970 determined and published by Van Amstel et al. (1993), was used to compile the dataset, with the assumption that during the Second World War hardly any waste was landfilled. These data are also used in the FOD model, while missing years (1945–1950, 1951–1954, 1956–1959, 1961–1964 and 1966–1969) have been extrapolated linearly.

Accurate data on production and waste treatment are available from 1970 onwards (Spakman et al., 2003). Landfill site operators systematically monitor the amount of waste dumped (weight and composition) at each waste site. Since 1993, monitoring has occurred by weighing the amount of waste dumped and by regulating dumping via compulsory environmental permits.

Data on the amounts of waste dumped since 1991 is supplied by the WAR (Rijkswaterstaat) and included in the annual report 'Waste processing in the Netherlands'. Information on how this data is gathered and the scope of the information used can be found in these reports, available from the WAR since 1991.

Since 2005, landfill operators have been obliged to register their waste according to European Waste List (EWL) codes. Landfill operators also use EWL codes for the annual survey by the WAR so the WAR has a complete overview of the landfilled waste for every EWL code.

Fraction of degradable organic carbon
The amount of degradable organic carbon (DOC) for the 1945–1990 period was determined at 132 kg/ton (Spakman et. al., 2003). In the 1991–1997 period, the fraction of degradable organic carbon (DOCf) value slowly declined due to the start of separate organic waste

collection from households in 1992 and the introduction of landfill bans for municipal waste in 1995.

Rijkswaterstaat gathers information on the amounts and composition of a large number of waste flows as part of its work to draw up its annual 'Netherlands Waste in Figures' report (Rijkswaterstaat, 2022). The results of several other research projects also helped to determine the composition of the waste dumped. This method was used until 2004. In the 2000–2004 period, effects of the policy of reducing the amount of DOC being landfilled (especially in waste from households) resulted in a decrease in the DOC value from 110 kg/ton in 2000 to 74 kg/ton in 2004.

From 2005 onwards, all landfilled waste has been included in the figures. This includes waste streams with a low DOC content (contaminated soil, dredging spoils) or no DOC at all (inert waste). This results in a low average DOC value of a ton of landfilled waste compared with the IPCC default values.

An amount of degradable carbon is determined for each EWL code (Tauw, 2011), and DOC values are allotted to ten different groups of waste streams. Each type of waste (corresponding to an EWL code) that is allowed to be landfilled (liquid waste may not be landfilled, for example) is allocated to one of the groups. Each group has an individual DOC content. As an illustration, Table 7.3 presents the waste stream groups, their DOC values and the amounts landfilled in 2022. Table 7.4 presents the amounts landfilled per waste stream group since 2005.

Table 7.3 Amount of waste landfilled in 2022 and DOC value of each group

Waste stream group	**Amount landfilled (Mg)**	**DOC value (kg/Mg)**	**Total DOC landfilled (Mg)**
Waste from households	19,529	182	3,554
Bulky household waste	0	NO	0
Commercial waste	0	NO	0
Cleansing waste	6,982	43.4	303
Waste that contains high level of DOC	47,942	112	5,370
Stabilised organic waste	233,082	130	30,301
Waste that contains low level of DOC	765,612	44	33,687
Contaminated soil	252,140	11.5	2,900
Dredging spoils	28,885	42.4	1,225
Inert waste	737,949	0	0
Wood waste	1,838	430	790
Total	**2,093,958**		**78,129**

Table 7.4 Amount of waste 2005-2022 by waste stream group (Gg)

Waste stream group	2005	2010	2015	2019	2020	2021	2022
Waste from households	347	22	153	83	34	20	20
Bulky household waste	22	0	0	0	0	0	0
Cleansing waste	62	6	5	12	7	2	7
Waste that contains high content of DOC	97	26	80	78	61	54	48
Stabilised organic waste	555	159	167	571	351	265	233
Waste that contains low content of DOC	965	604	738	752	913	769	766
Contaminated soil	735	633	218	301	205	215	252
Dredging spoils	232	194	140	23	23	19	29
Inert Waste	486	481	841	986	815	800	738
Wood waste	7	0	0	3	1	2	2
Total	**3,509**	**2,126**	**2,342**	**2,808**	**2,409**	**2,145**	**2,094**

The DOC values were determined from the composition of mixed household waste (Tauw, (2011): Table B3.2), the composition of other waste streams (Tauw, (2011): Annex 3) and expert judgement. The average DOC value of a ton of waste landfilled is calculated by dividing the total DOC landfilled by the amount landfilled.

Degradable organic carbon that decomposes (DOCf)
The fraction of degradable organic carbon that decomposes (DOCf) is an estimate of the amount of carbon ultimately released from SWDS, and reflects the fact that some degradable organic carbon does not decompose or degrades very slowly under anaerobic conditions in the SWDS.
Before 2005, a country-specific value of 0.58 was used (Oonk et al., 1994). An attempt in 2011 to validate the country-specific parameters (DOCf and k-value) for the model was unsuccessful (Tauw, 2011). The method to determine the DOCf factor was refined in the 2019 IPCC refinements. Research shows that various components of biodegradable waste dissimilate differently within a landfill under anaerobic conditions. For example, organic kitchen and garden waste and sewage sludge are dissimilated by 70%, while wood only does so by 10%.
From 2005 onwards, the DOCf factor has been calculated annually (see Table 7.2). By multiplying the composition of the waste by the dissimilation factor per component, the DOCf factor can be calculated. In this calculation only biodegradable components are taken into account. Non-biodegradable components are excluded, while the amount of biodegradable organic carbon already corrects this. Table 7.5 presents the calculated DOCf factor per waste stream from 2005 onwards.

Table 7.5 Calculated DOCf factor by waste stream group

Waste stream group	**DOCf value per waste stream group**
Waste from households	0.58
Bulky household waste	0.40
Cleansing waste	0.50
Waste that contains high level of DOC	0.70
Stabilised organic waste	0.30
Waste that contains low level of DOC	0.21
Contaminated soil	0.50
Dredging spoils	0.50
Inert Waste	0.50
Wood waste	0.10

k-value
The k-value is a rate constant related to the half-life value for waste to decay to half its initial mass. The assumption is that the majority of degradable waste landfilled in the Netherlands consists of paper, wood, and textiles (slowly degrading) and not of sewage sludge or food waste (rapid degrading). Paper, wood and textiles can, for example, be found in construction and demolition waste and in waste from shredding vehicles and electronic equipment.

The IPCC default value is between 0.03 and 0.06 for slowly degrading waste (wood, paper, textiles) in a wet and temperate climate zone.
In the 1989-2004 period, a country-specific value for k (0.094) was determined by means of a validation of a landfill gas model (Oonk, 1994). Due to changing waste composition as a result of waste policies in the early 1990s, the value was changed to 0.0693 for the years 1990-2004. A new attempt to validate the landfill gas model to derive improved parameters (Tauw, 2011) was unsuccessful. Therefore, a default value of 0.05 for the k-value has been used in the Dutch model from 2005 onwards. The value of 0,05 is in the range for slowly degrading waste in a wet and temperate climate zone (table 3.3 in IPCC 2006, chapter solid waste disposal).

Degradable waste is not landfilled in large quantities in the Netherlands. There is still a quantity of landfilled mixed municipal waste (EWL code 200301). In theory, this code applies to several waste streams, e.g. waste from households and commercial waste. In fact, in recent years, only commercial waste has been landfilled, because waste from households is incinerated.

If residues from waste treatment have to be landfilled, in most cases, this is because they are not combustible or recyclable. In some cases, waste incinerator operators argue that the caloric value is too high as well, mainly due to a high content of plastics in the residues. Residues do not generally contain rapidly degrading waste such as food waste or sewage sludge.

Other waste streams landfilled in large quantities, such as contaminated soil (EWL code 170504) and sludges from physicochemical treatment (EWL code 190206: in fact, mainly residues from soil remediation), have a low DOC value. It is reasonable to assume that these residues only contain slowly degrading waste, because the organic content is stabilised.

Methane correction factor (MCF)
All sites in operation after World War II can be regarded as being managed in conformity with the IPCC Guidelines, according to which they must have controlled waste placement (i.e. waste is directed to specific deposition areas and there is a degree of control over scavenging and the outbreak of fire) and feature at least one of the following: (i) cover material; (ii) mechanical compacting; or (iii) levelling.

Many landfill sites are situated near urban areas. In order to prevent odour and scavenging animals (birds, rats), the management of landfill sites has been closely monitored since the start of the 20th century. A major study conducted in 2005 (NAVOS, 2005) investigated about 4,000 old landfill sites and concluded that:

- From 1930, a method of placing the waste in defined layers and covering it with ashes, soil, sand or dirt from street sweeping became common practice.
- In the early 1970s, the waste sector introduced a 'code of practice' in which a method of environmentally friendly landfilling was described.
- During the 1970s and early 1980s, national legislation introduced an obligation to landfill in a controlled manner. Some old permits for landfill sites (from the early 1970s) contained obligations to compact and cover the waste and to deposit waste in specific parts of the site covering a certain maximum size instead of using the whole area simultaneously. Several permits also paid attention to fire prevention.

On the basis of these findings, waste disposal sites can be generally considered as having been managed throughout the relevant period. Therefore the Netherlands uses the MCF of 1 in its model.

A few landfill sites are semi-aerobic. At three selected landfill sites, research is currently being conducted into how the site should be managed after it is closed. This is the responsibility of the regional authorities. A few parts of these landfills are semi-aerobic, but emissions from all waste landfilled at these sites are included in the emissions from anaerobic landfills.

Fraction of methane generated in landfill gas
Most models of CH_4 formation in landfills and emissions from landfills are based on landfills of municipal solid waste. This type of waste was landfilled in the Netherlands until the early 1990s, but Dutch waste policy has changed since then. The landfilling of waste with large amounts of biodegradables (such as household waste) was first discouraged and then banned. Food and garden waste are now collected separately and composted. Other types of household waste are mostly

incinerated and or recycled. As a result, existing models have been extrapolated to deal with this changed waste composition.

Another explanation for a lower fraction of methane generated in landfill gas is the reduced methane content in the landfill gas being formed. Landfill gas is produced from a broad range of materials. Cellulose and hemicellulose, for example, produce gas with a theoretical methane concentration of about 50%. Proteins and fats, however, produce gas with a significantly higher methane concentration. When waste is landfilled, it is conceivable that the more readily degradable components decompose first, resulting in a methane concentration that gradually declines, e.g. from 57% to approximately 50%. Since less and less readily degradable material is landfilled in the Netherlands, it is possible that the observed decline is at least partially the result of a decline in CH_4 concentration in the gas formed (Oonk, 2011).

On the basis of measurements by Coops et al. (1995), the amount of methane in landfill gas was determined at 60%. In earlier research, the amount of CO_2 absorbed in seepage water was not included. Research by Oonk, (2016) estimated that 2–10% of the CO_2 is removed by the leachate. In the calculations, 10% of the CO_2 is removed, resulting in a fraction of methane in landfill gas of 57.4% for the 1990–2004 period. From 2005 onwards, the IPCC default value of 50% methane has been used.

Recovered landfill gas
The amounts of recovered landfill gas are recorded annually by the WAR. The WAR also collects data on the distribution of recovered gas between landfill gas engines and flares by all operators of landfill sites. Emissions from gas engines are reported under CRF 1A4a.

At almost all landfill sites, the amount of recovered landfill gas is measured. Only the percentage of methane in older landfill sites is occasionally estimated. In 2022, the methane content and amount of recovered landfill gas at four landfill sites was estimated. Table 7.6 presents the amounts of recovered landfill gas, the average methane content, and the amount flared or used for energy purposes.

Table 7.6 Amount of landfill gas recovery

Parameter	1990	2000	2005	2010	2015	2020	2021	2022
Free emission of landfill gas (million m3)	1,564	1,055	770	532	376	270	254	236
Free emission of methane (kton)	547	369	233	162	115	83	78	72
Recovered landfill gas (million m3)	64	162	130	102	60	51	46	46
Amount used for energy purposes (million m3)	48	119	98	79	43	23	20	22
Amount combusted in flares (million m3)	16	43	32	22	17	28	27	23
Percentage of methane in recovered landfill gas (%)	57.4	57.4	53.2	51.3	49.6	46.1	45.6	45.5

Parameter	1990	2000	2005	2010	2015	2020	2021	2022
Amount recovered methane (kton)	25	63	47	35	20	16	14	14
Amount recovered methane useful applied (kton)	19	46	35	28	15	7	6	7
Amount recovered methane flared (kton)	6	17	12	8	6	9	8	7

Use of country-specific values before 2005
Between 1990 and 2004, the Netherlands used a landfill gas model containing country-specific values. The country-specific values for DOCf and the k-value were derived from the study by Oonk et al. (1994). The k-value was later adjusted in a study by Spakman, (2003) due to the changes in the composition and degradability of the waste. In 2010, the Netherlands tried to validate the country-specific values by means of a study by Tauw. The conclusion of this study (Tauw, 2011) was that it was not possible to validate the country-specific values. Therefore, the landfill model has used the IPCC default values for DOCf and the k-value from 2005 onwards. The assumption was made that the country-specific values were still applicable until 2004.

Trend information on IPCC Tier 2 method parameters that change over time is provided in Table 7.7. The integration time for the emissions calculation is defined as the period from 1945 to the year for which the calculation is made.

Table 7.7 Parameters used in the IPCC Tier 2 method that change over time (additional information on solid waste handling)

Parameter	1990	2000	2005	2010	2015	2020	2021	2022
Fraction DOC in landfilled waste	0.13	0.11	0.06	0.03	0.04	0.04	0.04	0.04
CH_4 generation rate constant (k)	0.09	0.07	0.05	0.05	0.05	0.05	0.05	0.05
Number of SWDS recovering CH_4	45	55	50	53	54	52	53	53
Fraction CH_4 in landfill gas	0.57	0.57	0.5	0.5	0.5	0.5	0.5	0.5

7.2.3 *Uncertainty and time series consistency*

Uncertainty
The uncertainty analysis in Annex 2 provides estimates of uncertainties by IPCC source category and gas that are based on error propagation. The uncertainty in CH_4 emissions from SWDS is estimated at approximately 24%. The uncertainty in the activity data and the EF is estimated to be 0.4% and 24%, respectively. For a more detailed analysis of these uncertainties, see Rijkswaterstaat, (2014).

Time series consistency
The estimates for all years are calculated from the same model, which means that the methodology is consistent throughout the time series. The time series consistency of the activity data is very good, due to the continuity in the data provided.

7.2.4 *Category-specific QA/QC and verification*

The source categories are covered by the general QA/QC procedures discussed in Chapter 1, and the specific QA/QC described in the document on the QA/QC of outside agencies (Wanders, 2021).

In general, the QA/QC procedures within the Waste sector are:
- checking activity data against other sources within the monitoring of waste, for example the notifications of landfill operators at the 'Landelijk Meldpunt Afvalstoffen';
- checking trends in the resulting emissions.

Several explanations are given for differences between deposited amounts in the WAR and data at Eurostat:
1) For Eurostat, the start of the cycle is used and then how the waste is processed is estimated. In the WAR, landfill operators are questioned, giving an idea of how much waste is landfilled.
2) A number of waste materials dumped deep underground are included in the Eurostat data. In the WAR these quantities are missing.
3) Waste landfilled abroad (for example, highly leachable waste or residues from waste processing) are not included in the WAR but are included in the Eurostat data.

7.2.5 *Category-specific recalculations*

Compared to the previous submission, the introduction of an annually calculated DOCf factor caused lower methane emissions. From 2005 onwards, emissions of methane are lower compared to previous submissions. Due to the new methodology, the emission from methane dropped to 78 Gg in 2021, while on the basis of the 'old' methodology the amount of methane from landfills would be 84 Gg in 2021. This is a difference of 0.17 Tg in CO_2 -equivalents. Furthermore, there are some updated figures with regard to the amount of extracted landfill gas. These figures are minor compared to the change in methodology.

7.2.6 *Category-specific planned improvements*

No improvements have been planned.

7.3 Biological treatment of solid waste (5B)

7.3.1 *Category description*

This source category consists of CH_4 and N_2O emissions from:
- the composting and digesting of separately collected organic waste from households;
- organic waste from gardens and horticulture;
- emissions from manure from agriculture.

Emissions from the small-scale composting of garden waste and food waste by households are not estimated, as these are assumed to be negligible.

The amount of composted and digested organic waste increased from almost nothing in 1990 to 3.5 million tons in 2022. In 2022, this treatment accounted for 6.2% of the emissions in the Waste sector (see Table 7.1). The biological treatment of solid waste is a key source of CH_4 emissions.

7.3.2 *Methodological issues*

Detailed information on activity data and EFs can be found in section 2.3.2.3 in Honig et al. (2024).

The activity data for the amount of organic waste composted at industrial composting facilities derives mainly from the annual survey performed by the WAR at all industrial composting sites in the Netherlands (Rijkswaterstaat, 2024). Amounts of organic waste treated by green waste composting plants were collected from the Landelijk Meldpunt Afvalstoffen, which registers waste numbers, as required by Dutch legislation. All amounts are based on a wet weight basis.

The amount of animal manure used in digesters is based on registered manure transports (data from the Netherlands Enterprise Agency; RVO). The emissions are calculated using the National Emissions Model Agriculture (NEMA) described in Chapter 5, and the methodology report for agricultural emissions (Van der Zee et al., 2024).

Table 7.8 Total amount of treated collected organic waste from households and green waste from gardens and companies

Year	Organic waste from households (Mton)		Green waste from gardens and enterprises (Mton)	
	Composted	Digested	Composted	Digested
	(5B1a)	(5B2a)	(5B1b)	(5B2b)
1990	228	-	-	-
1995	1,409	44	2,057	-
2000	1,498	70	2,473	2
2005	1,326	41	2,770	14
2009	1,178	81	2,648	0
2010	1,066	154	2,424	13
2011	1,091	182	2,384	25
2012	1,009	292	2,417	30
2013	942	331	2,299	42
2014	911	445	2,086	59
2015	882	475	1,992	85
2016	966	465	2,321	78
2017	1,027	465	2,335	107
2018	1,044	448	2,376	94
2019	1,103	457	2,192	84
2020	1,237	461	2,180	73
2021	1,280	419	2,246	68
2022	1,101	422	1,929	73

In 2010, an independent study on the EFs was conducted (DHV, 2010). The EFs were compared with those in other, predominantly European, countries. The current EF is backed up by most of the data considered relevant, as discussed in the 2010 study by DHV. DHV used studies of measurements carried out at German, Dutch and Austrian composting plants (DHV, 2010).

The EF for green waste from gardens and enterprises composted in the open air is derived from a study by the Austrian Umweltbundesamt (Lampert et al., 2011).

7.3.3 Uncertainty and time series consistency

Uncertainty

Emissions from this source category are calculated using an average EF obtained from the literature. The uncertainty in annual CH_4 and N_2O emissions is estimated at 74% and 60%, respectively. The uncertainty is mainly determined by uncertainties in the EF (73% for CH_4 and 59% for N_2O); whereas the uncertainty in the activity data is about 11%. For a more detailed analysis of these uncertainties, see Rijkswaterstaat (2014).

Time series consistency

Due to the continuity in the data provided, the time series consistency of the activity data is very good.

7.3.4 Category-specific QA/QC and verification

The source categories are covered by the general QA/QC procedures, discussed in Chapter 1, and the specific QA/QC described in the document for the QA/QC of outside agencies (Wanders, 2021).
In general, the QA/QC procedures within the Waste sector are:

- checking activity data against other sources within the monitoring of waste;
- checking trends in the resulting emissions;
- checking EFs against EFs in other European countries.

7.3.5 Category-specific recalculations

Compared to the previous submission, no changes in the data have been made in this submission.

7.3.6 Category-specific planned improvements

No improvements have been planned.

7.4 Waste incineration (5C)

7.4.1 Category description

This category mainly comprises emissions from activities of the waste incineration facilities that process municipal solid waste and other waste streams.

In general, open burning of waste does not occur in the Netherlands, as it is prohibited by law. However, bonfires (wood burning) are occasionally allowed, and since 2020, they have been included in the inventory. Bonfires occur mainly at New Year's Eve and Easter. They are fuelled by biomass waste (wooden pallets, organic degradable waste, pruning woods). Municipalities grant permits for these bonfires, so their number is known. An average volume is calculated on the basis of the permits. Due to regulations during the COVID-19 period, many bonfires were cancelled in 2020 and 2021. During the process of open burning, emissions of N_2O and CH_4 occur. This is a minor source.

Emissions from the source category Waste incineration, such as occur in Waste Incinerations plants (WIPs), are included in category 1A1 (Energy industries) as part of the source 1A1a (Public electricity and heat production). This is because all municipal waste incineration facilities in the Netherlands also produce electricity and/or heat for energy purposes. According to the 2006 IPCC Guidelines, these activities should be included in category 1A1a (Public electricity and heat production: Other fuels); see section 3.2.4.

This sector comprises no key categories.

7.4.2 *Methodological issues*

Detailed information on activity data and EFs (waste incineration in WIPs) can be found in section 2.3.2.1 of Honig et al. (2024).

Bonfires

Uncertainties in the bonfire-related emissions (both CH_4 and N_2O) are high: over 300%. This relates to uncertainties in activity data as well as in EFs; estimated at 100% and 300% respectively for both gases.

Time series consistency

Consistent methodologies have been used throughout the time series for this source category. Time series consistency of the activity data is considered to be very good, due to the continuity of the data provided by the WAR.

7.4.3 *Category-specific QA/QC and verification*

The data on the amounts of waste incinerated is also checked when performing the annual R1 test. The results of this test determine whether an incinerator is a recovery plant or a disposal plant.

The source categories are covered by the general QA/QC procedures, discussed in Chapter 1, and the specific QA/QC described in the document for the QA/QC of outside agencies (Wanders et al, 2021).

7.4.4 *Category-specific recalculations*

There have been no category-specific recalculations.

7.4.5 *Category-specific planned improvements*

EFs for household waste are planned to be updated; especially the carbon content, the biogenic part of carbon, the energy content and the biogenic part of the energy, and the biogenic part of the mass of several components of household waste.

7.5 Wastewater handling (5D)

7.5.1 *Category description*

This source category includes emissions from industrial wastewater, domestic (urban) wastewater, septic tanks and indirect emissions as a result of discharges. In 2022, only 0.35% of the Dutch population was not connected to a closed sewer system, and these households were obliged to treat wastewater in a small-scale on-site treatment system (a septic tank or a more advanced system).

Subcategory **5D1 Domestic wastewater handling**: In 2022, urban wastewater (the mixture of domestic, industrial and commercial wastewater, including urban run-off) was treated aerobically in 313 public wastewater treatment plants (WWTPs). During wastewater treatment, the biological breakdown of degradable organic compounds (DOC) and nitrogen compounds results in CH_4 and N_2O emissions. The

treatment of the residual wastewater sludges is mainly accomplished by anaerobic digesters. Incidental venting of biogas also results in CH_4 emissions.
Following eventual on-site sludge digestion and dewatering processes, almost all sludges from domestic WWTPs are incinerated in mono-incinerators, or co-incinerated in either power plants or cement factories. For a time series of final treatment of sludges from domestic WWTP, see Statline Urban wastewater treatment (2023). Data on 2022 will be added by the end of March 2024.

Subcategory **5D2 Industrial wastewater handling** includes CH_4 emissions from the operational anaerobic industrial WWTPs (IWWTPs) (2022: 51 plants) as well as N_2O emissions from aerobic biological industrial WWTPs (2022: 145 plants).

Subcategory **5D3 Septic tanks and indirect emissions from discharges to surface water**:
The discharge of effluents, as well as other direct discharges from households and companies, result in indirect N_2O and CH_4 emissions from surface water due to the natural breakdown of residual nitrogen compounds and residual organic compounds. As 0.35% of the resident population is still connected to a septic tank, CH_4 emissions from septic tanks are also calculated, but these are very small compared with those from public WWTPs.

The incorporation of the methods of the 2019 Refinement to the 2006 IPCC guidelines for category 5D resulted in major changes in the 2023 submission of the NIR. In the 2024 submission, there is again a major change: instead of the default emission factor from the 2019 refinement, for N_2O emissions from biological wastewater treatment an adjusted emission factor is used. This is explained in more detail in section 7.5.5.

N_2O emissions from category 5D (see Tables 7.1 and 7.9) contributed about 7.5 % of total N_2O emissions in 2022 and 0.3% in total CO_2 equivalent emissions. In the 1990–2022 period, N_2O emissions from domestic wastewater treatment (5D1) increased by 13%, while N_2O emissions from industrial wastewater treatment (5D2) decreased by 9%. Indirect N_2O emissions from surface waters (5D3) decreased by 69%. Overall, the N_2O emissions from category 5D decreased by 8%.

The contribution made by 5D Wastewater handling to national total CH_4 emissions in 2022 was 1.2%, or 0.14% of total GHG emissions in CO_2 equivalents. Since 1994, CH_4 emissions from public WWTPs have decreased due to the 1990 introduction of a new sludge stabilisation system in one of the largest WWTPs. As the operation of the plant took a few years to optimise, venting emissions were higher in the introductory period (1991–1994) than under subsequent normal operating conditions. During the 1990–2022 period, CH_4 emissions from category 5D wastewater handling decreased by 49%. The amount of wastewater and sludge being treated has not changed much over time. Therefore, the annual changes in methane emissions can be explained by varying fractions of methane being vented incidentally instead of flared or used for energy purposes. It should be noted that non-CO_2 emissions from the combustion of biogas at wastewater treatment facilities are allocated to category 1A4 (Fuel combustion – other sectors) because this combustion is partly used for heat or power generation at the treatment plants.

Table 7.9 presents the trend in GHG emissions from the various types of wastewater handling.

Table 7.9 Wastewater handling emissions of CH_4 and N_2O (Gg/year)

	1990	2000	2010	2015	2020	2021	2022
CH_4 domestic WWTP1)	5.84	4.36	4.69	4.45	4.78	4.69	4.66
CH_4 industrial WWTP	0.29	0.39	0.38	0.38	0.41	0.41	0.41
CH_4 septic tanks	3.93	1.99	0.68	0.63	0.52	0.46	0.41
Indirect CH_4 from effluents	4.99	3.14	2.46	2.22	2.32	2.34	2.18
Net CH_4 emissions	15.05	9.88	8.21	7.69	8.03	7.90	7.65
CH_4 recovered2) and/or flared	33.0	40.6	40.0	44.4	47.3	47.9	42.4
N_2O domestic WWTP	1.41	1.46	1.52	1.54	1.62	1.62	1.60
N_2O industrial WWTP	0.13	0.13	0.09	0.11	0.11	0.11	0.12
Indirect N_2O from effluents	0.501	0.302	0.174	0.168	0.167	0.167	0.156
Total N_2O emissions	2.04	1,89	1.79	1.82	1.90	1.90	1.87

1) Including emissions caused by venting of biogas at public WWTPs.
2) Includes use for energy purposes on site at public WWTPs and/or flared, so excludes CH_4 in external delivered biogas and in vented amounts.

This sector comprises the following key category:

5D Wastewater treatment and discharge N_2O

7.5.2 *Methodological issues*

Activity data and EFs

Most of the activity data on domestic wastewater treatment is collected by Statistics Netherlands via annual questionnaires that cover all public WWTPs and is presented in StatLine (Statistics Netherlands, 2023); see also Statline for detailed statistics on wastewater treatment. Table 7.10 outlines the development in the main activity data with respect to domestic wastewater treatment.

Data on anaerobic and aerobic industrial WWTPs also stems from Statistics Netherlands (Statistics Netherlands, 2018) but the time series only covers the 1990-2016 period. The years 2017-2022 are reconstructed as much as possible, using information from mainly company websites on the internet and a pilot survey among a selection of companies that provide data in the Annual Environmental Reporting system, conducted in 2023. However, most of the data is copied from 2016. In 2024, as a follow-up of the pilot survey, a new integral survey via an AER reporting module will result in actual timely data on the population of industrial WWTPs for the year 2023. On the basis of these new results, the data on 2017-2022 will be reconstructed in the next submission of the NIR.

Due to varying weather conditions, the volumes of treated wastewater and of the total load of DOC and total nitrogen of domestic wastewater can fluctuate

from year to year, depending on the amount of run-off rainwater that enters the sewerage systems. In the method developed for calculating methane emissions of domestic WWT, the DOC (or total organics in wastewater, TOW) is based on an organic load expressed in terms of chemical oxygen demand (COD). In the calculation of the COD of sewage sludge, the average content of 1.4 kg COD per kg organic dry solids is used (STOWA, 2014). Organic dry solids weights are determined by measurements of sewage sludge at all public WWTPs.
Nitrogen loads in the incoming wastewater of domestic WWTPs are determined by measurements at all WWTPs. This is already a longstanding standard procedure and covers the whole 1990-2021 time series. All this data has been collected by Statistics Netherlands.

It can be concluded from Table 7.10 that in the last years, the DOC of treated domestic wastewater and sludge produced has shown minor fluctuations over time. In 2022, methane emissions from domestic WWTPs decreased by 0.5% compared to 2021. Interannual changes in CH_4 emissions can often be explained by varying fractions of CH_4 being vented instead of flared or used for energy purposes.

Emissions from the source category Septic tanks have steadily decreased since 1990. This can be explained by the increased number of households connected to the sewerage system in the Netherlands (and therefore no longer using septic tanks; see Table 7.10).

Total direct discharges of N have also decreased steadily, due to improved wastewater treatment and prevention measures.

Detailed information on activity data and EFs can be found in section 2.3.2.4 in Honig et al. (2024).

Table 7.10 Activity data on domestic and industrial wastewater handling and discharges to surface water

Domestic (urban) WWTPs:

	Unit	1990	2000	2010	2015	2020	2021	2022
Domestic (urban) WWTPs:								
Treated volume	Mm^3/yr	1,711	2,034	1,934	1,957	1,938	1,964	1,808
TOW as COD[1)] load	Gg/year	933	921	953	999	1,056	1,040	1,011
Nitrogen load	Gg/year	81.4	84.7	87.9	89.1	93.7	93.6	92.4
Sludge DOC as COD[1)2)]	Gg/year	365	431	476	505	533	529	503
Sludge dry solids to digesters	Gg/year	246	285	327	351	400	408	407
Biogas recovered [3)]	mio m^3/yr	74	87.9	98.5	107	130	137	132
Biogas flared	mio m^3/yr	8.96	6.15	7.36	7.41	9.79	10.4	6.97
Biogas vented	1,000 m^3/yr	2,524	284	1,066	82.3	131	81.1	78.5
Actual PE load WWTP[4)]	1,000	23,798	23,854	24,745	25,686	27,031	26,798	26,179

Industrial WWTPs:

	Unit	1990	2000	2010	2015	2020	2021	2022
TOW as COD[1)] anaerobic WWTPs	Gg/year	144	194	192	190	206	208	203
Biogas recovered[3)]	Mio m^3/year					78.7 [5)]	77.5 [5)]	85.2 [5)]
Nitrogen load to aerobic WWTPs	Gg/year	7.42	7.26	5.46	6.61	6.53	6.53	6.78

Septic tanks:

	Unit	1990	2000	2010	2015	2020	2021	2022
Resident population [6)]	1,000	14,952	15,926	16,615	16,940	17,442	17,533	17,704
inhabitants with septic tank	% of pop.	4	1.9	0.62	0.57	0.45	0.40	0.35

Discharges to surface water:

	Unit	1990	2000	2010	2015	2020	2021	2022
Nitrogen discharges[7)], total	Gg/yr	63.79	38.45	22.13	21.35	21.281	21.285	19.87
- Via effluents from UWWTP[8)]	Gg/yr	42.68	30.44	17.69	17.05	16.96	17.006	15.58
- Via industrial discharges[9)]	Gg/yr	12.71	4.51	2.36	2.29	2.02	2.07	2.07
- Via other direct discharges[10)]	Gg/yr	8.40	3.51	2.07	2.01	2.30	2.22	2.22
COD discharges, total	Gg/yr	178	112	87.8	79.2	83.0	83.7	77.78
- Via effluents from UWWTPs	Gg/yr	131	91.0	75.5	69.8	72.3	72.5	67.2

	Unit	1990	2000	2010	2015	2020	2021	2022
- Via industrial discharges	Gg/yr	46.8	21.1	12.3	9.48	10.7	11.1	10.5

1) Chemical oxygen demand.
2) Primary and secondary sludge produced, before eventual sludge digestion.
3) Sum of measured biogas, total for energy conversion, flaring, venting and external deliveries.
4) PE = Pollution Equivalents, representing the total load of biodegradable substances in the mixture of domestic and industrial wastewater treated in urban WWTPs (UWWTPs).
5) Total amount of biogas recovered; partly estimated.
6) Average population over a year.
7) Sum of domestic and industrial discharges of N in wastewater to surface water.
8) Including discharges from combined sewer overflows and storm water sewers.
9) All direct discharges of companies to surface waters.
10) Direct discharges of households, agricultural companies and traffic activities.

CH_4 emissions from domestic wastewater treatment (5D1)
In 2022, 99.7% of the population was connected to closed sewer systems, which were in turn connected to 313 public WWTPs. All public WWTPs in the Netherlands are of the advanced aerobic treatment type, with nutrient removal steps. In addition, sludge digestion is carried out in the larger plants. In these plants, sludges from smaller plants (in the vicinity) are digested also.

For the category 5D1 (Domestic wastewater treatment), CH_4 emissions from three types of processes are calculated:

1. Wastewater treatment process emissions: small amounts of methane can be formed during certain wastewater treatment process steps and, for example, there can be small emissions from the influent cellars, anaerobic zones created for phosphorus removal, and anaerobic pockets in zones with poor aeration.
2. Anaerobic sludge digestion emissions: in addition to the methane recovered and used for energy processes, uncontrolled CH_4 emissions can arise from sludge digestion process equipment.
3. Emissions from incidental venting of biogas: the incidental venting of biogas produced in anaerobic sludge digesters is also a source of CH_4 emissions.

Detailed information on activity data and EFs can be found in sections 2.3.2.4.2 and 2.3.2.4.3 of Honig et al. (2024). The calculation of emissions from these processes is summarised below.

1. Wastewater treatment process emissions
Methane emissions from the wastewater treatment process are calculated using a Tier1 method with the default emission factor and country-specific activity data. The default emission factor for centralised aerobic treatment is 0.0075 kg CH_4/kg COD and is now based on the B_0 and MCF from the 2019 Refinement to the 2006 IPCC Guidelines (IPCC, 2019).

The country-specific activity data on the influent COD, as well as the amounts of sludge produced in all public WWTPs, are derived from the annual survey conducted by Statistics Netherlands among the Water Boards, and are based on monitoring at the WWTPs following strict procedures. For the years from 1990 until present, data on influent COD is available for each treatment plant.

Data on the sludge produced annually is available for the years 1990 until 2016, and for 2018 and 2020. Due to a re-evaluation of the statistical programme, this data has only been inventoried for even years from 2016 onwards. For odd years (starting 2017), the data from the previous year is used as a best estimate; see also section 2.3.2.4.2 of Honig et al. (2024).

The COD of sludge is calculated using the conversion factor 1.4 kg COD per kg organic solids (STOWA, 2014). Organic solids are calculated as total dry solids minus the inorganic fraction. The total dry solids are measured at each public WWTP; the inorganic fraction is calculated on the basis of measurements of the ash content.

Table 7.10 gives the time series of the values of influent COD, organic solids weight of sludge, and sludge COD.

2. Anaerobic sludge digestion emissions
Emissions of CH_4 from anaerobic sludge digestion are re-calculated for the whole time series using the default TIER 1 method from the 2019 Refinement (IPCC, 2019) and are based on an EF per kg dry solids of ingoing sludge of the digesters, being 0.002 kg CH_4/kg ingoing dry solids. The emissions are calculated per WWTP with sludge digestion facilities. In 2021, 67 urban WWTPs (UWWTPs) were equipped with sludge digesters. See also section 2.3.2.4.2 of Honig et al. (2024).

Default activity data on the ingoing dry solids amount at public WWTPs with sludge digesters is derived from the annual survey conducted by Statistics Netherlands among the Water Boards.

3. Emissions from incidental venting of biogas
Incidental venting of biogas at public WWTPs is recorded by the plant operators and reported to Statistics Netherlands. In 2022, the amount of CH_4 emitted by the venting of biogas was 0.0335 Gg CH_4, equalling 0.7% of total CH_4 emissions from the category Domestic wastewater. In the last decade, this value ranged between 0.3% and 9%, so the venting of biogas in 2021 was relatively low.

Recovered biogas is largely used for energy generation purposes, but a small amount is flared, vented, or delivered to third parties. Table 7.10 provides data on the recovery of CH_4 (total) and CH_4 combusted via flaring. See also section 2.3.2.4.3 of Honig et al. (2024).

CH_4 emissions from anaerobic industrial wastewater treatment (5D2)
For industrial WWTP, the calculation of the methane emissions has not yet changed as a result of adopting the 2019 refinement methods. The first reason is that there were not enough resources to recalculate the various wastewater emissions at one time in one inventory year. The second, but more important, reason is that in 2023, new updated activity data on industrial WWTPs would become available, making it possible to reconstruct the population of IWWTPs between 2016 and 2021. This is postponed to the next submission, as the data is not yet available. When more accurate data on COD in influent wastewater is available, it will be possible to switch to the methodology of the 2019 Refinement.

In the calculation of methane emissions from anaerobic industrial wastewater treatment, the Netherlands thus still uses country-specific activity data for the TOW, as well as a country-specific fraction for losses of methane by leakage. Recovered biogas is generally used as fuel in energy processes. Emissions from biogas combustion are included in the Energy sector. A more detailed description of the method and the EF used can be found in section 2.3.2.4.5 in Honig et al. (2024).

In the Netherlands, no information is available on the actual load of COD treated in the IWWTPs. The TOW has thus to be determined in an alternative way. The TOW is estimated by using statistics on the design

capacity of the IWWTPs and an assumed average loading rate of 80% of the design capacity (Oonk, 2004). The design capacity is expressed in terms of a standardised value for quantifying organic pollution in industrial wastewater: Pollution Equivalents (PE). One PE equals an amount of 40 kg COD per year. Data on the design capacity is available from Statistics Netherlands (2018). TOW (expressed as COD) is thus calculated as:
TOW = P.E. * 0.8 * 40
Where:
P.E. = total design capacity in Pollution Equivalents
0.8 = average loading rate (80%)
40 = kg COD per P.E. per year (factor to calculate from P.E. to COD).

Using the default maximum CH_4 producing capacity (B_o) of 0.25 kg CH_4/kg COD, a default Methane Conversion Factor of 0.8 and a methane loss (Mrind) of 1% from the digestion process, the Emission Factor is calculated as B_o * MCF * Mrind= 0.002 kg CH_4/kg COD. A further description of the method and the EF used can be found in section 2.3.2.4.5 in Honig et al. (2024).
Table 7.10 provides the time series of total TOW for IWWTPs.

In 2017, the inventory on industrial wastewater treatment was discontinued. Information on existing anaerobic WWTPs is no longer updated on a regular basis. As already addressed above, in 2023 a pilot survey resulted in partly actual data on the population of industrial WWTPs for the year 2022. In 2024, an integral survey will be rolled out as part of the Annual Environmental Reporting system. On the basis of these new results, the population IWWTPs for 2017-2023 will be reconstructed.

In 2022, 66% of the anaerobic capacity was installed in the food and beverage industry. Other sectors with anaerobic wastewater treatment are waste processing facilities (15%), the chemical industry (13%), and the paper and cardboard industry (6%).

Numerical estimate of the recovered CH_4 in anaerobic industrial wastewater treatment plants available for 2019-2022
In response to a 2016 review question, we investigated whether the data on biogas production from industrial anaerobic wastewater treatment plants can be derived or estimated from information becoming available via the individual Annual Emission (e-PRTR) Reports. This could only be carried out for 2019, 2020, 2021 and 2022 (see also Table 7.10).

The total amount of IWWTP biogas recovered in 2022 equalled 60.9 million m^3, but this only includes data from 29 out of the 51 anaerobic IWWTPs, equalling 71% of total TOW treated. For the remaining 22 plants, no data is available, but on the basis of the amount of TOW, this missing volume can be estimated at an additional 24.3 million m^3. Total recovery can then be estimated at 85.2 million m^3 biogas.

No specific information is available on the methane content of biogas from anaerobic industrial wastewater treatment plants. If we use the average value for biogas from domestic wastewater sludge digestion

(0.44 kg CH_4/m^3 biogas, see Honig et al., 2024), a total recovery of 37.5 Gg CH_4 can be calculated for 2022. Applying a loss by leakage of 1% of total CH_4 recovered (Honig et al., 2024), this results in an emission of 0.375 Gg CH_4. This figure can be compared with the current CS method, resulting in an emission of 0.411 Gg CH_4 (9% higher). Given the uncertain factors of both methods, this difference is acceptable.

The methane (CH_4) implied emission factor (IEF) is based on gross CH_4 emissions and is calculated as follows: IEF = Gross CH_4 emission (= Net CH_4 emission + CH_4 recovered or flared) / total organic product. For the years 1990-2018, there is no data on the CH_4 recovery, resulting in a relatively low IEF. But from 2019 onwards, availability of data on CH_4 recovery has caused a higher numerator in the calculation of the IEF and thus a higher IEF.

CH_4 emissions from septic tanks (5D3)
Emissions of methane from septic tanks are calculated using IPCC default values for B_0 and MCF and the IPCC value of TOW of 60 g BOD (biological oxygen demand) per connected person per day (IPCC, 2006: Table 6.4). Detailed information on activity data and EFs can be found in section 2.3.2.4.4 of Honig et al. (2024).

Table 7.10 presents the time series of the percentage of the population connected to septic tanks. This percentage decreased from 4% in 1990 to 0.30% in 2022. This data derives from surveys, estimates and expert judgement by various organisations in the Netherlands, such as Rioned, (2009, 2016), WHO (2023) and the National Water Authorities.

Indirect CH_4 emissions from surface water as a result of discharge of domestic and industrial effluents (5D3, Wastewater effluents)
Indirect methane emissions from surface water as a result of discharge of domestic and industrial effluents are calculated using the Tier 1 default emission factor of 0.028 kg CH_4/kg COD discharged as provided in the 2019 Refinement of the IPCC 2006 Guidelines (IPCC, 2019).

The country-specific activity data on kg COD discharged per year via industrial and domestic effluents is derived from the wastewater statistics (see Statline) and from the Netherlands' PRTR database. These COD loads to surface water are based on frequent monitoring of all domestic WWTPs and of all industrial discharges. Detailed information on the method and activity data can be found in section 2.3.2.4.8 of Honig et al. (2024).

N_2O emissions from centralised wastewater treatment (5D1)
N_2O emissions from domestic wastewater handling are recalculated by means of new methodology provided by the 2019 Refinement (IPCC, 2019). The Tier 2 method uses an adjusted emission factor of 0.011 kg N_2O-N/kg N (De Haas & Andrews, 2022) and country-specific activity data on the total influent loads of nitrogen at all domestic WWTPs in the Netherlands. The activity data derives from the wastewater statistics (see Statline) and is based on frequent monitoring of the incoming wastewater at all domestic WWTPs. Detailed information on the method and activity data can be found in section 2.3.2.4.2 of Honig et al. (2024).

The influent data on total nitrogen includes the loads from households, from industrial and commercial activities as well as the loads from urban run-off into the sewerage system. In equation 6.10 from the 2019 Refinement document, the total nitrogen load in the influent can thus replace all the terms in the right part of the equation. Table 7.10 provides a time series of total nitrogen load of the influent. In 2022, total nitrogen in the influent equalled 92.4 million kg N.

As wastewater treated at public WWTPs is a mixture of household wastewater, (urban) run-off rainwater and wastewater from industries and services, the N_2O emissions are reported under category 5D1 (Domestic and commercial wastewater). Moreover, as the Netherlands does not make use of equation 6.10, information on population, protein consumption, fraction of nitrogen in protein, FNON-CON, FIND-COM and TPLANT values are reported as 'NA' in the additional information table of CRF Table 5.D.

N_2O emissions from aerobic industrial wastewater treatment (5D2)

For the calculation of N_2O emissions from aerobic industrial wastewater treatment, a Tier1 method is used on the basis of an adjusted emission factor of 0.011 kg N_2O-N/kg N (De Haas & Andrews, 2022) and country-specific activity data on the total influent loads of nitrogen at all industrial aerobic WWTPs in the Netherlands.

The activity data stems from a time series of aerobic industrial wastewater plants derived from statistics on industrial wastewater sludges (see Statline), as well as from data on total nitrogen discharged from the Dutch PRTR database. For most of the IWWTPs an effluent load could be coupled. For the remaining installations, the effluent load was estimated on the basis of the size of the plant and derived estimators like total nitrogen discharged per population equivalent design capacity. Subsequently, influent nitrogen loads were estimated using the default removal rate of 0.40 for secondary treatment, as provided by Table 6.10.c in the 2019 Refinement document. A more detailed description of the method, the EF used as well as the activity data can be found in section 2.3.2.4.6 of Honig et al. (2024).

Indirect N_2O emissions from surface water as a result of discharge of domestic and industrial effluents (5D3, Wastewater effluents)

For the calculation of indirect (or better: 'delayed') N_2O emissions from wastewater effluents, the Netherlands uses the default EF of 0.005 kg N_2O-N/kg N discharged (IPCC, 2019) and country-specific activity data on $N_{Effluent,DOM}$.

The country-specific activity data on kg N discharged per year via industrial, domestic and commercial effluents is derived from the wastewater statistics (see Statline) and from the Netherlands' PRTR database (regarding both sources: 2022 data is not yet published). Most of the effluent loads of total nitrogen are determined by frequent monitoring of treated wastewater flows or – in the case of discharges from sewer overflows – estimated with a model. In equation 6.8 (updated) of the 2019 Refinement document, the total nitrogen load in the effluents can thus replace all the terms in the right part of the equation.

As the Netherlands does not make use of the right part of equation 6.8 and related equation 6.10, information on population, protein consumption, fraction of nitrogen in protein, FNON-CON, FIND-COM and TPLANT values are reported as ‘NA’ in the additional information table of CRF Table 5.D.

Detailed information on the method used can be found in section 2.3.2.4.7 in Honig et al. (2024). Table 7.10 provides a time series of the activity data: total N discharges.

Emissions not calculated within category 5D
Within category 5D the following emissions are not estimated (NE) or not occurring (NO):

Direct N_2O emissions from septic tanks (5D3: NO)
Direct emissions of N_2O from septic tanks are not calculated since they are unlikely to occur, given the anaerobic circumstances in these tanks. Indirect N_2O emissions from septic tank effluents are included in CRF category 5D3 (Indirect N_2O emissions from surface water as a result of discharge of domestic and industrial effluents).

CH_4 emissions from industrial sludge treatment (5D2: NE)
From a recent survey among IWWTPs conducted by Statistics Netherlands in 2016, it can be concluded that anaerobic sludge digestion within industries is applied at only 2 industrial WWTP. This data has not been published on www.cbs.statline.nl for reasons of confidentiality.
Via a rough estimate, it was calculated that the methane emissions from this source amounts to approximately 6.2 tons of CH_4 per year, equalling 0.00085% of national methane emissions in 2016. Forthcoming CH_4 emissions are therefore reported as NE for 1990-2022.

7.5.3 Uncertainty and time series consistency

Uncertainty
The uncertainty analysis in Annex 2 provides estimates of uncertainties by IPCC source category and gas that are based on error propagation. The uncertainty in annual N_2O and CH_4 emissions from wastewater handling is estimated to be 23% and 40%, respectively.

The uncertainty in activity data for domestic WWT is based on expert judgement (Ramirez, 2006) and is estimated to be 25%. The annual loads of $DOC_{influent}$, DOC_{sludge} $N_{influent}$ and $N_{effluent}$ are calculated on the basis of wastewater and sludge sampling and analysis, as well as flow measurements at all the WWTPs; all these measurements can involve uncertainty.
For industrial WWT the uncertainty in activity data is based on IPCC (2019) and is estimated to be 30%.

The uncertainty in the EFs for CH_4 differs per type of emission source and is estimated to be between 32% and 300% IPCC (2019). For N_2O, the uncertainty also varies per emission source and is estimated to be between 15% and 100% (IPCC, 2019; De Haas & Andrews, 2022).

An international study (GWRC, 2011), in which the Dutch public wastewater sector participated, showed that N_2O EFs, in particular, are highly variable between WWTPs as well as at the same WWTP during different seasons or even at different times of day. Moreover, the same study concluded that the use of a generic EF (such as the IPCC default) to estimate N_2O emissions from an individual WWTP is inadequate. The study provides no alternative method, however, except the recommendation that GHG emissions from an individual WWTP can only be determined on the basis of continuous measurements over the whole operational range of the WWTP (GWRC, 2011). The results of this study, therefore, provide no starting point from which to improve the method for estimating CH_4 and N_2O emissions and the related uncertainty.

Time series consistency
The same methodology has been used to estimate emissions annually, providing good time series consistency. The time series consistency of the activity data is very good, due to the continuity in the data provided by Statistics Netherlands.

7.5.4 *Category-specific QA/QC and verification*

The source categories are covered by the general QA/QC procedures, as discussed in Chapter 1. Statistical data is covered by the specific QA/QC procedures of Statistics Netherlands (CBS).

For annual CH_4 and N_2O emissions from domestic and commercial wastewater handling, the (GWRC, 2011) study neither supports nor rejects the use of current methods (see also section 7.5.3). The Dutch wastewater sector will continue research into more precisely determining the factors and circumstances that result in the formation of CH_4 and N_2O in public WWTPs.

7.5.5 *Category-specific recalculations*

For category **5D1 (domestic wastewater handling)** and **5D2 (industrial wastewater handling)** a major change was introduced for the whole 1990-2022 time series: For the calculation of N_2O emissions from aerobic industrial wastewater treatment, an adjusted emission factor of 0.011 kg N_2O-N/kg N (De Haas & Andrews, 2022) was introduced. This EF is an improved factor, taking into account more recent measurements at UWWTPs and revisiting the data used to calculate the IPCC default value of 0.016 kg N_2O-N/kg N. Compared to the previous submission, this results in a 31.3% decrease in the N_2O emissions from 5D1 as well as 5D2, for the whole 1990-2021 period.

Apart from the above-mentioned major changes, there were also some smaller recalculations due to final or revised activity data.
In 2021, the indirect N_2O emissions from surface water as a result of the discharge of domestic and industrial effluents (5D3. Wastewater effluents) increased by 0.00003 Gg N_2O (+0.02%) compared to the previous submission.
Due to a revised estimate of the % of inhabitants connected to septic tanks for 2020 and 2021, the CH_4 emission from septic tanks decreased by 0.046 Gg CH_4 (-9%) in 2020 and by 0.092 Gg CH_4 (-20%) in 2021.

7.5.6 *Category-specific planned improvements*

Category-specific improvements are planned for the next submission. For methane emissions from industrial anaerobic wastewater treatment, revised activity data will become available; also, the methodology of the 2019 refinement will be introduced for this source.
Regarding indirect emissions of CH_4 from surface waters as a result of discharge of wastewaters, it still has to be investigated whether a distinction between types of surface water (stagnant waters versus rivers) can be introduced to the method. Depending on available resources, this is planned for the next submission.

8 Other (CRF sector 6)

The Netherlands allocates all GHG emissions to sectors 1 to 5. Therefore, no sources of GHG emissions are included in sector 6.

9 Indirect CO_2 emissions

9.1 Description of sources

Methane, carbon monoxide (CO), and NMVOC emissions are oxidised to CO_2 in the atmosphere. This chapter describes indirect CO_2 emissions as a result of this atmospheric oxidation.

As the Netherlands already assumes 100% oxidation during the combustion of fuels, only process emissions of NMVOC (mainly from product use) are used to calculate indirect CO_2 emissions. These process emissions originate from the use and/or evaporation of NMVOC in the following sectors:

1. Energy (Energy, Traffic and transport, and Refineries).
2. IPPU (Consumers, Commercial and governmental institutions, Industry, and Construction and building industries).
3. Agriculture. Indirect CO_2 emissions from agriculture originate from NMVOC in pesticides. These emissions are accounted for in the CRF under ‘other product use’ (2. IPPU).
5. Waste.

Indirect CO_2 emissions decreased from 0.9 Tg in 1990 to 0.5 Tg in 2022, mainly as a result of the Dutch policy to reduce NMVOC emissions.

The source category 6 Indirect emissions (CO_2) is a key category.

Table 9.1 Overview of Indirect CO_2 emissions in the base year and the last two years of the inventory

Sector/category	Gas	1990	2021	2022	2022 vs 1990	Contribution to total in 2022 (%) by		
		Emissions in Tg CO_2-eq			%	sector	total gas	total CO_2-eq
Indirect CO_2 emissions	CO_2	0.9	0.5	0.5	-50.1%	3.0	0.3%	0.3%

9.2 Methodological issues

Indirect CO_2 emissions are calculated as follows:
*CO_2 (in Gg) = NMVOC emission (in Gg) * C * 44/12*

Where:
C = default IPCC carbon content (C) of 0.6

NMVOC emissions data per sector is obtained from the Dutch PRTR.

9.3 Uncertainty and time series consistency

On the basis of expert judgement, the uncertainty in NMVOC emissions is estimated at c. 25% and the uncertainty in carbon content at 10%, resulting in an uncertainty in CO_2 emissions of approximately 27%. Consistent methodologies and activity data have been used to estimate indirect CO_2 emissions.

9.4 Category-specific QA/QC and verification

The source categories are covered by the general QA/QC procedures discussed in Chapter 1.

9.5 Category-specific recalculations

There have been no category-specific recalculations.

9.6 Category-specific planned improvements

No improvements have been planned.

10 Recalculations and improvements

Major recalculations and improvements compared to the National Inventory Report 2023

For the NIR 2024, the most recent data (2022) has been added to the inventory and corresponding Common Reporting Format (CRF).

As a result of recommendations of the 2022 submission from the internal and external reviews (UNFCCC and EU), improvements have been made to both the inventory and the NIR.

Recalculations have been performed as a result of changes of method and/or on the basis of new, improved activity data, and/or improved EFs.
Furthermore, error corrections were performed of the data in the previous submission, resulting in changes in emissions over the entire 1990–2021 period.

For details of the effects of and justification for the recalculations, see Chapters 3–8.

10.1 Explanation of and justification for the recalculations in the GHG emissions inventory

For the NIR 2024, the Netherlands used the CRF Reporter software v6.0.10_AR5.

Previous ERT reviews of the UNFCCC and the EU review reports suggested there was still room for improvement in the Dutch GHG inventory. Where possible (and deemed necessary), the review recommendations have been incorporated in this NIR and CRF, and accordingly, in the methodology reports.

The UNFCCC review issues are listed in Annex 10, including the actions undertaken to resolve them.

Besides these externally induced improvements, additional improvements have been made as a result of our own QA/QC programme:

- methodological changes and data improvements;
- changes in source allocation;
- error corrections.

Methodological changes and data improvements

The improvements to QA/QC activities in the Netherlands implemented in recent years (process of assessing and documenting methodological changes) are still in place. This process includes a brief checklist for timely discussion on proposed changes for the 2024 inventory with relevant experts and information users (among others, policy makers). This process improves the peer review and timely documentation of the background to and justifications for changes made in the current inventory.

The most significant recalculations in this submission (compared to the NIR 2023) are:

- *Energy sector:*
  - As in every year, the inventory follows all changes/improvement in the national energy statistics affecting the emissions of CO_2, CH_4 and N_2O. Major changes in energy consumption and allocation were implemented for the years 2015 -2021. These changes also induced changes in plant-specific EFs.
  - In response to review recommendation (E.2, 2022) and in line with the IPCC 2006 Guidelines (vol. 3, Chapter 1, box 1.1 and vol. 3, Chapter 3.9.4.2), the emissions from the combustion of chemical waste gas and phosphor oven gas have been reallocated from 1A2c to 2B10. This results in a reduction of emission in 1A2c (in Gg) (see section 3.2.5.5).
  - In 2023, the allocation of the total gasoline and diesel use in traffic and transport has been adapted on the basis of updated data on transport performance.
  - Improved fuel data for 2021 in Agriculture came available.
  - Data on fleet composition in NRMM has been improved (also for historical years) and the N_2O emission factors have been adapted for diesel fuelled equipment with SCR. The latter significantly increased the N_2O emissions from NRMM in recent years, especially in 1.A.4.
  - The CO_2, CH_4 and N_2O emissions from transport and NRMM changed (categories 1.A.2 to 1.A.4) due the above improvements over the total time series.

The above recalculations and error correction changed the total CO_2-eq emissions in the Energy sector by -3.5% in 1990 to -5.5% in 2021 compared to previous submission.

- *IPPU sector:*
  - In response to review recommendation (E.2, 2022) and in line with the IPCC 2006 Guidelines (vol. 3, Chapter 1, box 1.1 and vol. 3, Chapter 3.9.4.2), the emissions from combustion of waste gases occurring within the same source category are now allocated to CRF 2B10. This includes chemical waste gas and phosphor oven gas emissions combusted in the chemical industry (see section 4.1).
  - Due to improvement in the energy statistics the emission from lubricant use (2D) changed compared to the previous submission.
  - Improved activity data for fireworks affecting category 2G.
  - The same holds for the urea use in transport (2005-2021), also reported in 2D3.
  - Error corrections for PFC and HFC emissions.

The above recalculations changed the total CO_2-eq emissions in the IPPU sector by less than +28% in 1990 to 89% in 2021 compared to previous submission.

- *Agriculture sector:*
  - Bedding material has been added to the calculations resulting in higher N_2O emissions throughout the time series from manure management (3B) and crop production (3D).
  - The N_2O emissions related to losses/gains in soil organic matter content have been added to the time series.
  - The N_2O emissions from manure treatment of veal calves has been calculated on the basis of the annual TAN excretion instead of a fixed value.
  - For the years 2018-2022, the N content of manure sent to treatment facilities has been based on the mandatory transport certificates instead of on defaults. This affects N_2O and CH_4 emissions from manure treatment.
  - The N_2O emissions from crop residues (3Da4) have been recalculated for the entire time series. The area of mown grasslands changed due to the inclusion of mown natural grasslands as well as the shift to the agricultural census instead of the grassland survey.
  - Final usage rates of inorganic fertilisers, compost, liming and urea differ from the preliminary rates. This affects the N_2O emissions from Agricultural soils (3D), Liming (3G) and Urea application (3H).

The above recalculations changed the total CO_2-eq emissions in the Agriculture sector by +0.30 % in 1990 and by +0.28 % in 2021 compared to previous submission.

- *LULUCF sector:*
  - This year, four methodological changes have been implemented, resulting in modifications to the carbon stock changes and associated emissions and removals along the time series:
    - Spatially explicit input data on soil management for the years 1990-2004 is introduced in the Tier 3 model (RothC) to calculate carbon stock changes in mineral soils in Cropland and agricultural grasslands. This data was previously missing.
    - Changes were implemented regarding the build-up of carbon stock in litter on Land converted to forest land.
    - A Tier 1 methodology was implemented to calculate CH_4 emissions from reservoirs, fresh-water ponds, canals, and ditches (>3m wide) created since 1900.
      Lastly, new data for Forest land has been incorporated, the reference years for the NFI data were updated accordingly, and new country-specific data on carbon content in litter in forest land was applied to convert litter thickness to litter carbon stocks.

The above recalculations changed the total CO_2-eq emissions in the LULUCF sector by -13.9% in 1990 and by +1.7 % in 2021 compared to previous submission.

- *Waste sector:*
    - Compared to the previous submission, the introduction of an annually calculated DOC_f factor caused lower methane emissions in category 5A. From 2005 onwards, emissions of methane are lower compared to previous submissions.
    - For category 5D1 (domestic wastewater handling) and 5D2 (industrial wastewater handling) a major change was introduced for the whole 1990-2022 time series: For the calculation of N_2O emissions from aerobic industrial wastewater treatment, an adjusted default emission factor of 0.011 kg N_2O-N/kg N (De Haas & Andrews, 2022) was introduced.

The above recalculations changed the total of CO_2-eq emissions in the Waste sector by -1.1% in 1990 and by -11 % in 2021 compared to previous submission.

Additional to the above changes, small changes in emissions occur every year (compared to the previous submission) due to the availability of final statistics for activity data (for this submission, in 2021 and in some cases, earlier years).

The total changes in GHG emissions per sector compared to the previous submission are presented in Table 10.1 (in Gg CO_2-eq) for the years 1990, 2000, 2010, 2020 and 2021. Positive values represent recalculations, which increased the emissions compared to the 2023 submission and negative values represent decreased emissions in the 2024 submission.
Recalculations in the Energy, IPPU, LULUCF and Waste sectors dominate the changes in the National emissions compared to the 2023 submission.

The decrease in total GHG emissions is for all years is below -0.5 % GHG compared to the 2023 submission.

Table 10.1 Summary of recalculations for the 1990–2021 period (Gg CO_2-eq)

Gas(es)		1990	2000	2010	2020	2021
CO_2, CH_4, N_2O	1.A.1 Energy Industries	0.0	0.0	0.0	0.4	20.3
CO_2, CH_4, N_2O	1.A.2. Manufacturing industries and construction	-5,613.0	-4,124.8	-7,749.1	-7,541.5	-7,413.9
CO_2, CH_4, N_2O	1.A.3. Transport	-38.7	-40.4	-39.7	26.4	111.0
CO_2, CH_4, N_2O	1.A.4. Other sectors	56.9	-106.3	-210.1	-82.2	-323.7
CO_2, CH_4, N_2O	2.B. Chemical industry	5,712.1	4,184.3	7,913.4	7,599.7	7,444.0
CO_2	2.C. Metal industry	0.0	0.0	0.0	0.0	-64.6
CO_2, CH_4	2.D. Non-energy products from fuels and solvent use	0.4	0.2	15.9	-3.5	-3.9
CO_2, CH_4, N_2O	2.G. Other product manufacture and use	-0.5	-0.2	-1.2	-5.1	-1.8
PFC	2.E.1. Integrated circuit or semiconductor	-0.7	-7.9	-9.4	-3.5	-7.1
HFC	2.F.1. Refrigeration and air conditioning	0.0	0.0	0.0	-13.3	-13.3
HFC	2.F.6. Other applications	0.0	0.2	0.1	0.0	0.0
CH_4, N_2O	3.B Manure management	3.2	4.6	1.0	-1.9	-2.6
N_2O	3.D Agricultural soils	71.4	96.0	107.7	58.6	48.5
CO_2	3.G Liming	0.0	0.0	0.0	0.0	1.5
CO_2	3.H Urea application	0.0	0.0	0.0	0.0	3.3
CO_2, CH_4, N_2O	4 LULUCUF	-863.9	-309.5	330.3	184.0	73.9
CH_4	5.A Solid waste disposal	0.0	0.0	-87.0	-154.9	-170.9
CH_4, N_2O	5.D Waste water Handling	-185.6	-191.1	-194.3	-209.6	-210.9
Total Difference		**-858.3**	**-494.9**	**77.5**	**-146.4**	**-509.7**
	*Total emissions NIR 2023 **	228,935	225,681	219,790	168,929	171,969
	Total emissions NIR 2024*	***228,077***	***225,186***	***219,868***	***168,783***	***171,459***

*: including LULUCF and indirect CO_2 emissions

Changes in source allocation
Changes in the source allocation of secondary fuels (from the energy sector to the IPPU sector) as requested in the latest review are now implemented and are the main reason for the CO_2 changes in these sectors compared to the previous submission.

10.2 Implications for emissions levels GHG emissions inventory

This section summarises the implications of the changes described in Section 10.1 for the emissions levels reported in the GHG emissions inventory.

For the base year 1990, the recalculations resulted in a decreased GHG emission total compared to the previous submission of -0.37% (including LULUCF and indirect CO_2).

For 2021, the recalculated emissions decreased by 0.29% compared to the previous submission (including LULUCF and indirect CO_2).

Table 10.1 is not presenting the emissions changes per individual gas. In Table 10.2 the changes per individual gas and per sector in 1990 and 2021 are elaborated.

Table 10.2 Summary of the emission changes due to recalculations per gas and sector (Gg CO_2-eq) for 1990 and 2021, compared to the NIR 2023

CO_2	**1990**	**2021**
1 Energy	-5,569.7	-7,588.8
2 IPPU	5,701.5	7,360.7
3 Agriculture	0.0	4.8
4 LULUCF	-1,154.9	-277.0
5 Waste	NA	NA
Indirect emissions	0.0	0.0
CH_4		
1 Energy	-23.0	-30.2
2 IPPU	8.6	9.7
3 Agriculture	0.0	-0.3
4 LULUCF	291.4	350.9
5 Waste	0.0	-173.4
N_2O		
1 Energy	-2.0	13.1
2 IPPU	1.9	3.4
3 Agriculture	74.7	46.2
4 LULUCF	-0.4	0.0
5 Waste	-185.6	-208.4
HFCs		
2 IPPU	0.0	-13.3
PFCs		
2 IPPU	-0.7	-7.1
SF_6		
2 IPPU	0.0	0.0

In relation to the abovementioned changes (and others), figures for emissions from precursor gases changed over the entire time series. The explanation for the recalculations can be found in the IIR report (Wever et al., 2024).

10.3 Implications for emissions trends, including time series consistency

The recalculations (including error corrections) have further improved both the accuracy and the time series consistency of the estimated emissions.
Table 10.3 presents the changes made due to the recalculations for 1990, 2000, 2010, 2015, 2020 and 2021 (compared to the NIR 2023).
It appears from Table 10.3 that the recalculations (including LULUCF) changed national emissions in 2020 and 2021 to a small extent (-0.1% and -0.3%, respectively), compared to the previous NIR. Changes to the 1990 emissions (base year) are in the same order of magnitude (- 0.4%).

*Table 10.3 Differences between the NIR 2023 and NIR 2024 for the 1990–2021 period due to recalculations (Units: **Tg CO_2-eq**; for F-gases: **Gg CO_2-eq**)*

Gas	Source	1990	2000	2010	2020	2021
CO_2 [Tg]	NIR 2024	167.5	176.6	187.0	140.3	143.4
	NIR 2023	168.5	177.3	187.1	140.5	143.9
	Difference	*-0.6%*	*-0.4%*	*-0.1%*	*-0.1%*	*-0.3%*
CH_4 [Tg]	NIR 2024	36.3	27.7	22.2	19.4	19.1
	NIR 2023	36.0	27.4	21.9	19.2	19.0
	Difference	*0.8%*	*1.2%*	*1.3%*	*1.0%*	*0.8%*
N_2O [Tg]	NIR 2024	16.1	14.3	7.8	7.4	7.1
	NIR 2023	16.2	14.4	7.9	7.5	7.2
	Difference	*-0.7%*	*-0.6%*	*-1.1%*	*-1.9%*	*-2.0%*
PFCs [Gg]	NIR 2024	2,396.6	1,715.2	290.5	61.8	72.4
	NIR 2023	2,397.3	1,723.2	299.9	65.3	79.5
	Difference	*0.0%*	*-0.5%*	*-3.1%*	*-5.4%*	*-8.9%*
HFCs [Gg]	NIR 2024	4,697.2	4,029.3	1,978.0	1,043.3	1,159.1
	NIR 2023	4,697.2	4,029.0	1,977.9	1,056.6	1,172.5
	Difference	*0.0%*	*0.0%*	*0.0%*	*-1.3%*	*-1.1%*
SF_6 [Gg]	NIR 2024	213.1	234.6	108.1	128.4	123.9
	NIR 2023	213.1	234.6	108.1	128.4	123.9
	Difference	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*
Total [Tg CO_2-eq]	NIR 2024	228.1	225.2	219.9	168.8	171.5
	NIR 2023	228.9	225.7	219.8	168.9	172.0
	Difference	*-0.4%*	*-0.2%*	*0.0%*	*-0.1%*	*-0.3%*

10.4 Response to the review process and planned improvements

10.4.1 Response to the review process

Public and peer review

The NIR is subject to a (when possible, annual) process of a general public review and a peer review.

The peer review, carried out by an independent expert party, pays special attention to a specific sector or topic, and checks the report for transparency, readability and consistency with 2006 IPCC Guidelines (IPCC, 2006).

The peer review on the NIR 2023 (CLM, 2023) focused on the CH_4 and CO_2 emissions from the Agricultural sector. This included the topics of enteric fermentation (3A), manure management (3B), liming (3G) and urea application (3H). The review concluded that, overall, the documentation on these categories was written in a clear manner and was understandable for readers with sufficient background knowledge. Suggestions were made to clarify certain parts of the NIR for readers unfamiliar with the Dutch context and to increase transparency by improving references. These suggestions are implemented in this NIR 2024.

Peer reviews in past years have focused on the following sectors and categories:

- Energy (CE Delft, 2022)
- LULUCF (South Pole, 2021)
- Waste and wastewater (Oonk, 2020)
- Transport (VITO, 2019);
- Reference approach and waste incineration (CE Delft, 2018);
- N_2O and CO_2 emissions from Agriculture (Kuikman, 2017);
- Energy (excluding transport) (CE Delft, 2014);
- Industrial process emissions (Royal HaskoningDHV, 2013);
- LULUCF (Somogyi, 2012);
- Waste (Oonk, 2011);
- Transport (Hanschke et al., 2010);
- Combustion and process emissions in industry (Neelis and Blinde, 2009);
- Agriculture (Monteny, 2008).

In general, the conclusion of these peer reviews has been that the Dutch NIR adequately describes how the Netherlands calculates the emissions of greenhouse gases. The major recommendations refer to the readability and transparency of the NIR, with some suggestions for textual improvement.

UNFCCC review

A UNFCCC review was conducted on the NIR 2022. The final review report was received in May 2023 and is used to structure Annex 10, which includes responses to each of the findings.

ESR review and EU initial checks

Until 2022, an annual ESD review was conducted by an EU expert review team in line with Article 19(1) of Regulation (EU) No 525/2013 (the ‘Monitoring Mechanism Regulation’, MMR.
In 2025, 2027 and 2032 comprehensive EU ESR reviews will be conducted in line with the Regulation 2018/1999 on governance of the Energy Union and climate action in order to determine the annual targets of net GHG emissions reductions of the Member States.

During the years that no comprehensive reviews take place, potential issues are still identified during the initial checks of the draft NIR from 15 January. These issues can potentially result in improvements of (the descriptions in) the NIR/CRF.

10.4.1.1 Completeness of the NIR

The Netherlands' GHG emission inventory includes all sources identified by the revised Intergovernmental Panel on Climate Change (IPCC) Guidelines (IPCC, 2006), and for a significant part the 2019 Refinement to the 2006 IPCC Guidelines, with the exception of the following, very minor, sources:

- CO_2 from asphalt roofing (2A4d), due to negligible amounts (below threshold);
- CO_2 from road paving (2A4d), due to negligible amounts (below threshold);
- CH_4 from enteric fermentation in poultry (3A4), due to missing EFs;
- N_2O from septic tanks (5D3), due to missing method and negligible amounts (below threshold);
- Part of CH_4 from industrial wastewater (5D2 sludge), due to negligible amounts;
- Precursor emissions (i.e. CO, NO_x, NMVOC) and SO_2) from memo item 'International bunkers' (international transport), as these emissions are not part of the national total.

For more detailed information on this issue, see Annex 6.

10.4.1.2 Completeness of CRF tables

As the Industrial processes source categories in the Netherlands often relate to only a few companies, it is generally not possible to report detailed and disaggregated data. Activity data is confidential and not reported when a source category comprises three or fewer companies. During (in-country) reviews, however, this data will be made available to the ERT on request.

10.4.1.3 Planned improvements

The Netherlands' National System was established at the end of 2005, in line with the requirements of the Kyoto Protocol and the EU Monitoring Mechanism, as a result of the implementation of a monitoring improvement programme (see Section 1.6). The conclusion of the initial review (2007) was that the Netherlands' National System had been established in accordance with the guidelines for National Systems set out in Article 5, section 1 of the Kyoto Protocol (decision 19/CMP.1) and that it met the requirements for the implementation of the general functions of a National System, as well as the specific functions of inventory planning, inventory preparation, and inventory management. The latest UNFCCC review from 2022 confirmed that the Netherlands' inventory and inventory process are still in line with the rules for National Systems.

Notwithstanding the replacement of the Kyoto Protocol by the Paris Agreement and the replacement of the EU Monitoring Mechanism by the Governance Regulation of the Energy Union, the national arrangements for the preparation of the inventory (including quality assurance and control procedures) must still be implemented and maintained, similar to the previous requirements. With regard to quality assurance and quality control procedures, the QA/QC programme for the Netherlands' national arrangements was revised and updated in 2023, as detailed further below (Quality assurance and quality control , RVO, 2023).

Monitoring improvement
The National System includes an annual evaluation and improvement process. The evaluation is based on experience in previous years and the results of UN and EU reviews, peer reviews, and audits. Where needed, improvements are included in the update of the QA/QC programme (RVO, 2023).

QA/QC programme
The QA/QC programme was revised and updated. Previously, this programme covered a fixed period of about one year and the entire document was updated on a yearly basis. From 2023 onwards, a slightly revised structure has been incorporated.

As the core aspects of the QA/QC programme are cyclical, the programme is described with a more indefinite time frame to enable a broader time-horizon. Outcomes of specific QA/QC activities continue to be reported in the relevant sections of the NIR. At the same time, the annual experiences from reviews and improvement actions will also still be captured at a more granular level in the annual internal memo 'Main QA/QC experiences inventory' (RVO) shared with the NIE Advisory Board (this document will be held available for reviews). This internal document describes in a concise manner the key actions taken that year and reflection on the implementation thereof, as well as incorporating learnings from (bi)annual reviews and evaluations. Any practical considerations therein will subsequently feed into finetuning of the overall QA/QC programme. As such, the programme will continue to be reviewed as part of the evaluation and improvement cycle and is to be updated as appropriate in line with relevant reporting guidelines from the EU and UNFCCC.

The QA/QC programme continues the assessment of long-term improvement options on the basis of the 2006 IPCC Guidelines and the 2019 Refinement to the 2006 IPCC Guidelines. Improvement actions for new methodologies and changes of EF will be performed as governed by the annual Work Plan (RIVM, 2023)

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The emissions and activity data in the Netherlands' inventory was converted into the IPCC source categories contained in the Common Reporting Format (CRF) tables, which form a supplement to this report.

The description of the various sources, the analysis of trends and the uncertainty estimates (see Chapters 3 to 8) were made in cooperation with the following emissions experts: Eric Arets and Sven van Baren (Land use), Bas van Huet and Olaf van Hunnik (Waste), Kathleen Geertjes (Transport), Romuald te Molder, Martin Kosterman and Guido Hollman (key categories and uncertainty analysis), Rianne Dröge (Energy, Industrial processes and product use and uncertainty assessment), Johanna Montfoort (Fugitive emissions), Erik Honig (Industrial processes and product use), Kees Baas (Wastewater handling) and Tim van der Zee (Agriculture). Bas Guis provided pivotal information on CO_2 emissions related to energy use. Peter Coenen contributed to Chapter 10 'Recalculations and improvements', and (with the support of Alexander de Jong) coordinated the filling of the CRF tables.

This group also provided activity data and additional information for the CRF tables in cases where it was not included in the data sheets submitted by the PRTR Task Forces.
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Annex 1 Key categories

A1.1 Introduction

As explained in the 2006 Guidelines (IPCC, 2006), a key source category is prioritised within the national inventory system because its estimate has a significant influence on a country’s total inventory of direct GHGs in terms of the absolute level of emissions, the trend in emissions or both.

For the identification of key categories in the Netherlands’ inventory (Key Category Analysis or KCA), national emissions are allocated to the Intergovernmental Panel on Climate Change’s potential key source list, as presented in table 4.1 in Chapter 4 of the 2006 IPCC Guidelines (Volume 1). For KCA, no major modifications with respect to the 2006 IPCC Guidelines have occurred but a simplification of the equation to perform key category analysis using trend assessment (Approach 1 without uncertainties)

As suggested in the guidance, carbon dioxide (CO_2) emissions from stationary combustion (1A1, 1A2 and 1A4) are aggregated by fuel type. CO_2, methane (CH_4) and nitrous oxide (N_2O) emissions from mobile combustion – road vehicles (1A3) – are assessed separately. CH_4 and N_2O emissions from aircraft and ships are relatively small (about 1–2 Gg CO_2-eq). Other mobile sources are not assessed separately by gas. Fugitive emissions from oil and gas operations (1B) are important sources of GHG emissions in the Netherlands. The most important gas/source combinations in this category are separately assessed. Emissions in other IPCC sectors are disaggregated, as suggested by the IPCC.

The first step of the KCA (IPCC Approach 1 method) consists of ranking the list of source category/gas combinations according to their contribution to annual national total emissions and to the national total trend. The categories at the top of the tables in this annex are the key categories , the total of whose emissions add up to 95% of the national total. This results in 39 categories for annual level assessment (emissions in 2022) and 47 categories for the trend assessment out of a total of 124 source categories.

The second step of the KCA (IPCC Approach 2 method) requires the incorporation of the uncertainty per category before ordering the list of shares. In this case, total uncertainties per category are calculated using error propagation, using the uncertainty estimates for both data and emission factors as presented in Annex 2 (for details of the uncertainty analysis see the methodology reports (RIVM reports 2024-0014, 2024-0015, 2024-0016 and 2024-0023 and Van Baren et al. (2024)).

Here, a total contribution of up to 90% to the overall uncertainty has been used to avoid the inclusion of too many small sources. The results of the of the Approach 1 and 2 level and trend assessments are summarised in Table A1.1. A combination of approach 1 and 2 for both level and trend assessment, shows a total of 65 key categories. As expected, the incorporation of uncertainty in the level and trend assessments increases the importance of highly uncertain sources. With uncertainties added, 8 additional key categories are identified, as shown in table A1.1.

Table A1.1 Additional key categories after incorporation of uncertainty data

Category	**Name**	**Gas**	**Key category**
1A4b	Residential: all fuels	CH_4	Key(L2,)
2A4d	Other	CO_2	Key(L,T)
2B8	Petrochemical and carbon black production	CO_2	Key(L,T)
2B8	Chemical industry: Petrochemical and carbon black production	CH_4	Key(L2,T)
3A3	Swine	CH_4	Key(L2,)
3B4	Poultry	CH_4	Key(,T)
3B5	Indirect emissions	N_2O	Key(L2,T2)
4B	Cropland	N_2O	Key(L2,)

Annex 1 also includes information on key categories in 1990; Table A1.3 shows the results.

The 2022 inventory contains, in comparison with 1990, 10 additional key categories on the basis of a level assessment (including LULUCF). Please note that a trend assessment for 1990 key categories is not relevant.

*Table A1.2 Key category list identified by the Approach 1 level and trend assessments (without uncertainty data) for **2022** emissions (**including** LULUCF sources)*

CRF	Source category	Gas	Key source	Approach 1 level recent year (excl.uncertainty)	Approach 1 trend (excl.uncertainty)	Approach 2 level recent year (incl. uncertainty,error propagation)	Approach 2 trend (incl. uncertainty, error propagation)
1A1	Energy Industries: all fuels	CH_4	Non key	0	0	0	0
1A1	Energy Industries: all fuels	N_2O	Key(,T)	0	1	0	1
1A1a	Public Electricity and Heat Production: liquids	CO_2	Key(,T)	0	1	0	1
1A1a	Public Electricity and Heat Production: solids	CO_2	Key(L,T)	1	1	1	1
1A1a	Public Electricity and Heat Production: gaseous	CO_2	Key(L1,T1)	1	1	0	0
1A1a	Public Electricity and Heat Production: other fuels: waste incineration	CO_2	Key(L,T)	1	1	1	1
1A1b	Petroleum Refining: liquids	CO_2	Key(L,T)	1	1	1	1
1A1b	Petroleum Refining: gaseous	CO_2	Key(L1,T1)	1	1	0	0
1A1c	Manufacture of Solid Fuels: solids	CO_2	Key(L,T)	1	1	1	1
1A1c	Manufacture of Solid Fuels: gaseous	CO_2	Key(L,T1)	1	1	1	0
1A2	Manufacturing Industries and Construction: liquids	CO_2	Key(L1,T1)	1	1	0	0
1A2	Manufacturing Industries and Construction: solids	CO_2	Key(L,T)	1	1	1	1
1A2	Manufacturing Industries and Construction: gaseous	CO_2	Key(L,T1)	1	1	1	0
1A2	Manufacturing Industries and Construction: all fuels	CH_4	Non key	0	0	0	0
1A2	Manufacturing Industries and Construction: all fuels	N_2O	Non key	0	0	0	0
1A3 excl 1A3b	Other	CH_4	Non key	0	0	0	0
1A3 excl 1A3b	Other	N_2O	Non key	0	0	0	0

CRF	Source category	Gas	Key source	Approach 1 level recent year (excl.uncertainty)	Approach 1 trend (excl.uncertainty)	Approach 2 level recent year (incl. uncertainty,error propagation)	Approach 2 trend (incl. uncertainty, error propagation)
1A3a	Domestic aviation	CO_2	Non key	0	0	0	0
1A3b	Road transportation: gasoline	CO_2	Key(L,T)	1	1	1	1
1A3b	Road transportation: diesel oil	CO_2	Key(L,T)	1	1	1	1
1A3b	Road transportation: LPG	CO_2	Key(,T)	0	1	0	1
1A3b	Road transportation: gaseous	CO_2	Key(,T1)	0	1	0	0
1A3b	Road transportation	CH_4	Non key	0	0	0	0
1A3b	Road transportation	N_2O	Non key	0	0	0	0
1A3c	Railways	CO_2	Non key	0	0	0	0
1A3d	Domestic navigation	CO_2	Key(L1,T1)	1	1	0	0
1A3e	Other	CO_2	Key(,T1)	0	1	0	0
1A4 excl 1A4c	Liquids	CO_2	Key(L,T)	1	1	1	1
1A4	Solids	CO_2	Non key	0	0	0	0
1A4	Other Sectors: all fuels	N_2O	Non key	0	0	0	0
1A4a	Commercial/Institutional: gaseous	CO_2	Key(L,)	1	0	1	0
1A4a	Commercial/Institutional: all fuels	CH_4	Non key	0	0	0	0
1A4b	Residential gaseous	CO_2	Key(L,T1)	1	1	1	0
1A4b	Residential: all fuels	CH_4	Key(L2,)	0	0	1	0
1A4c	Agriculture/Forestry/Fisheries: liquids	CO_2	Key(L1,T1)	1	1	0	0
1A4c	Agriculture/Forestry/Fisheries: gaseous	CO_2	Key(L,)	1	0	1	0
1A4c	Agriculture/Forestry/Fisheries: all fuels	CH_4	Key(L,T)	1	1	1	1
1A5b	Military use: liquids	CO_2	Non key	0	0	0	0
1A5b	Military use: liquids	CH_4	Non key	0	0	0	0
1A5b	Military use: liquids	N_2O	Non key	0	0	0	0

CRF	Source category	Gas	Key source	Approach 1 level recent year (excl.uncertainty)	Approach 1 trend (excl.uncertainty)	Approach 2 level recent year (incl. uncertainty,error propagation)	Approach 2 trend (incl. uncertainty, error propagation)
1B1b	Solid fuel transformation	CO_2	Non key	0	0	0	0
1B1b	Solid fuel transformation	CH_4	Non key	0	0	0	0
1B2	Fugitive emissions from oil and gas operations	CO_2	Key(L1,T1)	1	1	0	0
1B2a	Oil	CH_4	Non key	0	0	0	0
1B2b	Natural gas	CH_4	Non key	0	0	0	0
1B2c	Venting and flaring	CH_4	Key(,T)	0	1	0	1
2A1	Cement production	CO_2	Key(,T1)	0	1	0	0
2A2	Lime production	CO_2	Key(L2,T2)	0	0	1	1
2A3	Glass production	CO_2	Non key	0	0	0	0
2A4a	Ceramics	CO_2	Non key	0	0	0	0
2A4b	Other uses of soda ash	CO_2	Non key	0	0	0	0
2A4d	Other	CO_2	Key(L,T)	1	1	1	1
2B	Fluorochemical production	HFC	Key(,T)	0	1	0	1
2B1	Ammonia production	CO_2	Key(L,)	1	0	1	0
2B10	Other	CO_2	Key(L,T)	1	1	1	1
2B10	Other	N_2O	Key(L2,T)	0	1	1	1
2B2	Nitric acid production	N_2O	Key(,T)	0	1	0	1
2B4	Caprolactam production	N_2O	Key(,T)	0	1	0	1
2B7	Soda ash production	CO_2	Non key	0	0	0	0
2B8	Petrochemical and carbon black production	CO_2	Key(L,T)	1	1	1	1
2B8	Chemical industry: Petrochemical and carbon black production	CH_4	Key(L2,T)	0	1	1	1
2B9	Fluorochemical production	PFC	Non key	0	0	0	0
2C1	Iron and steel production	CO_2	Non key	0	0	0	0
2C3	Aluminium production	CO_2	Key(,T1)	0	1	0	0

CRF	Source category	Gas	Key source	Approach 1 level recent year (excl.uncertainty)	Approach 1 trend (excl.uncertainty)	Approach 2 level recent year (incl. uncertainty,error propagation)	Approach 2 trend (incl. uncertainty, error propagation)
2C3	Aluminium production	PFC	Key(,T1)	0	1	0	0
2D1	Lubricant use	CO_2	Non key	0	0	0	0
2D2	Paraffin wax use	CO_2	Key(L2,T)	0	1	1	1
2D2	Paraffin wax use	CH_4	Non key	0	0	0	0
2D3	Other	CO_2	Non key	0	0	0	0
2E	Electronic Industry	PFC	Non key	0	0	0	0
2F1	Refrigeration and airconditioning	HFC	Key(L,T)	1	1	1	1
2F6	Other	HFC	Key(,T2)	0	0	0	1
2G	Other product manufacture and use	CO_2	Non key	0	0	0	0
2G	Other product manufacture and use	CH_4	Non key	0	0	0	0
2G	Other product manufacture and use	N_2O	Non key	0	0	0	0
2G2	SF_6 use	SF_6	Non key	0	0	0	0
2H	Other industrial	CO_2	Non key	0	0	0	0
3A1	Mature dairy cattle	CH_4	Key(L,T)	1	1	1	1
3A1	Other mature cattle	CH_4	Non key	0	0	0	0
3A1	Young cattle	CH_4	Key(L,)	1	0	1	0
3A2, 3A4	Other	CH_4	Key(L1,)	1	0	0	0
3A3	Swine	CH_4	Key(L2,)	0	0	1	0
3B1	Mature dairy cattle	CH_4	Key(L,T)	1	1	1	1
3B1	Other mature cattle	CH_4	Non key	0	0	0	0
3B1	Growing cattle	CH_4	Key(L1,)	1	0	0	0
3B1	Mature dairy cattle	N_2O	Non key	0	0	0	0
3B1	Other mature cattle	N_2O	Non key	0	0	0	0
3B1	Growing cattle	N_2O	Non key	0	0	0	0
3B2	Sheep	N_2O	Non key	0	0	0	0

CRF	Source category	Gas	Key source	Approach 1 level recent year (excl.uncertainty)	Approach 1 trend (excl.uncertainty)	Approach 2 level recent year (incl. uncertainty,error propagation)	Approach 2 trend (incl. uncertainty, error propagation)
3B2, 3B4	Other	CH_4	Non key	0	0	0	0
3B3	Swine	CH_4	Key(L,T)	1	1	1	1
3B3	Swine	N_2O	Non key	0	0	0	0
3B4	Poultry	CH_4	Key(,T)	0	1	0	1
3B4	Other livestock	N_2O	Non key	0	0	0	0
3B5	Indirect emissions	N_2O	Key(L2,T2)	0	0	1	1
3Da	Direct emissions from agricultural soils	N_2O	Key(L,T)	1	1	1	1
3Db	Indirect emissions from managed soils	N_2O	Key(L,T)	1	1	1	1
3G	Liming	CO_2	Non key	0	0	0	0
3H	Ureum use	CO_2	Non key	0	0	0	0
4A	Forest Land	CO_2	Key(L,)	1	0	1	0
4A	Forest Land	N_2O	Non key	0	0	0	0
4A	Forest Land	CH_4	Non key	0	0	0	0
4B	Cropland	CO_2	Key(L,)	1	0	1	0
4B	Cropland	N_2O	Key(L2,)	0	0	1	0
4B	Cropland	CH_4	Non key	0	0	0	0
4C	Grassland	CO_2	Key(L,T)	1	1	1	1
4C	Grassland	N_2O	Non key	0	0	0	0
4C	Grassland	CH_4	Key(L2,)	0	0	1	0
4D	Wetlands	CO_2	Non key	0	0	0	0
4D	Wetlands	N_2O	Non key	0	0	0	0
4E	Settlements	CO_2	Key(L,T)	1	1	1	1
4E	Settlements	N_2O	Non key	0	0	0	0
4F	Other Land	CO_2	Key(L2,T2)	0	0	1	1

CRF	Source category	Gas	Key source	Approach 1 level recent year (excl.uncertainty)	Approach 1 trend (excl.uncertainty)	Approach 2 level recent year (incl. uncertainty,error propagation)	Approach 2 trend (incl. uncertainty, error propagation)
4F	Other Land	N_2O	Non key	0	0	0	0
4H	Other	N_2O	Non key	0	0	0	0
4G	Harvested wood products	CO_2	Non key	0	0	0	0
5A	Solid waste disposal	CH_4	Key(L,T)	1	1	1	1
5B	Biological treatment of solid waste: composting	CH_4	Key(,T2)	0	0	0	1
5B	Biological treatment of solid waste: composting	N_2O	Non key	0	0	0	0
5C	Open burning of waste	CH_4	Non key	0	0	0	0
5C	Open burning of waste	N_2O	Non key	0	0	0	0
5D	Wastewater treatment and discharge	CH_4	Non key	0	0	0	0
5D	Wastewater treatment and discharge	N_2O	Key(L,)	1	0	1	0
6	Indirect CO2	CO_2	Key(,T1)	0	1	0	0
	SUM			39	47	41	37

*Table A1.3 Key source list identified by the Approach 1 level assessments for **1990** emissions (**including** LULUCF sources)*

CRF	**Source category**	**Gas**	**Key source**	**Approach 1 level 1990 excl. uncertainty**	**Approach 1 level 1990 incl. uncertainty, error propagation**
1A1	Energy Industries: all fuels	CH_4	Non key	0	0
1A1	Energy Industries: all fuels	N_2O	Non key	0	0
1A1a	Public Electricity and Heat Production: liquids	CO_2	Non key	0	0
1A1a	Public Electricity and Heat Production: solids	CO_2	Key(L,)	1	1
1A1a	Public Electricity and Heat Production: gaseous	CO_2	Key(L1,)	1	0
1A1a	Public Electricity and Heat Production: other fuels: waste incineration	CO_2	Key(L1,)	1	0
1A1b	Petroleum Refining: liquids	CO_2	Key(L,)	1	1
1A1b	Petroleum Refining: gaseous	CO_2	Key(L1,)	1	0
1A1c	Manufacture of Solid Fuels: solids	CO_2	Key(L,)	1	1
1A1c	Manufacture of Solid Fuels: gaseous	CO_2	Key(L1,)	1	0
1A2	Manufacturing Industries and Construction: liquids	CO_2	Key(L1,)	1	0
1A2	Manufacturing Industries and Construction: solids	CO_2	Key(L,)	1	1
1A2	Manufacturing Industries and Construction: gaseous	CO_2	Key(L,)	1	1
1A2	Manufacturing Industries and Construction: all fuels	CH_4	Non key	0	0
1A2	Manufacturing Industries and Construction: all fuels	N_2O	Non key	0	0
1A3 excl 1A3b	Other	CH_4	Non key	0	0
1A3 excl 1A3b	Other	N_2O	Non key	0	0
1A3a	Domestic aviation	CO_2	Non key	0	0
1A3b	Road transportation: gasoline	CO_2	Key(L,)	1	1
1A3b	Road transportation: diesel oil	CO_2	Key(L,)	1	1

CRF	Source category	Gas	Key source	Approach 1 level 1990 excl. uncertainty	Approach 1 level 1990 incl. uncertainty, error propagation
1A3b	Road transportation: LPG	CO_2	Key(L1,)	1	0
1A3b	Road transportation: gaseous	CO_2	Non key	0	0
1A3b	Road transportation	CH_4	Non key	0	0
1A3b	Road transportation	N_2O	Non key	0	0
1A3c	Railways	CO_2	Non key	0	0
1A3d	Domestic navigation	CO_2	Key(L1,)	1	0
1A3e	Other	CO_2	Non key	0	0
1A4 excl 1A4c	Liquids	CO_2	Key(L,)	1	1
1A4	Solids	CO_2	Non key	0	0
1A4	Other Sectors: all fuels	N_2O	Non key	0	0
1A4a	Commercial/Institutional: gaseous	CO_2	Key(L,)	1	1
1A4a	Commercial/Institutional: all fuels	CH_4	Non key	0	0
1A4b	Residential gaseous	CO_2	Key(L,)	1	1
1A4b	Residential: all fuels	CH_4	Key(L2,)	0	1
1A4c	Agriculture/Forestry/Fisheries: liquids	CO_2	Key(L1,)	1	0
1A4c	Agriculture/Forestry/Fisheries: gaseous	CO_2	Key(L,)	1	1
1A4c	Agriculture/Forestry/Fisheries: all fuels	CH_4	Non key	0	0
1A5b	Military use: liquids	CO_2	Non key	0	0
1A5b	Military use: liquids	CH_4	Non key	0	0
1A5b	Military use: liquids	N_2O	Non key	0	0
1B1b	Solid fuel transformation	CO_2	Non key	0	0
1B1b	Solid fuel transformation	CH_4	Non key	0	0
1B2	Fugitive emissions from oil and gas operations	CO_2	Key(L1,)	1	0
1B2a	Oil	CH_4	Non key	0	0
1B2b	Natural gas	CH_4	Non key	0	0
1B2c	Venting and flaring	CH_4	Key(L,)	1	1

CRF	Source category	Gas	Key source	Approach 1 level 1990 excl. uncertainty	Approach 1 level 1990 incl. uncertainty, error propagation
2A1	Cement production	CO_2	Non key	0	0
2A2	Lime production	CO_2	Non key	0	0
2A3	Glass production	CO_2	Non key	0	0
2A4a	Ceramics	CO_2	Non key	0	0
2A4b	Other uses of soda ash	CO_2	Non key	0	0
2A4d	Other	CO_2	Key(L2,)	0	1
2B	Fluorochemical production	HFC	Key(L,)	1	1
2B1	Ammonia production	CO_2	Key(L,)	1	1
2B10	Other	CO_2	Key(L,)	1	1
2B10	Other	N_2O	Non key	0	0
2B2	Nitric acid production	N_2O	Key(L,)	1	1
2B4	Caprolactam production	N_2O	Key(L,)	1	1
2B7	Soda ash production	CO_2	Non key	0	0
2B8	Petrochemical and carbon black production	CO_2	Key(L2,)	0	1
2B8	Chemical industry: Petrochemical and carbon black production	CH_4	Key(L2,)	0	1
2B9	Fluorochemical production	PFC	Non key	0	0
2C1	Iron and steel production	CO_2	Non key	0	0
2C3	Aluminium production	CO_2	Non key	0	0
2C3	Aluminium production	PFC	Key(L1,)	1	0
2D1	Lubricant use	CO_2	Non key	0	0
2D2	Paraffin wax use	CO_2	Non key	0	0
2D2	Paraffin wax use	CH_4	Non key	0	0
2D3	Other	CO_2	Non key	0	0
2E	Electronic Industry	PFC	Non key	0	0
2F1	Refrigeration and airconditioning	HFC	Non key	0	0
2F6	Other	HFC	Non key	0	0

CRF	Source category	Gas	Key source	Approach 1 level 1990 excl. uncertainty	Approach 1 level 1990 incl. uncertainty, error propagation
2G	Other product manufacture and use	CO_2	Non key	0	0
2G	Other product manufacture and use	CH_4	Non key	0	0
2G	Other product manufacture and use	N_2O	Non key	0	0
2G2	SF_6 use	SF_6	Non key	0	0
2H	Other industrial	CO_2	Non key	0	0
3A1	Mature dairy cattle	CH_4	Key(L,)	1	1
3A1	Other mature cattle	CH_4	Non key	0	0
3A1	Young cattle	CH_4	Key(L,)	1	1
3A2, 3A4	Other	CH_4	Non key	0	0
3A3	Swine	CH_4	Key(L2,)	0	1
3B1	Mature dairy cattle	CH_4	Key(L,)	1	1
3B1	Other mature cattle	CH_4	Non key	0	0
3B1	Growing cattle	CH_4	Non key	0	0
3B1	Mature dairy cattle	N_2O	Non key	0	0
3B1	Other mature cattle	N_2O	Non key	0	0
3B1	Growing cattle	N_2O	Non key	0	0
3B2	Sheep	N_2O	Non key	0	0
3B2, 3B4	Other	CH_4	Non key	0	0
3B3	Swine	CH_4	Key(L,)	1	1
3B3	Swine	N_2O	Non key	0	0
3B4	Poultry	CH_4	Key(L2,)	0	1
3B4	Other livestock	N_2O	Non key	0	0
3B5	Indirect emissions	N_2O	Key(L2,)	0	1
3Da	Direct emissions from agricultural soils	N_2O	Key(L,)	1	1
3Db	Indirect emissions from managed soils	N_2O	Key(L,)	1	1
3G	Liming	CO_2	Non key	0	0
3H	Ureum use	CO_2	Non key	0	0

CRF	Source category	Gas	Key source	Approach 1 level 1990 excl. uncertainty	Approach 1 level 1990 incl. uncertainty, error propagation
4A	Forest Land	CO_2	Key(L,)	1	1
4A	Forest Land	N_2O	Non key	0	0
4A	Forest Land	CH_4	Non key	0	0
4B	Cropland	CO_2	Key(L,)	1	1
4B	Cropland	N_2O	Key(L2,)	0	1
4B	Cropland	CH_4	Non key	0	0
4C	Grassland	CO_2	Key(L,)	1	1
4C	Grassland	N_2O	Non key	0	0
4C	Grassland	CH_4	Non key	0	0
4D	Wetlands	CO_2	Non key	0	0
4D	Wetlands	N_2O	Non key	0	0
4E	Settlements	CO_2	Key(L,)	1	1
4E	Settlements	N_2O	Non key	0	0
4F	Other Land	CO_2	Non key	0	0
4F	Other Land	N_2O	Non key	0	0
4H	Other	N_2O	Non key	0	0
4G	Harvested wood products	CO_2	Non key	0	0
5A	Solid waste disposal	CH_4	Key(L,)	1	1
5B	Biological treatment of solid waste: composting	CH_4	Non key	0	0
5B	Biological treatment of solid waste: composting	N_2O	Non key	0	0
5C	Open burning of waste	CH_4	Non key	0	0
5C	Open burning of waste	N_2O	Non key	0	0
5D	Wastewater treatment and discharge	CH_4	Non key	0	0
5D	Wastewater treatment and discharge	N_2O	Non key	0	0
6	Indirect CO2	CO_2	Key(L,)	1	1
	SUM			39	37

A1.2 Changes in key categories compared to previous submission

Due to the use of emissions data for 2022, there are some changes in key categories in comparison with the previous NIR: One category that was key in the previous submission is no longer a key category:

2B7 Soda ash production CO_2

The Netherlands includes 5 extra key categories compared to the key source analysis in 2023:

1A1a	Public Electricity and Heat Production: liquids	CO_2
2A2	Lime production	CO_2
2B4	Caprolactam production	N_2O
2F6	Other	HFC
3B1	Growing cattle	CH_4

A1.3 Changes in key categories 2022 compared to 1990

Table A1.4 shows the result of a comparison of the key categories in 1990 (level) and 2022 (level and trend). A comparison on the basis of a level assessment only, shows 4 additional key categories in 2022 compared to 1990. Fourteen additional categories (shaded in table A1.4) are added, when also the trend analysis is taken into account.

Table A1.4 additional key categories in 2022 (compared to 1990)

1A1	Energy Industries: all fuels	N_2O	Key(,T)
1A1a	Public Electricity and Heat Production: liquids	CO_2	Key(,T)
1A3b	Road transportation: gaseous	CO_2	Key(,T1)
1A3e	Other	CO_2	Key(,T1)
1A4c	Agriculture/Forestry/Fisheries: all fuels	CH_4	Key(L,T)
2A1	Cement production	CO_2	Key(,T1)
2A2	Lime production	CO_2	Key(L2,T2)
2B10	Other	N_2O	Key(L2,T)
2C3	Aluminium production	CO_2	Key(,T1)
2D2	Paraffin wax use	CO_2	Key(L2,T)
2F1	Refrigeration and airconditioning	HFC	Key(L,T)
2F6	Other	HFC	Key(,T2)
3A2, 3A4	Other	CH_4	Key(L1,)
3B1	Growing cattle	CH_4	Key(L1,)
4C	Grassland	CH_4	Key(L2,)
4F	Other Land	CO_2	Key(L2,T2)
5B	Biological treatment of solid waste: composting	CH_4	Key(,T2)
5D	Wastewater treatment and discharge	N_2O	Key(L,)

A1.4 Approach 1 key category assessment (level and trend excluding uncertainties)

In Table A1.5 the source ranking is done according to the contribution to the 2022 annual emissions total and in Table A1.6 according to the base-year-to-2022 trend. This results in 40 level key sources and 49 trend key sources.

Table A1.5 Source ranking using IPCC Approach 1 ***level*** *assessment for 2021 emissions, including LULUCF (amounts in Gg CO_2-eq)*

CRF Category		Gas	2022 estimate (Gg CO_2-eq)	Level assessment %	Cumulative total %
1A1a	Public Electricity and Heat Production: solids	CO_2	16480.4	10.2	10.2
1A1a	Public Electricity and Heat Production: gaseous	CO_2	13541.5	8.4	18.6
1A4b	Residential gaseous	CO_2	13316.9	8.3	26.9
1A3b	Road transportation: diesel oil	CO_2	12784.8	7.9	34.9
1A2	Manufacturing Industries and Construction: gaseous	CO_2	12608.4	7.8	42.7
1A3b	Road transportation: gasoline	CO_2	10863.2	6.7	49.4
1A1b	Petroleum Refining: liquids	CO_2	8276.4	5.1	54.6
2B10	Other	CO_2	7641.3	4.7	59.3
3A1	Mature dairy cattle	CH_4	6021.5	3.7	63.1
1A4a	Commercial/Institutional: gaseous	CO_2	5368.2	3.3	66.4
1A4c	Agriculture/Forestry/Fisheries: gaseous	CO_2	5143.6	3.2	69.6
1A2	Manufacturing Industries and Construction: solids	CO_2	3771.7	2.3	71.9
3Da	Direct emissions from agricultural soils	N_2O	3633.6	2.3	74.2
1A1a	Public Electricity and Heat Production: other fuels: waste incineration	CO_2	2667.1	1.7	75.9
4C	Grassland	CO_2	2431.4	1.5	77.4
3A1	Young cattle	CH_4	2045.2	1.3	78.6
5A	Solid waste disposal	CH_4	2027.0	1.3	79.9
4B	Cropland	CO_2	1918.3	1.2	81.1
1A2	Manufacturing Industries and Construction: liquids	CO_2	1879.7	1.2	82.3
2B1	Ammonia production	CO_2	1839.6	1.1	83.4
3B1	Mature dairy cattle	CH_4	1715.3	1.1	84.5
3B3	Swine	CH_4	1680.3	1.0	85.5
1A4c	Agriculture/Forestry/Fisheries: liquids	CO_2	1631.8	1.0	86.5
4A	Forest Land	CO_2	1425.2	0.9	87.4
1A1c	Manufacture of Solid Fuels: solids	CO_2	1282.1	0.8	88.2

CRF Category		Gas	2022 estimate (Gg CO_2-eq)	Level assessment %	Cumulative total %
4E	**Settlements**	**CO_2**	**1190.9**	**0.7**	**88.9**
1A1b	**Petroleum Refining: gaseous**	**CO_2**	**1155.6**	**0.7**	**89.7**
1A1c	**Manufacture of Solid Fuels: gaseous**	**CO_2**	**1088.0**	**0.7**	**90.3**
1B2	**Fugitive emissions from oil and gas operations**	**CO_2**	**1024.3**	**0.6**	**91.0**
1A4c	**Agriculture/Forestry/Fisheries: all fuels**	**CH_4**	**970.7**	**0.6**	**91.6**
1A3d	**Domestic navigation**	**CO_2**	**856.7**	**0.5**	**92.1**
2F1	**Refrigeration and airconditioning**	**HFC**	**763.6**	**0.5**	**92.6**
2A4d	**Other**	**CO_2**	**647.4**	**0.4**	**93.0**
2B8	**Petrochemical and carbon black production**	**CO_2**	**546.0**	**0.3**	**93.3**
3Db	**Indirect emissions from managed soils**	**N_2O**	**515.2**	**0.3**	**93.6**
3A2, 3A4	**Other**	**CH_4**	**504.0**	**0.3**	**94.0**
1A4 excl 1A4c	**Liquids**	**CO_2**	**496.3**	**0.3**	**94.3**
5D	**Wastewater treatment and discharge**	**N_2O**	**495.8**	**0.3**	**94.6**
3B1	**Growing cattle**	**CH_4**	**488.9**	**0.3**	**94.9**
3A3	**Swine**	**CH_4**	**471.9**	**0.3**	**95.2**
1A1a	Public Electricity and Heat Production: liquids	CO_2	462.2	0.3	95.5
6	Indirect CO_2	CO_2	457.5	0.3	95.7
2B8	Chemical industry: Petrochemical and carbon black production	CH_4	354.2	0.2	96.0
1A4b	Residential: all fuels	CH_4	342.2	0.2	96.2
2B10	Other	N_2O	311.9	0.2	96.4
1A3b	Road transportation: LPG	CO_2	291.1	0.2	96.5
1A1	Energy Industries: all fuels	N_2O	249.7	0.2	96.7
1B2b	Natural gas	CH_4	241.1	0.1	96.8
2D2	Paraffin wax use	CO_2	214.7	0.1	97.0
5D	Wastewater treatment and discharge	CH_4	214.1	0.1	97.1
1A5b	Military use: liquids	CO_2	211.7	0.1	97.2
3B5	Indirect emissions	N_2O	202.7	0.1	97.4
2A2	Lime production	CO_2	199.4	0.1	97.5
4C	Grassland	CH_4	195.1	0.1	97.6

CRF Category		Gas	2022 estimate (Gg CO_2-eq)	Level assessment %	Cumulative total %
4F	Other Land	CO_2	185.8	0.1	97.7
1A3b	Road transportation	N_2O	180.0	0.1	97.8
3B1	Mature dairy cattle	N_2O	163.0	0.1	97.9
1A3b	Road transportation: gaseous	CO_2	146.1	0.1	98.0
2B	Fluorochemical production	HFC	144.0	0.1	98.1
2B2	Nitric acid production	N_2O	133.7	0.1	98.2
4G	Harvested wood products	CO_2	130.0	0.1	98.3
5B	Biological treatment of solid waste: composting	CH_4	128.8	0.1	98.4
2F6	Other	HFC	128.7	0.1	98.5
2A4a	Ceramics	CO_2	128.4	0.1	98.5
2G2	SF_6 use	SF_6	125.5	0.1	98.6
1A1	Energy Industries: all fuels	CH_4	124.9	0.1	98.7
2B4	Caprolactam production	N_2O	124.1	0.1	98.8
1B2c	Venting and flaring	CH_4	119.0	0.1	98.8
3B1	Growing cattle	N_2O	116.4	0.1	98.9
2A4b	Other uses of soda ash	CO_2	115.0	0.1	99.0
3A1	Other mature cattle	CH_4	114.4	0.1	99.1
2D1	Lubricant use	CO_2	93.1	0.1	99.1
3B4	Other livestock	N_2O	87.5	0.1	99.2
1A3e	Other	CO_2	85.0	0.1	99.2
3B3	Swine	N_2O	79.0	0.0	99.3
3B4	Poultry	CH_4	71.4	0.0	99.3
1B1b	Solid fuel transformation	CO_2	71.4	0.0	99.4
5B	Biological treatment of solid waste: composting	N_2O	71.3	0.0	99.4
2G	Other product manufacture and use	N_2O	69.8	0.0	99.4
1A2	Manufacturing Industries and Construction: all fuels	CH_4	60.5	0.0	99.5
1A3b	Road transportation	CH_4	60.4	0.0	99.5
1A3c	Railways	CO_2	59.9	0.0	99.6
3H	Ureum use	CO_2	57.0	0.0	99.6
1A4	Other Sectors: all fuels	N_2O	51.4	0.0	99.6

CRF Category		Gas	2022 estimate (Gg CO_2-eq)	Level assessment %	Cumulative total %
2G	Other product manufacture and use	CH_4	51.1	0.0	99.7
4D	Wetlands	CO_2	48.3	0.0	99.7
1A4a	Commercial/Institutional: all fuels	CH_4	45.4	0.0	99.7
4B	Cropland	CH_4	45.4	0.0	99.7
1A2	Manufacturing Industries and Construction: all fuels	N_2O	43.4	0.0	99.8
4B	Cropland	N_2O	43.1	0.0	99.8
2E	Electronic Industry	PFC	40.3	0.0	99.8
2D3	Other	CO_2	33.0	0.0	99.8
3G	Liming	CO_2	32.2	0.0	99.9
1A3a	Domestic aviation	CO_2	32.1	0.0	99.9
3B2, 3B4	Other	CH_4	26.1	0.0	99.9
2H	Other industrial	CO_2	25.0	0.0	99.9
4E	Settlements	N_2O	19.6	0.0	99.9
1B2a	Oil	CH_4	16.0	0.0	99.9
2C1	Iron and steel production	CO_2	15.9	0.0	99.9
2C3	Aluminium production	CO_2	15.1	0.0	100.0
2B9	Fluorochemical production	PFC	12.1	0.0	100.0
3B1	Other mature cattle	CH_4	9.9	0.0	100.0
4F	Other Land	N_2O	9.4	0.0	100.0
4C	Grassland	N_2O	6.4	0.0	100.0
1A3 excl 1A3b	Other	N_2O	6.3	0.0	100.0
1B1b	Solid fuel transformation	CH_4	5.1	0.0	100.0
1A3 excl 1A3b	Other	CH_4	4.3	0.0	100.0
4A	Forest Land	N_2O	4.3	0.0	100.0
4A	Forest Land	CH_4	3.9	0.0	100.0
1A5b	Military use: liquids	N_2O	2.8	0.0	100.0
5C	Open burning of waste	CH_4	2.8	0.0	100.0
3B1	Other mature cattle	N_2O	2.7	0.0	100.0
4D	Wetlands	N_2O	2.1	0.0	100.0
5C	Open burning of waste	N_2O	1.5	0.0	100.0

CRF Category		Gas	2022 estimate (Gg CO_2-eq)	Level assessment %	Cumulative total %
3B2	Sheep	N_2O	1.5	0.0	100.0
1A5b	Military use: liquids	CH_4	0.5	0.0	100.0
2G	Other product manufacture and use	CO_2	0.4	0.0	100.0
1A4	Solids	CO_2	0.4	0.0	100.0
2D2	Paraffin wax use	CH_4	0.4	0.0	100.0
2A3	Glass production	CO_2	0.1	0.0	100.0
2A1	Cement production	CO_2	0.0	0.0	100.0
2B7	Soda ash production	CO_2	0.0	0.0	100.0
2C3	Aluminium production	PFC	0.0	0.0	100.0
4H	Other	N_2O	0.0	0.0	100.0
		Total	160991		

Lines in bold represent the key sources.

Table A1.6 Source ranking using IPCC Approach 1 ***trend*** *assessment for 2021 emissions compared to the base year,* ***including*** *LULUCF (Gg CO_2-eq)*

CRF category		Gas	1990 Estimate (Gg CO_2-eq)	2022 Estimate (Gg CO_2-eq)	Trend Assessment %	% Contribution to trend	Cumulative Total %
5A	Solid waste disposal	CH_4	15320.8	2027.0	7.7	14.7	14.7
1A1a	Public Electricity and Heat Production: gaseous	CO_2	13329.1	13541.5	3.9	7.4	22.0
1A3b	Road transportation: diesel oil	CO_2	13008.5	12784.8	3.4	6.4	28.5
2B2	Nitric acid production	N_2O	5410.9	133.7	3.2	6.2	34.7
1A3b	Road transportation: gasoline	CO_2	10664.4	10863.2	3.1	5.9	40.6
2B	Fluorochemical production	HFC	4697.2	144.0	2.8	5.3	45.9
2B10	Other	CO_2	6738.9	7641.3	2.7	5.1	51.0
1A1a	Public Electricity and Heat Production: other fuels: waste incineration	CO_2	601.5	2667.1	2.0	3.8	54.8
3A1	Mature dairy cattle	CH_4	5805.2	6021.5	1.8	3.4	58.2
2C3	Aluminium production	PFC	2373.9	0.0	1.5	2.8	61.1
1A3b	Road transportation: LPG	CO_2	2578.4	291.1	1.3	2.6	63.6
1A1a	Public Electricity and Heat Production: solids	CO_2	25862.2	16480.4	1.3	2.5	66.1
1A1b	Petroleum Refining: liquids	CO_2	9968.2	8276.4	1.2	2.3	68.4
1B2c	Venting and flaring	CH_4	1669.8	119.0	0.9	1.8	70.2
1A2	Manufacturing Industries and Construction: liquids	CO_2	4095.6	1879.7	0.9	1.6	71.8
3B3	Swine	CH_4	3772.8	1680.3	0.8	1.6	73.4
1A4c	Agriculture/Forestry/Fisheries: all fuels	CH_4	81.1	970.7	0.8	1.6	75.0
3B1	Mature dairy cattle	CH_4	1212.7	1715.3	0.8	1.5	76.5
1A2	Manufacturing Industries and Construction: solids	CO_2	6623.4	3771.7	0.7	1.4	77.9
3Da	Direct emissions from agricultural soils	N_2O	6346.1	3633.6	0.7	1.3	79.2
2F1	Refrigeration and airconditioning	HFC	0.0	763.6	0.7	1.3	80.5
1A1c	Manufacture of Solid Fuels: solids	CO_2	916.3	1282.1	0.6	1.1	81.6

CRF category		Gas	1990 Estimate (Gg CO_2-eq)	2022 Estimate (Gg CO_2-eq)	Trend Assessment %	% Contribution to trend	Cumulative Total %
1A2	**Manufacturing Industries and Construction: gaseous**	**CO_2**	**19044.2**	**12608.4**	**0.5**	**1.0**	**82.6**
4E	**Settlements**	**CO_2**	**1003.7**	**1190.9**	**0.4**	**0.8**	**83.5**
1B2	**Fugitive emissions from oil and gas operations**	**CO_2**	**774.6**	**1024.3**	**0.4**	**0.8**	**84.3**
3Db	**Indirect emissions from managed soils**	**N_2O**	**1436.3**	**515.2**	**0.4**	**0.8**	**85.1**
1A4b	**Residential gaseous**	**CO_2**	**19894.1**	**13316.9**	**0.4**	**0.8**	**85.9**
1A4 excl 1A4c	**Liquids**	**CO_2**	**1366.6**	**496.3**	**0.4**	**0.8**	**86.7**
1A1b	**Petroleum Refining: gaseous**	**CO_2**	**1042.2**	**1155.6**	**0.4**	**0.7**	**87.5**
4C	**Grassland**	**CO_2**	**2929.8**	**2431.4**	**0.4**	**0.7**	**88.1**
1A3d	**Domestic navigation**	**CO_2**	**725.5**	**856.7**	**0.3**	**0.6**	**88.7**
2B4	**Caprolactam production**	**N_2O**	**658.0**	**124.1**	**0.3**	**0.6**	**89.3**
2A4d	**Other**	**CO_2**	**481.2**	**647.4**	**0.3**	**0.5**	**89.8**
2B8	**Petrochemical and carbon black production**	**CO_2**	**335.6**	**546.0**	**0.3**	**0.5**	**90.4**
1A1a	**Public Electricity and Heat Production: liquids**	**CO_2**	**233.2**	**462.2**	**0.3**	**0.5**	**90.9**
2A1	**Cement production**	**CO_2**	**415.8**	**0.0**	**0.3**	**0.5**	**91.4**
2C3	**Aluminium production**	**CO_2**	**408.4**	**15.1**	**0.2**	**0.5**	**91.8**
1A1c	**Manufacture of Solid Fuels: gaseous**	**CO_2**	**1184.2**	**1088.0**	**0.2**	**0.5**	**92.3**
3B4	**Poultry**	**CH_4**	**481.7**	**71.4**	**0.2**	**0.4**	**92.7**
6	**Indirect CO_2**	**CO_2**	**917.2**	**457.5**	**0.2**	**0.3**	**93.1**
2B10	**Other**	**N_2O**	**219.4**	**311.9**	**0.1**	**0.3**	**93.3**
1A1	**Energy Industries: all fuels**	**N_2O**	**131.8**	**249.7**	**0.1**	**0.3**	**93.6**
1A3e	**Other**	**CO_2**	**342.2**	**85.0**	**0.1**	**0.3**	**93.9**
1A3b	**Road transportation: gaseous**	**CO_2**	**0.0**	**146.1**	**0.1**	**0.2**	**94.1**
2B8	**Chemical industry: Petrochemical and carbon black production**	**CH_4**	**301.8**	**354.2**	**0.1**	**0.2**	**94.4**
2D2	**Paraffin wax use**	**CO_2**	**102.6**	**214.7**	**0.1**	**0.2**	**94.6**
1A4c	**Agriculture/Forestry/Fisheries: liquids**	**CO_2**	**2543.0**	**1631.8**	**0.1**	**0.2**	**94.8**

CRF category		Gas	1990 Estimate (Gg CO_2-eq)	2022 Estimate (Gg CO_2-eq)	Trend Assessment %	% Contribution to trend	Cumulative Total %
3A1	**Young cattle**	**CH_4**	**3138.0**	**2045.2**	**0.1**	**0.2**	**95.0**
2F6	Other	HFC	0.0	128.7	0.1	0.2	95.3
5B	Biological treatment of solid waste: composting	CH_4	4.8	128.8	0.1	0.2	95.5
4F	Other Land	CO_2	93.4	185.8	0.1	0.2	95.7
5D	Wastewater treatment and discharge	N_2O	541.1	495.8	0.1	0.2	95.9
1A3b	Road transportation	N_2O	89.4	180.0	0.1	0.2	96.1
1A4	Solids	CO_2	162.7	0.4	0.1	0.2	96.3
3A2, 3A4	Other	CH_4	576.4	504.0	0.1	0.2	96.5
2A3	Glass production	CO_2	142.4	0.1	0.1	0.2	96.6
3B1	Growing cattle	CH_4	563.3	488.9	0.1	0.2	96.8
3G	Liming	CO_2	183.2	32.2	0.1	0.2	97.0
2A2	Lime production	CO_2	162.7	199.4	0.1	0.1	97.1
1B2b	Natural gas	CH_4	471.6	241.1	0.1	0.1	97.3
4G	Harvested wood products	CO_2	68.6	130.0	0.1	0.1	97.4
1A3b	Road transportation	CH_4	204.2	60.4	0.1	0.1	97.5
4A	Forest Land	CO_2	2168.3	1425.2	0.1	0.1	97.7
5D	Wastewater treatment and discharge	CH_4	421.3	214.1	0.1	0.1	97.8
4B	Cropland	CO_2	2877.6	1918.3	0.1	0.1	97.9
1A1	Energy Industries: all fuels	CH_4	77.4	124.9	0.1	0.1	98.1
2G	Other product manufacture and use	N_2O	200.0	69.8	0.1	0.1	98.2
2A4b	Other uses of soda ash	CO_2	68.6	115.0	0.1	0.1	98.3
5B	Biological treatment of solid waste: composting	N_2O	5.8	71.3	0.1	0.1	98.4
3A3	Swine	CH_4	584.4	471.9	0.1	0.1	98.5
1A4c	Agriculture/Forestry/Fisheries: gaseous	CO_2	7328.7	5143.6	0.1	0.1	98.6
3H	Ureum use	CO_2	1.5	57.0	0.1	0.1	98.7
3B4	Other livestock	N_2O	53.9	87.5	0.0	0.1	98.8
3A1	Other mature cattle	CH_4	235.4	114.4	0.0	0.1	98.9
3B1	Mature dairy cattle	N_2O	169.1	163.0	0.0	0.1	99.0

CRF category		Gas	1990 Estimate (Gg CO_2-eq)	2022 Estimate (Gg CO_2-eq)	Trend Assessment %	% Contribution to trend	Cumulative Total %
2B7	Soda ash production	CO_2	63.8	0.0	0.0	0.1	99.0
4D	Wetlands	CO_2	11.1	48.3	0.0	0.1	99.1
4C	Grassland	CH_4	225.7	195.1	0.0	0.1	99.2
3B5	Indirect emissions	N_2O	346.9	202.7	0.0	0.1	99.2
2D1	Lubricant use	CO_2	84.9	93.1	0.0	0.1	99.3
2D3	Other	CO_2	0.0	33.0	0.0	0.1	99.4
2A4a	Ceramics	CO_2	140.1	128.4	0.0	0.1	99.4
2B1	Ammonia production	CO_2	2695.0	1839.6	0.0	0.0	99.5
1A3a	Domestic aviation	CO_2	84.2	32.1	0.0	0.0	99.5
3B1	Growing cattle	N_2O	130.2	116.4	0.0	0.0	99.6
2H	Other industrial	CO_2	72.5	25.0	0.0	0.0	99.6
2E	Electronic Industry	PFC	22.7	40.3	0.0	0.0	99.6
2G2	SF_6 use	SF_6	213.1	125.5	0.0	0.0	99.7
1A2	Manufacturing Industries and Construction: all fuels	N_2O	32.2	43.4	0.0	0.0	99.7
1A4	Other Sectors: all fuels	N_2O	45.0	51.4	0.0	0.0	99.7
1A2	Manufacturing Industries and Construction: all fuels	CH_4	65.8	60.5	0.0	0.0	99.8
2C1	Iron and steel production	CO_2	43.7	15.9	0.0	0.0	99.8
2B9	Fluorochemical production	PFC	0.0	12.1	0.0	0.0	99.8
2G	Other product manufacture and use	CH_4	57.8	51.1	0.0	0.0	99.8
1A4a	Commercial/Institutional: gaseous	CO_2	7757.8	5368.2	0.0	0.0	99.9
1A4a	Commercial/Institutional: all fuels	CH_4	52.2	45.4	0.0	0.0	99.9
4B	Cropland	CH_4	76.9	45.4	0.0	0.0	99.9
3B3	Swine	N_2O	124.7	79.0	0.0	0.0	99.9
3B1	Other mature cattle	CH_4	24.8	9.9	0.0	0.0	99.9
1A4b	Residential: all fuels	CH_4	503.7	342.2	0.0	0.0	99.9
1A5b	Military use: liquids	CO_2	314.0	211.7	0.0	0.0	99.9
4F	Other Land	N_2O	5.1	9.4	0.0	0.0	99.9
1B1b	Solid fuel transformation	CO_2	110.4	71.4	0.0	0.0	99.9

CRF category		Gas	1990 Estimate (Gg CO_2-eq)	2022 Estimate (Gg CO_2-eq)	Trend Assessment %	% Contribution to trend	Cumulative Total %
4E	Settlements	N_2O	21.0	19.6	0.0	0.0	100.0
1B1b	Solid fuel transformation	CH_4	12.3	5.1	0.0	0.0	100.0
4B	Cropland	N_2O	57.7	43.1	0.0	0.0	100.0
3B2	Sheep	N_2O	6.4	1.5	0.0	0.0	100.0
1A3c	Railways	CO_2	90.7	59.9	0.0	0.0	100.0
4C	Grassland	N_2O	5.5	6.4	0.0	0.0	100.0
1A3 excl 1A3b	Other	CH_4	2.6	4.3	0.0	0.0	100.0
1A3 excl 1A3b	Other	N_2O	6.1	6.3	0.0	0.0	100.0
3B1	Other mature cattle	N_2O	6.2	2.7	0.0	0.0	100.0
4A	Forest Land	CH_4	3.8	3.9	0.0	0.0	100.0
1A5b	Military use: liquids	N_2O	4.9	2.8	0.0	0.0	100.0
4D	Wetlands	N_2O	2.1	2.1	0.0	0.0	100.0
1B2a	Oil	CH_4	22.8	16.0	0.0	0.0	100.0
2G	Other product manufacture and use	CO_2	0.2	0.4	0.0	0.0	100.0
2D2	Paraffin wax use	CH_4	0.2	0.4	0.0	0.0	100.0
5C	Open burning of waste	CH_4	4.2	2.8	0.0	0.0	100.0
1A5b	Military use: liquids	CH_4	0.9	0.5	0.0	0.0	100.0
3B2, 3B4	Other	CH_4	37.8	26.1	0.0	0.0	100.0
5C	Open burning of waste	N_2O	2.1	1.5	0.0	0.0	100.0
4A	Forest Land	N_2O	6.3	4.3	0.0	0.0	100.0
4H	Other	N_2O	0.0	0.0	0.0	0.0	100.0
	total		232242	160991			

A1.5 Approach 2 key category assessment including uncertainties (error propagation)

Using the uncertainty estimate for each key source as a weighting factor (see Annex 2), the key source assessment was performed again. The results of this assessment **including** LULUCF – are presented in Tables A1.7 (contribution to the 2022 annual emissions total) and A1.8 (contribution to the 1990-2022 trend).

The inclusion of uncertainty data results in 42 key sources in total. Among them are seven LULUCF sources: 4A Forest land CO_2, 4B Cropland CO_2, 4B Cropland N_2O, 4C Grassland CO_2, 4C Grassland CH_4, 4E Settlements CO_2 and 4F Other Land CO_2.

*Table A1.7 Source ranking using IPCC Approach 2 **level** assessment for 2021 emissions, including LULUCF (Gg CO_2-eq)*

CRF category		Gas	Gg CO_2-eq 2022	Share %	Uncertainty estimate%	Level * uncertainty%	Share L*U%	Cum. Share L*U%
1A1b	Petroleum Refining: liquids	CO_2	8276.4	5.1	25.7	1.32	8.2	8.2
2B10	Other	CO_2	7641.3	4.7	27.0	1.28	7.9	16.1
4C	Grassland	CO_2	2431.4	1.5	75.0	1.13	7.0	23.1
3Da	Direct emissions from agricultural soils	N_2O	3633.6	2.3	35.7	0.81	5.0	28.1
3Db	Indirect emissions from managed soils	N_2O	515.2	0.3	218.2	0.70	4.3	32.4
1A1a	Public Electricity and Heat Production: solids	CO_2	16480.4	10.2	5.9	0.60	3.7	36.2
3A1	Mature dairy cattle	CH_4	6021.5	3.7	15.1	0.57	3.5	39.7
1A2	Manufacturing Industries and Construction: solids	CO_2	3771.7	2.3	23.8	0.56	3.5	43.1
4B	Cropland	CO_2	1918.3	1.2	44.0	0.52	3.2	46.4
4E	Settlements	CO_2	1190.9	0.7	69.0	0.51	3.2	49.5
3B5	Indirect emissions	N_2O	202.7	0.1	400.4	0.50	3.1	52.7
1A4b	Residential gaseous	CO_2	13316.9	8.3	5.0	0.41	2.6	55.2
3B1	Mature dairy cattle	CH_4	1715.3	1.1	38.1	0.41	2.5	57.8
1A4a	Commercial/Institutional: gaseous	CO_2	5368.2	3.3	10.9	0.36	2.3	60.0
1A4c	Agriculture/Forestry/Fisheries: gaseous	CO_2	5143.6	3.2	10.0	0.32	2.0	62.0
1A1c	Manufacture of Solid Fuels: solids	CO_2	1282.1	0.8	38.5	0.31	1.9	63.9
5A	Solid waste disposal	CH_4	2027.0	1.3	23.7	0.30	1.8	65.7
2B1	Ammonia production	CO_2	1839.6	1.1	25.6	0.29	1.8	67.5
1A4c	Agriculture/Forestry/Fisheries: all fuels	CH_4	970.7	0.6	48.3	0.29	1.8	69.3
3B3	Swine	CH_4	1680.3	1.0	24.7	0.26	1.6	70.9
2A4d	Other	CO_2	647.4	0.4	60.8	0.24	1.5	72.5
2B8	Petrochemical and carbon black production	CO_2	546.0	0.3	70.7	0.24	1.5	73.9
1A3b	Road transportation: diesel oil	CO_2	12784.8	7.9	2.8	0.22	1.4	75.3

CRF category		Gas	Gg CO_2-eq 2022	Share %	Uncertainty estimate%	Level * uncertainty%	Share L*U%	Cum. Share L*U%
1A3b	**Road transportation: gasoline**	**CO_2**	**10863.2**	**6.7**	**2.8**	**0.19**	**1.2**	**76.5**
2F1	**Refrigeration and airconditioning**	**HFC**	**763.6**	**0.5**	**39.3**	**0.19**	**1.2**	**77.7**
4F	**Other Land**	**CO_2**	**185.8**	**0.1**	**152.0**	**0.18**	**1.1**	**78.8**
1A2	**Manufacturing Industries and Construction: gaseous**	**CO_2**	**12608.4**	**7.8**	**2.0**	**0.16**	**1.0**	**79.7**
2B8	**Chemical industry: Petrochemical and carbon black production**	**CH_4**	**354.2**	**0.2**	**70.7**	**0.16**	**1.0**	**80.7**
2D2	**Paraffin wax use**	**CO_2**	**214.7**	**0.1**	**102.0**	**0.14**	**0.8**	**81.5**
2B10	**Other**	**N_2O**	**311.9**	**0.2**	**70.1**	**0.14**	**0.8**	**82.4**
3A3	**Swine**	**CH_4**	**471.9**	**0.3**	**40.5**	**0.12**	**0.7**	**83.1**
1A1a	**Public Electricity and Heat Production: other fuels: waste incineration**	**CO_2**	**2667.1**	**1.7**	**7.1**	**0.12**	**0.7**	**83.9**
3A1	**Young cattle**	**CH_4**	**2045.2**	**1.3**	**9.3**	**0.12**	**0.7**	**84.6**
1A4b	**Residential: all fuels**	**CH_4**	**342.2**	**0.2**	**55.2**	**0.12**	**0.7**	**85.3**
4B	**Cropland**	**N_2O**	**43.1**	**0.0**	**400.0**	**0.11**	**0.7**	**86.0**
1A1c	**Manufacture of Solid Fuels: gaseous**	**CO_2**	**1088.0**	**0.7**	**15.8**	**0.11**	**0.7**	**86.6**
4A	**Forest Land**	**CO_2**	**1425.2**	**0.9**	**12.0**	**0.11**	**0.7**	**87.3**
1A4 excl 1A4c	**Liquids**	**CO_2**	**496.3**	**0.3**	**33.7**	**0.10**	**0.6**	**87.9**
4C	**Grassland**	**CH_4**	**195.1**	**0.1**	**79.0**	**0.10**	**0.6**	**88.5**
5D	**Wastewater treatment and discharge**	**N_2O**	**495.8**	**0.3**	**30.5**	**0.09**	**0.6**	**89.1**
2A2	**Lime production**	**CO_2**	**199.4**	**0.1**	**75.2**	**0.09**	**0.6**	**89.7**
3A2, 3A4	**Other**	**CH_4**	**504.0**	**0.3**	**27.2**	**0.09**	**0.5**	**90.2**
6	Indirect CO_2	CO_2	457.5	0.3	26.9	0.08	0.5	90.7
1A1	Energy Industries: all fuels	N_2O	249.7	0.2	46.6	0.07	0.4	91.1
1A1a	Public Electricity and Heat Production: liquids	CO_2	462.2	0.3	24.9	0.07	0.4	91.6
3B1	Mature dairy cattle	N_2O	163.0	0.1	68.4	0.07	0.4	92.0
1A4c	Agriculture/Forestry/Fisheries: liquids	CO_2	1631.8	1.0	5.8	0.06	0.4	92.4
2A4a	Ceramics	CO_2	128.4	0.1	70.7	0.06	0.3	92.7
1A3b	Road transportation	N_2O	180.0	0.1	50.0	0.06	0.3	93.1

CRF category		Gas	Gg CO_2-eq 2022	Share %	Uncertainty estimate%	Level * uncertainty%	Share L*U%	Cum. Share L*U%
5D	Wastewater treatment and discharge	CH_4	214.1	0.1	41.5	0.06	0.3	93.4
3B1	Growing cattle	CH_4	488.9	0.3	18.0	0.05	0.3	93.8
1B2b	Natural gas	CH_4	241.1	0.1	34.4	0.05	0.3	94.1
4E	Settlements	N_2O	19.6	0.0	400.0	0.05	0.3	94.4
1A1a	Public Electricity and Heat Production: gaseous	CO_2	13541.5	8.4	0.6	0.05	0.3	94.7
3B1	Growing cattle	N_2O	116.4	0.1	61.2	0.04	0.3	94.9
2F6	Other	HFC	128.7	0.1	53.9	0.04	0.3	95.2
2D1	Lubricant use	CO_2	93.1	0.1	70.7	0.04	0.3	95.5
5B	Biological treatment of solid waste: composting	CH_4	128.8	0.1	49.7	0.04	0.2	95.7
1B2c	Venting and flaring	CH_4	119.0	0.1	53.1	0.04	0.2	96.0
1A4	Other Sectors: all fuels	N_2O	51.4	0.0	114.7	0.04	0.2	96.2
2A4b	Other uses of soda ash	CO_2	115.0	0.1	50.0	0.04	0.2	96.4
1B2	Fugitive emissions from oil and gas operations	CO_2	1024.3	0.6	5.0	0.03	0.2	96.6
3B4	Other livestock	N_2O	87.5	0.1	54.2	0.03	0.2	96.8
1A3d	Domestic navigation	CO_2	856.7	0.5	5.3	0.03	0.2	97.0
5B	Biological treatment of solid waste: composting	N_2O	71.3	0.0	60.1	0.03	0.2	97.1
2G2	SF_6 use	SF_6	125.5	0.1	33.5	0.03	0.2	97.3
3B3	Swine	N_2O	79.0	0.0	52.4	0.03	0.2	97.4
1A2	Manufacturing Industries and Construction: liquids	CO_2	1879.7	1.2	2.1	0.02	0.1	97.6
2B4	Caprolactam production	N_2O	124.1	0.1	30.5	0.02	0.1	97.7
4F	Other Land	N_2O	9.4	0.0	400.0	0.02	0.1	97.9
1A1	Energy Industries: all fuels	CH_4	124.9	0.1	30.1	0.02	0.1	98.0
4D	Wetlands	CO_2	48.3	0.0	76.0	0.02	0.1	98.2
4B	Cropland	CH_4	45.4	0.0	79.0	0.02	0.1	98.3
1A2	Manufacturing Industries and Construction: all fuels	N_2O	43.4	0.0	79.7	0.02	0.1	98.4
1A3b	Road transportation	CH_4	60.4	0.0	50.0	0.02	0.1	98.6
3B4	Poultry	CH_4	71.4	0.0	40.5	0.02	0.1	98.7
4C	Grassland	N_2O	6.4	0.0	400.0	0.02	0.1	98.8

CRF category		Gas	Gg CO_2-eq 2022	Share %	Uncertainty estimate%	Level * uncertainty%	Share L*U%	Cum. Share L*U%
2G	Other product manufacture and use	CH_4	51.1	0.0	50.1	0.02	0.1	98.9
3A1	Other mature cattle	CH_4	114.4	0.1	20.9	0.01	0.1	99.0
1A2	Manufacturing Industries and Construction: all fuels	CH_4	60.5	0.0	35.0	0.01	0.1	99.0
2B	Fluorochemical production	HFC	144.0	0.1	13.6	0.01	0.1	99.1
4A	Forest Land	N_2O	4.3	0.0	400.0	0.01	0.1	99.2
1A4a	Commercial/Institutional: all fuels	CH_4	45.4	0.0	38.0	0.01	0.1	99.2
1A3b	Road transportation: LPG	CO_2	291.1	0.2	5.4	0.01	0.1	99.3
3H	Ureum use	CO_2	57.0	0.0	25.0	0.01	0.1	99.4
1A5b	Military use: liquids	CO_2	211.7	0.1	5.8	0.01	0.0	99.4
3B2, 3B4	Other	CH_4	26.1	0.0	46.3	0.01	0.0	99.5
1B2a	Oil	CH_4	16.0	0.0	71.3	0.01	0.0	99.5
1B1b	Solid fuel transformation	CO_2	71.4	0.0	15.0	0.01	0.0	99.5
2B2	Nitric acid production	N_2O	133.7	0.1	7.8	0.01	0.0	99.6
2E	Electronic Industry	PFC	40.3	0.0	25.5	0.01	0.0	99.6
2D3	Other	CO_2	33.0	0.0	26.9	0.01	0.0	99.7
5C	Open burning of waste	CH_4	2.8	0.0	316.2	0.01	0.0	99.7
2G	Other product manufacture and use	N_2O	69.8	0.0	12.4	0.01	0.0	99.7
4D	Wetlands	N_2O	2.1	0.0	400.0	0.01	0.0	99.7
1A3 excl 1A3b	Other	N_2O	6.3	0.0	131.3	0.01	0.0	99.8
3G	Liming	CO_2	32.2	0.0	25.0	0.01	0.0	99.8
1A3b	Road transportation: gaseous	CO_2	146.1	0.1	5.0	0.00	0.0	99.8
1A1b	Petroleum Refining: gaseous	CO_2	1155.6	0.7	0.6	0.00	0.0	99.9
5C	Open burning of waste	N_2O	1.5	0.0	316.2	0.00	0.0	99.9
1A5b	Military use: liquids	N_2O	2.8	0.0	116.5	0.00	0.0	99.9
3B1	Other mature cattle	CH_4	9.9	0.0	33.0	0.00	0.0	99.9
1A3a	Domestic aviation	CO_2	32.1	0.0	9.6	0.00	0.0	99.9
4A	Forest Land	CH_4	3.9	0.0	79.0	0.00	0.0	99.9
2B9	Fluorochemical production	PFC	12.1	0.0	20.0	0.00	0.0	99.9

CRF category		**Gas**	**Gg CO_2-eq 2022**	**Share %**	**Uncertainty estimate%**	**Level * uncertainty%**	**Share L*U%**	**Cum. Share L*U%**
1A3 excl 1A3b	Other	CH_4	4.3	0.0	52.5	0.00	0.0	100.0
3B1	Other mature cattle	N_2O	2.7	0.0	77.8	0.00	0.0	100.0
1A3e	Other	CO_2	85.0	0.1	2.0	0.00	0.0	100.0
3B2	Sheep	N_2O	1.5	0.0	111.7	0.00	0.0	100.0
2H	Other industrial	CO_2	25.0	0.0	5.4	0.00	0.0	100.0
1A3c	Railways	CO_2	59.9	0.0	2.2	0.00	0.0	100.0
4G	Harvested wood products	CO_2	130.0	0.1	1.0	0.00	0.0	100.0
2C1	Iron and steel production	CO_2	15.9	0.0	5.8	0.00	0.0	100.0
2C3	Aluminium production	CO_2	15.1	0.0	5.4	0.00	0.0	100.0
1B1b	Solid fuel transformation	CH_4	5.1	0.0	11.2	0.00	0.0	100.0
2D2	Paraffin wax use	CH_4	0.4	0.0	111.8	0.00	0.0	100.0
1A5b	Military use: liquids	CH_4	0.5	0.0	78.4	0.00	0.0	100.0
2G	Other product manufacture and use	CO_2	0.4	0.0	53.9	0.00	0.0	100.0
1A4	Solids	CO_2	0.4	0.0	42.7	0.00	0.0	100.0
2A3	Glass production	CO_2	0.1	0.0	50.0	0.00	0.0	100.0
2A1	Cement production	CO_2	0.0	0.0	11.0	0.00	0.0	100.0
2B7	Soda ash production	CO_2	0.0	0.0	5.0	0.00	0.0	100.0
2C3	Aluminium production	PFC	0.0	0.0	0.0	0.00	0.0	100.0
4H	Other	N_2O	0.0	0.0	0.0	0.00	0.0	100.0
	SUM		160991					

Lines in bold represent the key sources.

Compared to to Approach 1 level key sources, 1A1a Public Electricity and Heat Production: solids (CO_2), with the highest share in the national total, is not at the top of the list when uncertainty estimates are included. As Table A1.7 shows, 3 smaller but more uncertain sources are among the top five level key sources:

1A1b	Petroleum Refining: liquids	CO_2
2B10	Other	CO_2
4C	Grassland	CO_2

The uncertainty in these emissions is estimated in the range of 25-160%, an order of magnitude higher than the 1% uncertainty for CO_2 from 1A1a Public Electricity and Heat Production: solids.

*Table A1.8 Source ranking using IPCC Approach 2 **trend** assessment for 2022 emissions compared to the base year, including LULUCF (Gg CO_2-eq)*

CRF category		Gas	Gg CO_2-eq 1990	Gg CO_2-eq 2022	Trend assessment%	Uncertainty estimate %	Trend * uncertainty%	% Contr. to trend	Cumulative%
5A	**Solid waste disposal**	**CH_4**	**15320.8**	**2027.0**	**7.7**	**23.7**	**1.8**	**16.9**	**16.9**
3Db	**Indirect emissions from managed soils**	**N_2O**	**1436.3**	**515.2**	**0.4**	**218.2**	**0.9**	**8.7**	**25.6**
2B10	**Other**	**CO_2**	**6738.9**	**7641.3**	**2.7**	**27.0**	**0.7**	**6.7**	**32.3**
1B2c	**Venting and flaring**	**CH_4**	**1669.8**	**119.0**	**0.9**	**53.1**	**0.5**	**4.6**	**36.8**
1A4c	**Agriculture/Forestry/Fisheries: all fuels**	**CH_4**	**81.1**	**970.7**	**0.8**	**48.3**	**0.4**	**3.7**	**40.5**
2B	**Fluorochemical production**	**HFC**	**4697.2**	**144.0**	**2.8**	**13.6**	**0.4**	**3.5**	**44.0**
1A1b	**Petroleum Refining: liquids**	**CO_2**	**9968.2**	**8276.4**	**1.2**	**25.7**	**0.3**	**2.9**	**46.9**
4E	**Settlements**	**CO_2**	**1003.7**	**1190.9**	**0.4**	**69.0**	**0.3**	**2.8**	**49.8**
3B1	**Mature dairy cattle**	**CH_4**	**1212.7**	**1715.3**	**0.8**	**38.1**	**0.3**	**2.8**	**52.5**
3A1	**Mature dairy cattle**	**CH_4**	**5805.2**	**6021.5**	**1.8**	**15.1**	**0.3**	**2.5**	**55.1**
2F1	**Refrigeration and airconditioning**	**HFC**	**0.0**	**763.6**	**0.7**	**39.3**	**0.3**	**2.5**	**57.5**
4C	**Grassland**	**CO_2**	**2929.8**	**2431.4**	**0.4**	**75.0**	**0.3**	**2.5**	**60.0**
2B2	**Nitric acid production**	**N_2O**	**5410.9**	**133.7**	**3.2**	**7.8**	**0.3**	**2.3**	**62.4**
3Da	**Direct emissions from agricultural soils**	**N_2O**	**6346.1**	**3633.6**	**0.7**	**35.7**	**0.2**	**2.3**	**64.7**
1A1c	**Manufacture of Solid Fuels: solids**	**CO_2**	**916.3**	**1282.1**	**0.6**	**38.5**	**0.2**	**2.1**	**66.7**
3B3	**Swine**	**CH_4**	**3772.8**	**1680.3**	**0.8**	**24.7**	**0.2**	**1.9**	**68.6**
2B8	**Petrochemical and carbon black production**	**CO_2**	**335.6**	**546.0**	**0.3**	**70.7**	**0.2**	**1.8**	**70.5**
1A2	**Manufacturing Industries and Construction: solids**	**CO_2**	**6623.4**	**3771.7**	**0.7**	**23.8**	**0.2**	**1.6**	**72.1**
2A4d	**Other**	**CO_2**	**481.2**	**647.4**	**0.3**	**60.8**	**0.2**	**1.6**	**73.7**
4F	**Other Land**	**CO_2**	**93.4**	**185.8**	**0.1**	**152.0**	**0.2**	**1.5**	**75.2**

CRF category		Gas	Gg CO_2-eq 1990	Gg CO_2-eq 2022	Trend assessment%	Uncertainty estimate %	Trend * uncertainty%	% Contr. to trend	Cumulative%
1A1a	**Public Electricity and Heat Production: other fuels: waste incineration**	**CO_2**	**601.5**	**2667.1**	**2.0**	**7.1**	**0.1**	**1.3**	**76.5**
1A4 excl 1A4c	**Liquids**	**CO_2**	**1366.6**	**496.3**	**0.4**	**33.7**	**0.1**	**1.3**	**77.8**
3B5	**Indirect emissions**	**N_2O**	**346.9**	**202.7**	**0.0**	**400.4**	**0.1**	**1.3**	**79.1**
2D2	**Paraffin wax use**	**CO_2**	**102.6**	**214.7**	**0.1**	**102.0**	**0.1**	**1.2**	**80.3**
2B10	**Other**	**N_2O**	**219.4**	**311.9**	**0.1**	**70.1**	**0.1**	**0.9**	**81.2**
1A3b	**Road transportation: diesel oil**	**CO_2**	**13008.5**	**12784.8**	**3.4**	**2.8**	**0.1**	**0.9**	**82.1**
3B4	**Poultry**	**CH_4**	**481.7**	**71.4**	**0.2**	**40.5**	**0.1**	**0.9**	**83.0**
2B8	**Chemical industry: Petrochemical and carbon black production**	**CH_4**	**301.8**	**354.2**	**0.1**	**70.7**	**0.1**	**0.9**	**83.8**
2B4	**Caprolactam production**	**N_2O**	**658.0**	**124.1**	**0.3**	**30.5**	**0.1**	**0.8**	**84.7**
1A3b	**Road transportation: gasoline**	**CO_2**	**10664.4**	**10863.2**	**3.1**	**2.8**	**0.1**	**0.8**	**85.5**
1A1a	**Public Electricity and Heat Production: solids**	**CO_2**	**25862.2**	**16480.4**	**1.3**	**5.9**	**0.1**	**0.7**	**86.2**
1A3b	**Road transportation: LPG**	**CO_2**	**2578.4**	**291.1**	**1.3**	**5.4**	**0.1**	**0.7**	**86.9**
1A1a	**Public Electricity and Heat Production: liquids**	**CO_2**	**233.2**	**462.2**	**0.3**	**24.9**	**0.1**	**0.6**	**87.5**
1A1	**Energy Industries: all fuels**	**N_2O**	**131.8**	**249.7**	**0.1**	**46.6**	**0.1**	**0.6**	**88.1**
2F6	**Other**	**HFC**	**0.0**	**128.7**	**0.1**	**53.9**	**0.1**	**0.6**	**88.7**
2A2	**Lime production**	**CO_2**	**162.7**	**199.4**	**0.1**	**75.2**	**0.1**	**0.5**	**89.2**
5B	**Biological treatment of solid waste: composting**	**CH_4**	**4.8**	**128.8**	**0.1**	**49.7**	**0.1**	**0.5**	**89.7**
1A3b	**Road transportation**	**N_2O**	**89.4**	**180.0**	**0.1**	**50.0**	**0.1**	**0.5**	**90.2**
2A3	Glass production	CO_2	142.4	0.1	0.1	50.0	0.0	0.4	90.6
1A4	Solids	CO_2	162.7	0.4	0.1	42.7	0.0	0.4	91.0
6	Indirect CO_2	CO_2	917.2	457.5	0.2	26.9	0.0	0.4	91.4
1A1c	Manufacture of Solid Fuels: gaseous	CO_2	1184.2	1088.0	0.2	15.8	0.0	0.4	91.8
1A3b	Road transportation	CH_4	204.2	60.4	0.1	50.0	0.0	0.3	92.1

CRF category		Gas	Gg CO_2-eq 1990	Gg CO_2-eq 2022	Trend assessment%	Uncertainty estimate %	Trend * uncertainty%	% Contr. to trend	Cumulative%
5B	Biological treatment of solid waste: composting	N_2O	5.8	71.3	0.1	60.1	0.0	0.3	92.4
5D	Wastewater treatment and discharge	N_2O	541.1	495.8	0.1	30.5	0.0	0.3	92.7
2A4b	Other uses of soda ash	CO_2	68.6	115.0	0.1	50.0	0.0	0.3	93.0
4B	Cropland	CO_2	2877.6	1918.3	0.1	44.0	0.0	0.3	93.3
5D	Wastewater treatment and discharge	CH_4	421.3	214.1	0.1	41.5	0.0	0.3	93.6
2A1	Cement production	CO_2	415.8	0.0	0.3	11.0	0.0	0.3	93.8
3B1	Mature dairy cattle	N_2O	169.1	163.0	0.0	68.4	0.0	0.3	94.1
4D	Wetlands	CO_2	11.1	48.3	0.0	76.0	0.0	0.3	94.4
4C	Grassland	CH_4	225.7	195.1	0.0	79.0	0.0	0.3	94.6
1B2b	Natural gas	CH_4	471.6	241.1	0.1	34.4	0.0	0.2	94.9
3A2, 3A4	Other	CH_4	576.4	504.0	0.1	27.2	0.0	0.2	95.1
3B4	Other livestock	N_2O	53.9	87.5	0.0	54.2	0.0	0.2	95.3
3A3	Swine	CH_4	584.4	471.9	0.1	40.5	0.0	0.2	95.5
1A1a	Public Electricity and Heat Production: gaseous	CO_2	13329.1	13541.5	3.9	0.6	0.0	0.2	95.7
1B2	Fugitive emissions from oil and gas operations	CO_2	774.6	1024.3	0.4	5.0	0.0	0.2	95.9
2D1	Lubricant use	CO_2	84.9	93.1	0.0	70.7	0.0	0.2	96.1
1A4b	Residential gaseous	CO_2	19894.1	13316.9	0.4	5.0	0.0	0.2	96.3
3G	Liming	CO_2	183.2	32.2	0.1	25.0	0.0	0.2	96.5
4F	Other Land	N_2O	5.1	9.4	0.0	400.0	0.0	0.2	96.7
1A4	Other Sectors: all fuels	N_2O	45.0	51.4	0.0	114.7	0.0	0.2	96.9
2A4a	Ceramics	CO_2	140.1	128.4	0.0	70.7	0.0	0.2	97.1
1A1	Energy Industries: all fuels	CH_4	77.4	124.9	0.1	30.1	0.0	0.2	97.3
4E	Settlements	N_2O	21.0	19.6	0.0	400.0	0.0	0.2	97.5
1A2	Manufacturing Industries and Construction: liquids	CO_2	4095.6	1879.7	0.9	2.1	0.0	0.2	97.6
1A3d	Domestic navigation	CO_2	725.5	856.7	0.3	5.3	0.0	0.2	97.8
3B1	Growing cattle	CH_4	563.3	488.9	0.1	18.0	0.0	0.1	97.9

CRF category		Gas	Gg CO_2-eq 1990	Gg CO_2-eq 2022	Trend assessment%	Uncertainty estimate %	Trend * uncertainty%	% Contr. to trend	Cumulative%
1A2	Manufacturing Industries and Construction: all fuels	N_2O	32.2	43.4	0.0	79.7	0.0	0.1	98.1
3B1	Growing cattle	N_2O	130.2	116.4	0.0	61.2	0.0	0.1	98.2
2C3	Aluminium production	CO_2	408.4	15.1	0.2	5.4	0.0	0.1	98.3
3H	Ureum use	CO_2	1.5	57.0	0.1	25.0	0.0	0.1	98.4
4B	Cropland	N_2O	57.7	43.1	0.0	400.0	0.0	0.1	98.5
3A1	Young cattle	CH_4	3138.0	2045.2	0.1	9.3	0.0	0.1	98.6
1A2	Manufacturing Industries and Construction: gaseous	CO_2	19044.2	12608.4	0.5	2.0	0.0	0.1	98.7
4C	Grassland	N_2O	5.5	6.4	0.0	400.0	0.0	0.1	98.8
3A1	Other mature cattle	CH_4	235.4	114.4	0.0	20.9	0.0	0.1	98.9
4A	Forest Land	CO_2	2168.3	1425.2	0.1	12.0	0.0	0.1	99.0
2D3	Other	CO_2	0.0	33.0	0.0	26.9	0.0	0.1	99.1
2G	Other product manufacture and use	N_2O	200.0	69.8	0.1	12.4	0.0	0.1	99.1
1A4c	Agriculture/Forestry/Fisheries: liquids	CO_2	2543.0	1631.8	0.1	5.8	0.0	0.1	99.2
2G2	SF_6 use	SF_6	213.1	125.5	0.0	33.5	0.0	0.1	99.3
2B1	Ammonia production	CO_2	2695.0	1839.6	0.0	25.6	0.0	0.1	99.3
1A3b	Road transportation: gaseous	CO_2	0.0	146.1	0.1	5.0	0.0	0.1	99.4
1A4c	Agriculture/Forestry/Fisheries: gaseous	CO_2	7328.7	5143.6	0.1	10.0	0.0	0.1	99.4
4B	Cropland	CH_4	76.9	45.4	0.0	79.0	0.0	0.1	99.5
2E	Electronic Industry	PFC	22.7	40.3	0.0	25.5	0.0	0.1	99.5
2G	Other product manufacture and use	CH_4	57.8	51.1	0.0	50.1	0.0	0.0	99.6
1A2	Manufacturing Industries and Construction: all fuels	CH_4	65.8	60.5	0.0	35.0	0.0	0.0	99.6
3B3	Swine	N_2O	124.7	79.0	0.0	52.4	0.0	0.0	99.7
1A4b	Residential: all fuels	CH_4	503.7	342.2	0.0	55.2	0.0	0.0	99.7
1A4a	Commercial/Institutional: all fuels	CH_4	52.2	45.4	0.0	38.0	0.0	0.0	99.7
3B2	Sheep	N_2O	6.4	1.5	0.0	111.7	0.0	0.0	99.7
1A3e	Other	CO_2	342.2	85.0	0.1	2.0	0.0	0.0	99.8

CRF category		Gas	Gg CO_2-eq 1990	Gg CO_2-eq 2022	Trend assessment%	Uncertainty estimate %	Trend * uncertainty%	% Contr. to trend	Cumulative%
1A3 excl 1A3b	Other	N_2O	6.1	6.3	0.0	131.3	0.0	0.0	99.8
1A3a	Domestic aviation	CO_2	84.2	32.1	0.0	9.6	0.0	0.0	99.8
2B9	Fluorochemical production	PFC	0.0	12.1	0.0	20.0	0.0	0.0	99.8
1A1b	Petroleum Refining: gaseous	CO_2	1042.2	1155.6	0.4	0.6	0.0	0.0	99.8
3B1	Other mature cattle	CH_4	24.8	9.9	0.0	33.0	0.0	0.0	99.9
4D	Wetlands	N_2O	2.1	2.1	0.0	400.0	0.0	0.0	99.9
2B7	Soda ash production	CO_2	63.8	0.0	0.0	5.0	0.0	0.0	99.9
2H	Other industrial	CO_2	72.5	25.0	0.0	5.4	0.0	0.0	99.9
1A3 excl 1A3b	Other	CH_4	2.6	4.3	0.0	52.5	0.0	0.0	99.9
3B1	Other mature cattle	N_2O	6.2	2.7	0.0	77.8	0.0	0.0	99.9
1A4a	Commercial/Institutional: gaseous	CO_2	7757.8	5368.2	0.0	10.9	0.0	0.0	99.9
4A	Forest Land	CH_4	3.8	3.9	0.0	79.0	0.0	0.0	100.0
2C1	Iron and steel production	CO_2	43.7	15.9	0.0	5.8	0.0	0.0	100.0
4G	Harvested wood products	CO_2	68.6	130.0	0.1	1.0	0.0	0.0	100.0
1B1b	Solid fuel transformation	CO_2	110.4	71.4	0.0	15.0	0.0	0.0	100.0
1A5b	Military use: liquids	N_2O	4.9	2.8	0.0	116.5	0.0	0.0	100.0
5C	Open burning of waste	CH_4	4.2	2.8	0.0	316.2	0.0	0.0	100.0
1B1b	Solid fuel transformation	CH_4	12.3	5.1	0.0	11.2	0.0	0.0	100.0
1A5b	Military use: liquids	CO_2	314.0	211.7	0.0	5.8	0.0	0.0	100.0
2D2	Paraffin wax use	CH_4	0.2	0.4	0.0	111.8	0.0	0.0	100.0
5C	Open burning of waste	N_2O	2.1	1.5	0.0	316.2	0.0	0.0	100.0
1B2a	Oil	CH_4	22.8	16.0	0.0	71.3	0.0	0.0	100.0

CRF category		Gas	Gg CO_2-eq 1990	Gg CO_2-eq 2022	Trend assessment%	Uncertainty estimate %	Trend * uncertainty%	% Contr. to trend	Cumulative%
2G	Other product manufacture and use	CO_2	0.2	0.4	0.0	53.9	0.0	0.0	100.0
1A5b	Military use: liquids	CH_4	0.9	0.5	0.0	78.4	0.0	0.0	100.0
1A3c	Railways	CO_2	90.7	59.9	0.0	2.2	0.0	0.0	100.0
3B2, 3B4	Other	CH_4	37.8	26.1	0.0	46.3	0.0	0.0	100.0
4A	Forest Land	N_2O	6.3	4.3	0.0	400.0	0.0	0.0	100.0
2C3	Aluminium production	PFC	2373.9	0.0	1.5	0.0	0.0	0.0	100.0
4H	Other	N_2O	0.0	0.0	0.0	0.0	0.0	0.0	100.0
	Total		232242	160991					

Lines in bold represent the key sources.

Annex 2 Assessment of uncertainty

2.1 Description of methodology used for estimating uncertainty

In this NIR an Approach 2 assessment has been performed to estimate the uncertainty in total national GHG emissions and emissions trends. The assessment is carried out through error propagation (IPCC Guidelines 2006). Total uncertainty per CRF category is derived from uncertainties in both emission factors (EF) and activity data (AD). Details of the uncertainty analysis can be found in the methodology reports (RIVM reports 2024-0014, 2024-0015, 2024-0016 and 2024-0023 and Van Baren et al. (2024)). Results of this analysis for both level and trend are presented in table A2.1.

Uncertainties for the activity data and EFs are derived from a mixture of empirical data and expert judgement and are presented here as half the 95% confidence interval. The reason for halving the 95% confidence interval is that the value then corresponds to the familiar plus or minus value when uncertainties are loosely quoted as 'plus or minus x%'. Since 2012, all data on uncertainty for each source have been included in the PRTR database. At the start of the NIR compilation, the Task Forces are asked to submit new uncertainty information, which is included in the annual key category analysist of the NIR.

Table A2.1 Level and trend uncertainty estimates (based on error propagation) related to 2022 emissions (trend: 1990 – 2022)

	Uncertainty in emissions level	**Uncertainty in emissions trend**
CO_2	±3%	±1% of 22% decrease
CH_4	±8%	±5% of 50% decrease
N_2O	±29%	±5% of 59% decrease
F-gases	±25%	±5% of 83% decrease
Total	±3%	±3% of 31% decrease

Details of the Approach 2 calculation can be found in Table A2.3. It should be stressed that most uncertainty estimates in Table A2.3 are ultimately based on collective expert judgement and are therefore themselves rather uncertain (usually in the order of 50%). Nevertheless, these estimates help to identify the most important uncertain sources. For this purpose, a reasonable order-of-magnitude estimate of the uncertainty in activity data and in EFs is usually sufficient. Uncertainty estimates are a means of identifying and prioritizing inventory improvement activities, rather than an objective in themselves.

Part of the uncertainty is due to an inherent lack of knowledge concerning the sources. Another part, however, can be attributed to elements of the inventory whose uncertainty could be reduced over time by dedicated research initiated by either the NIE or other researchers. Table A2.2 ranks the ten sources contributing most to the *trend* uncertainty in the national total emissions including LULUCF in 2021 (based on the Approach 1).

Table A2.2 Ten sources contributing most to trend uncertainty in the national total in 2022 emissions (uncertainty assessment based on error propagation)

CRF cat.	**Category**	**Gas**	**Uncertainty introduced into the trend in total national emissions (%)**
5A	Solid waste disposal	CH_4	16.9
3Db	Indirect emissions from managed soils	N_2O	8.7
2B10	Other	CO_2	6.7
1B2c	Venting and flaring	CH_4	4.6
1A4c	Agriculture/Forestry/Fisheries: all fuels	CH_4	3.7
2B	Fluorochemical production	HFC	3.5
1A1b	Petroleum Refining: liquids	CO_2	2.9
4E	Settlements	CO_2	2.8
3B1	Mature dairy cattle	CH_4	2.8
3A1	Mature dairy cattle	CH_4	2.5

Table A2.3 Detailed level and trend uncertainty assessment 1990–2022 with the categories of the IPCC potential key source list (without adjustment for correlation sources), including LULUCF. Ranked in order of their contribution to the variance in 2022

CRF category		**Gas**	**CO_2-eq base year (Gg)**	**CO_2-eq last year (Gg)**	**AD uncertainty**	**AD uncertainty**	**EF Uncertainty estimate**	**EF Uncertainty estimate**	**Combined Uncertainty estimate**	**Combined Uncertainty estimate**	**Contribution to variance in last year**	**Inventory trend in national emissions compared to base year %**	**Uncertainty introduced into the trend in total national emissions**
					(-)	(+)	(-)	(+)	(-)	(+)		(% BY)	*(-) and (+)*
1A1b	Petroleum Refining: liquids	CO_2	9968.2	8276.4	0.05	0.05	0.25	0.25	0.26	0.26	0.19	-17.0	0.29
2B10	Other	CO_2	6738.9	7641.3	0.01	0.01	0.27	0.27	0.27	0.27	0.18	13.4	0.35
4C	Grassland	CO_2	2929.8	2431.4	0.00	0.00	0.75	0.75	0.75	0.75	0.14	-17.0	0.13
3Da	Direct emissions from agricultural soils	N_2O	6346.1	3633.6	0.08	0.08	0.35	0.35	0.36	0.36	0.07	-42.7	0.22
3Db	Indirect emissions from managed soils	N_2O	1436.3	515.2	0.32	0.32	2.16	2.16	2.18	2.18	0.05	-64.1	0.46
1A1a	Public Electricity and Heat Production: solids	CO_2	25862.2	16480.4	0.01	0.01	0.06	0.06	0.06	0.06	0.04	-36.3	0.10
3A1	Mature dairy cattle	CH4	5805.2	6021.5	0.02	0.02	0.15	0.15	0.15	0.15	0.04	3.7	0.15
1A2	Manufacturing Industries and Construction: solids	CO_2	6623.4	3771.7	0.02	0.02	0.24	0.24	0.24	0.24	0.03	-43.1	0.09
4B	Cropland	CO_2	2877.6	1918.3	0.00	0.00	0.44	0.44	0.44	0.44	0.03	-33.3	0.01
4E	Settlements	CO_2	1003.7	1190.9	0.00	0.00	0.69	0.69	0.69	0.69	0.03	18.7	0.15
3B5	Indirect emissions	N_2O	346.9	202.7	0.18	0.18	4.00	4.00	4.00	4.00	0.03	-41.6	0.07
1A4b	Residential gaseous	CO_2	19894.1	13316.9	0.05	0.05	0.00	0.00	0.05	0.05	0.02	-33.1	0.41
3B1	Mature dairy cattle	CH4	1212.7	1715.3	0.02	0.02	0.38	0.38	0.38	0.38	0.02	41.4	0.14
1A4a	Commercial/Institutional: gaseous	CO_2	7757.8	5368.2	0.11	0.11	0.00	0.00	0.11	0.11	0.01	-30.8	0.36
1A4c	Agriculture/Forestry/Fisheries: gaseous	CO_2	7328.7	5143.6	0.10	0.10	0.00	0.00	0.10	0.10	0.01	-29.8	0.31
1A1c	Manufacture of Solid Fuels: solids	CO_2	916.3	1282.1	0.14	0.14	0.36	0.36	0.39	0.39	0.01	39.9	0.15

CRF category		Gas	CO_2-eq base year (Gg)	CO_2-eq last year (Gg)	AD uncertainty	AD uncertainty	EF Uncertainty estimate	EF Uncertainty estimate	Combined Uncertainty estimate	Combined Uncertainty estimate	Contribution to variance in last year	Inventory trend in national emissions compared to base year %	Uncertainty introduced into the trend in total national emissions
5A	Solid waste disposal	CH4	15320.8	2027.0	0.00	0.00	0.24	0.24	0.24	0.24	0.01	-86.8	0.88
2B1	Ammonia production	CO_2	2695.0	1839.6	0.05	0.05	0.25	0.25	0.26	0.26	0.01	-31.7	0.06
1A4c	Agriculture/Forestry/Fisheries: all fuels	CH_4	81.1	970.7	0.10	0.10	0.47	0.47	0.48	0.48	0.01	1096.3	0.19
3B3	Swine	CH_4	3772.8	1680.3	0.08	0.08	0.23	0.23	0.25	0.25	0.01	-55.5	0.13
2A4d	Other	CO_2	481.2	647.4	0.25	0.25	0.55	0.55	0.61	0.61	0.01	34.5	0.12
2B8	Petrochemical and carbon black production	CO_2	335.6	546.0	0.50	0.50	0.50	0.50	0.71	0.71	0.01	62.7	0.18
1A3b	Road transportation: diesel oil	CO_2	13008.5	12784.8	0.02	0.02	0.02	0.02	0.03	0.03	0.01	-1.7	0.16
1A3b	Road transportation: gasoline	CO_2	10664.4	10863.2	0.02	0.02	0.02	0.02	0.03	0.03	0.00	1.9	0.14
2F1	Refrigeration and airconditioning	HFC	0.0	763.6	0.15	0.15	0.37	0.37	0.39	0.39	0.00	763631613.6	0.14
4F	Other Land	CO_2	93.4	185.8	0.00	0.00	1.52	1.52	1.52	1.52	0.00	99.0	0.08
1A2	Manufacturing Industries and Construction: gaseous	CO_2	19044.2	12608.4	0.02	0.02	0.00	0.00	0.02	0.02	0.00	-33.8	0.15
2B8	Chemical industry: Petrochemical and carbon black production	CH_4	301.8	354.2	0.50	0.50	0.50	0.50	0.71	0.71	0.00	17.4	0.11
2D2	Paraffin wax use	CO_2	102.6	214.7	1.00	1.00	0.20	0.20	1.02	1.02	0.00	109.4	0.13
2B10	Other	N_2O	219.4	311.9	0.50	0.50	0.50	0.50	0.70	0.70	0.00	42.2	0.10
3A3	Swine	CH_4	584.4	471.9	0.06	0.06	0.40	0.40	0.41	0.41	0.00	-19.3	0.02
1A1a	Public Electricity and Heat Production: other fuels: waste incineration	CO_2	601.5	2667.1	0.03	0.03	0.06	0.06	0.07	0.07	0.00	343.4	0.08
3A1	Young cattle	CH_4	3138.0	2045.2	0.01	0.01	0.09	0.09	0.09	0.09	0.00	-34.8	0.01

CRF category		Gas	CO_2-eq base year (Gg)	CO_2-eq last year (Gg)	AD uncertainty	AD uncertainty	EF Uncertainty estimate	EF Uncertainty estimate	Combined Uncertainty estimate	Combined Uncertainty estimate	Contribution to variance in last year	Inventory trend in national emissions compared to base year %	Uncertainty introduced into the trend in total national emissions
1A4b	Residential: all fuels	CH_4	503.7	342.2	0.09	0.09	0.54	0.54	0.55	0.55	0.00	-32.1	0.02
4B	Cropland	N_2O	57.7	43.1	0.00	0.00	4.00	4.00	4.00	4.00	0.00	-25.4	0.01
1A1c	Manufacture of Solid Fuels: gaseous	CO_2	1184.2	1088.0	0.15	0.15	0.05	0.05	0.16	0.16	0.00	-8.1	0.10
4A	Forest Land	CO_2	2168.3	1425.2	0.00	0.00	0.12	0.12	0.12	0.12	0.00	-34.3	0.00
1A4 excl 1A4c	Liquids	CO_2	1366.6	496.3	0.34	0.34	0.01	0.01	0.34	0.34	0.00	-63.7	0.10
4C	Grassland	CH_4	225.7	195.1	0.00	0.00	0.79	0.79	0.79	0.79	0.00	-13.6	0.01
5D	Wastewater treatment and discharge	N_2O	541.1	495.8	0.27	0.27	0.15	0.15	0.30	0.30	0.00	-8.4	0.08
2A2	Lime production	CO_2	162.7	199.4	0.75	0.75	0.05	0.05	0.75	0.75	0.00	22.6	0.09
3A2, 3A4	Other	CH_4	576.4	504.0	0.17	0.17	0.21	0.21	0.27	0.27	0.00	-12.6	0.05
6	Indirect CO_2	CO_2	917.2	457.5	0.25	0.25	0.10	0.10	0.27	0.27	0.00	-50.1	0.07
1A1	Energy Industries: all fuels	N_2O	131.8	249.7	0.01	0.01	0.47	0.47	0.47	0.47	0.00	89.5	0.03
1A1a	Public Electricity and Heat Production: liquids	CO_2	233.2	462.2	0.01	0.01	0.25	0.25	0.25	0.25	0.00	98.2	0.03
3B1	Mature dairy cattle	N_2O	169.1	163.0	0.02	0.02	0.68	0.68	0.68	0.68	0.00	-3.6	0.01
1A4c	Agriculture/Forestry/Fisheries: liquids	CO_2	2543.0	1631.8	0.06	0.06	0.01	0.01	0.06	0.06	0.00	-35.8	0.06
2A4a	Ceramics	CO_2	140.1	128.4	0.50	0.50	0.50	0.50	0.71	0.71	0.00	-8.4	0.04
1A3b	Road transportation	N_2O	89.4	180.0	0.02	0.02	0.50	0.50	0.50	0.50	0.00	101.2	0.03
5D	Wastewater treatment and discharge	CH_4	421.3	214.1	0.14	0.14	0.39	0.39	0.42	0.42	0.00	-49.2	0.02
3B1	Growing cattle	CH_4	563.3	488.9	0.01	0.01	0.18	0.18	0.18	0.18	0.00	-13.2	0.01
1B2b	Natural gas	CH_4	471.6	241.1	0.01	0.01	0.34	0.34	0.34	0.34	0.00	-48.9	0.01
4E	Settlements	N_2O	21.0	19.6	0.00	0.00	4.00	4.00	4.00	4.00	0.00	-6.9	0.01

CRF category		Gas	CO_2-eq base year (Gg)	CO_2-eq last year (Gg)	AD uncertainty	AD uncertainty	EF Uncertainty estimate	EF Uncertainty estimate	Combined Uncertainty estimate	Combined Uncertainty estimate	Contribution to variance in last year	Inventory trend in national emissions compared to base year %	Uncertainty introduced into the trend in total national emissions
1A1a	Public Electricity and Heat Production: gaseous	CO_2	13329.1	13541.5	0.01	0.01	0.00	0.00	0.01	0.01	0.00	1.6	0.04
3B1	Growing cattle	N_2O	130.2	116.4	0.23	0.23	0.57	0.57	0.61	0.61	0.00	-10.6	0.02
2F6	Other	HFC	0.0	128.7	0.20	0.20	0.50	0.50	0.54	0.54	0.00	128715124.0	0.03
2D1	Lubricant use	CO_2	84.9	93.1	0.50	0.50	0.50	0.50	0.71	0.71	0.00	9.6	0.03
5B	Biological treatment of solid waste: composting	CH_4	4.8	128.8	0.12	0.12	0.48	0.48	0.50	0.50	0.00	2589.6	0.03
1B2c	Venting and flaring	CH_4	1669.8	119.0	0.49	0.49	0.20	0.20	0.53	0.53	0.00	-92.9	0.10
1A4	Other Sectors: all fuels	N_2O	45.0	51.4	0.11	0.11	1.14	1.14	1.15	1.15	0.00	14.1	0.01
2A4b	Other uses of soda ash	CO_2	68.6	115.0	0.00	0.00	0.50	0.50	0.50	0.50	0.00	67.7	0.01
1B2	Fugitive emissions from oil and gas operations	CO_2	774.6	1024.3	0.01	0.01	0.05	0.05	0.05	0.05	0.00	32.2	0.01
3B4	Other livestock	N_2O	53.9	87.5	0.12	0.12	0.53	0.53	0.54	0.54	0.00	62.3	0.01
1A3d	Domestic navigation	CO_2	725.5	856.7	0.05	0.05	0.02	0.02	0.05	0.05	0.00	18.1	0.03
5B	Biological treatment of solid waste: composting	N_2O	5.8	71.3	0.11	0.11	0.59	0.59	0.60	0.60	0.00	1130.0	0.02
2G2	SF_6 use	SF_6	213.1	125.5	0.30	0.30	0.15	0.15	0.34	0.34	0.00	-41.1	0.02
3B3	Swine	N_2O	124.7	79.0	0.18	0.18	0.49	0.49	0.52	0.52	0.00	-36.7	0.01
1A2	Manufacturing Industries and Construction: liquids	CO_2	4095.6	1879.7	0.01	0.01	0.02	0.02	0.02	0.02	0.00	-54.1	0.01
2B4	Caprolactam production	N_2O	658.0	124.1	0.20	0.20	0.23	0.23	0.30	0.30	0.00	-81.1	0.04
4F	Other Land	N_2O	5.1	9.4	0.00	0.00	4.00	4.00	4.00	4.00	0.00	85.7	0.01
1A1	Energy Industries: all fuels	CH_4	77.4	124.9	0.01	0.01	0.30	0.30	0.30	0.30	0.00	61.4	0.01
4D	Wetlands	CO_2	11.1	48.3	0.00	0.00	0.76	0.76	0.76	0.76	0.00	336.7	0.01
4B	Cropland	CH_4	76.9	45.4	0.00	0.00	0.79	0.79	0.79	0.79	0.00	-41.0	0.00
1A2	Manufacturing Industries and Construction: all fuels	N_2O	32.2	43.4	0.05	0.05	0.80	0.80	0.80	0.80	0.00	34.5	0.01

CRF category		Gas	CO_2-eq base year (Gg)	CO_2-eq last year (Gg)	AD uncertainty	AD uncertainty	EF Uncertainty estimate	EF Uncertainty estimate	Combined Uncertainty estimate	Combined Uncertainty estimate	Contribution to variance in last year	Inventory trend in national emissions compared to base year %	Uncertainty introduced into the trend in total national emissions
1A3b	Road transportation	CH_4	204.2	60.4	0.02	0.02	0.50	0.50	0.50	0.50	0.00	-70.4	0.02
3B4	Poultry	CH_4	481.7	71.4	0.02	0.02	0.40	0.40	0.41	0.41	0.00	-85.2	0.05
4C	Grassland	N_2O	5.5	6.4	0.00	0.00	4.00	4.00	4.00	4.00	0.00	16.7	0.00
2G	Other product manufacture and use	CH_4	57.8	51.1	0.10	0.10	0.49	0.49	0.50	0.50	0.00	-11.5	0.00
3A1	Other mature cattle	CH_4	235.4	114.4	0.02	0.02	0.21	0.21	0.21	0.21	0.00	-51.4	0.00
1A2	Manufacturing Industries and Construction: all fuels	CH_4	65.8	60.5	0.03	0.03	0.35	0.35	0.35	0.35	0.00	-8.0	0.00
2B	Fluorochemical production	HFC	4697.2	144.0	0.00	0.00	0.14	0.14	0.14	0.14	0.00	-96.9	0.18
4A	Forest Land	N_2O	6.3	4.3	0.00	0.00	4.00	4.00	4.00	4.00	0.00	-30.8	0.00
1A4a	Commercial/Institutional: all fuels	CH_4	52.2	45.4	0.08	0.08	0.37	0.37	0.38	0.38	0.00	-13.0	0.00
1A3b	Road transportation: LPG	CO_2	2578.4	291.1	0.05	0.05	0.02	0.02	0.05	0.05	0.00	-88.7	0.02
3H	Ureum use	CO_2	1.5	57.0	0.25	0.25	0.01	0.01	0.25	0.25	0.00	3662.0	0.01
1A5b	Military use: liquids	CO_2	314.0	211.7	0.05	0.05	0.02	0.02	0.06	0.06	0.00	-32.6	0.01
3B2, 3B4	Other	CH_4	37.8	26.1	0.27	0.27	0.38	0.38	0.46	0.46	0.00	-30.9	0.00
1B2a	Oil	CH_4	22.8	16.0	0.02	0.02	0.71	0.71	0.71	0.71	0.00	-29.5	0.00
1B1b	Solid fuel transformation	CO_2	110.4	71.4	0.00	0.00	0.15	0.15	0.15	0.15	0.00	-35.4	0.00
2B2	Nitric acid production	N_2O	5410.9	133.7	0.05	0.05	0.06	0.06	0.08	0.08	0.00	-97.5	0.09
2E	Electronic Industry	PFC	22.7	40.3	0.05	0.05	0.25	0.25	0.25	0.25	0.00	77.0	0.00
2D3	Other	CO_2	0.0	33.0	0.25	0.25	0.10	0.10	0.27	0.27	0.00	33012797.9	0.01
5C	Open burning of waste	CH_4	4.2	2.8	1.00	1.00	3.00	3.00	3.16	3.16	0.00	-34.1	0.00
2G	Other product manufacture and use	N_2O	200.0	69.8	0.09	0.09	0.09	0.09	0.12	0.12	0.00	-65.1	0.00
4D	Wetlands	N_2O	2.1	2.1	0.00	0.00	4.00	4.00	4.00	4.00	0.00	-3.0	0.00

CRF category		Gas	CO_2-eq base year (Gg)	CO_2-eq last year (Gg)	AD uncertainty	AD uncertainty	EF Uncertainty estimate	EF Uncertainty estimate	Combined Uncertainty estimate	Combined Uncertainty estimate	Contribution to variance in last year	Inventory trend in national emissions compared to base year %	Uncertainty introduced into the trend in total national emissions
1A3 excl 1A3b	Other	N_2O	6.1	6.3	0.09	0.09	1.31	1.31	1.31	1.31	0.00	3.3	0.00
3G	Liming	CO_2	183.2	32.2	0.25	0.25	0.01	0.01	0.25	0.25	0.00	-82.4	0.00
1A3b	Road transportation: gaseous	CO_2	0.0	146.1	0.05	0.05	0.00	0.00	0.05	0.05	0.00	146066585.7	0.00
1A1b	Petroleum Refining: gaseous	CO_2	1042.2	1155.6	0.01	0.01	0.00	0.00	0.01	0.01	0.00	10.9	0.00
5C	Open burning of waste	N_2O	2.1	1.5	1.00	1.00	3.00	3.00	3.16	3.16	0.00	-27.1	0.00
1A5b	Military use: liquids	N_2O	4.9	2.8	0.07	0.07	1.16	1.16	1.17	1.17	0.00	-42.9	0.00
3B1	Other mature cattle	CH_4	24.8	9.9	0.02	0.02	0.33	0.33	0.33	0.33	0.00	-60.0	0.00
1A3a	Domestic aviation	CO_2	84.2	32.1	0.09	0.09	0.04	0.04	0.10	0.10	0.00	-61.9	0.00
4A	Forest Land	CH_4	3.8	3.9	0.00	0.00	0.79	0.79	0.79	0.79	0.00	0.4	0.00
2B9	Fluorochemical production	PFC	0.0	12.1	0.00	0.00	0.20	0.20	0.20	0.20	0.00	12130586.0	0.00
1A3 excl 1A3b	Other	CH_4	2.6	4.3	0.21	0.21	0.48	0.48	0.52	0.52	0.00	64.4	0.00
3B1	Other mature cattle	N_2O	6.2	2.7	0.02	0.02	0.78	0.78	0.78	0.78	0.00	-56.6	0.00
1A3e	Other	CO_2	342.2	85.0	0.02	0.02	0.00	0.00	0.02	0.02	0.00	-75.2	0.00
3B2	Sheep	N_2O	6.4	1.5	0.05	0.05	1.12	1.12	1.12	1.12	0.00	-76.8	0.00
2H	Other industrial	CO_2	72.5	25.0	0.02	0.02	0.05	0.05	0.05	0.05	0.00	-65.6	0.00
1A3c	Railways	CO_2	90.7	59.9	0.01	0.01	0.02	0.02	0.02	0.02	0.00	-33.9	0.00
4G	Harvested wood products	CO_2	68.6	130.0	0.00	0.00	0.01	0.01	0.01	0.01	0.00	89.5	0.00
2C1	Iron and steel production	CO_2	43.7	15.9	0.03	0.03	0.05	0.05	0.06	0.06	0.00	-63.7	0.00
2C3	Aluminium production	CO_2	408.4	15.1	0.02	0.02	0.05	0.05	0.05	0.05	0.00	-96.3	0.01
1B1b	Solid fuel transformation	CH_4	12.3	5.1	0.02	0.02	0.11	0.11	0.11	0.11	0.00	-58.7	0.00
2D2	Paraffin wax use	CH_4	0.2	0.4	1.00	1.00	0.50	0.50	1.12	1.12	0.00	109.4	0.00
1A5b	Military use: liquids	CH_4	0.9	0.5	0.08	0.08	0.78	0.78	0.78	0.78	0.00	-44.1	0.00

CRF category		Gas	CO_2-eq base year (Gg)	CO_2-eq last year (Gg)	AD uncertainty	AD uncertainty	EF Uncertainty estimate	EF Uncertainty estimate	Combined Uncertainty estimate	Combined Uncertainty estimate	Contribution to variance in last year	Inventory trend in national emissions compared to base year %	Uncertainty introduced into the trend in total national emissions
2G	Other product manufacture and use	CO_2	0.2	0.4	0.50	0.50	0.20	0.20	0.54	0.54	0.00	102.3	0.00
1A4	Solids	CO_2	162.7	0.4	0.42	0.42	0.05	0.05	0.43	0.43	0.00	-99.8	0.00
2A3	Glass production	CO_2	142.4	0.1	0.00	0.00	0.50	0.50	0.50	0.50	0.00	-100.0	0.02
2A1	Cement production	CO_2	415.8	0.0	0.05	0.05	0.10	0.10	0.11	0.11	0.00	-100.0	0.01
2B7	Soda ash production	CO_2	63.8	0.0	0.00	0.00	0.05	0.05	0.05	0.05	0.00	-100.0	0.00
2C3	Aluminium production	N_2O	0.0	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0	0.00
4H	Other	PFC	2373.9	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-100.0	0.00

2.2 Uncertainties 1990 emissions

Since the late nineties, the Netherlands has set up a programme for improving the quality of the greenhouse gas inventory. The set-up of this programme was motivated by the requirements of the Kyoto Protocol. At the start of this programme, a workshop was held involving all the experts engaged in the inventory programme; at that time still under the lead of the Ministry of Housing, Spatial Planning and the Environment (VROM). The results of this workshop are reported in Van Amstel et al (2000). As far as can be recollected at this time, this was the first systematic attempt to assess the uncertainties of greenhouse gas emissions in the Netherlands. Table A2.5 shows the assessment of the uncertainties in the respective gases at that time, which is based on expert judgement. To enable a comparison with the current Approach 2 analysis, the emissions per source category in 1990 combined with uncertainty insights per source category are added in a separate column.

Table A2.5 Uncertainties Greenhouse Gas emissions in 1990 (Approach 1)

Gas	**activity**	**Emission level base year (Gg)**	**Uncertainty 1990 (%) 2000**	**Uncertainty 1990 (%) 2020(1)**
CO_2	Fuel combustion	149.7	2	
	IPPU	11.7	25	
	(Land Use)	(-1.5)	(60)	
subtotal		**161.4**	**3**	**2.5**
CH_4	Energy	4.5	25	
	Agriculture	10.6	25	
	Waste	11.9	30	
subtotal		**27.0**	**17**	**8**
N_2O	Energy use	2.3	75	
	IPPU	9.8	35	
	Agriculture	6.9	75	
subtotal		**19.0**	**34**	**27**
HFC/SF_6	Energy sector	1.4	50	
	IPPU	5.1	50	
subtotal		**6.5**	**41**	
PFC	IPPU	2.4	100	
subtotal		**2.4**	**100**	**70(2)**
Other sectors	other	1.0	50	
Total emissions		**218.8**	**4.4**	**2.7**

(1) uncertainty 1990 assessed with 2022 methodology
(2) total F-gases

Note that the assessment of uncertainties for 1990 is based on a first order expert judgement, whereas uncertainties nowadays result from a more systematic approach; looking more in depth to the uncertainties on a source category level.

Table A2.5 shows that overall uncertainty for the 1990 emissions is smaller in the 2020 calculation.

Annex 3 Detailed methodological descriptions of individual sources or sink categories

A detailed description of methodologies per source/sink category, including a list of country-specific EFs, can be found in the relevant methodology reports on the website http://english.rvo.nl/nie.

These methodology reports are also integral part of this submission (see Annex 7).

Annex 4 CO_2: the national energy balance for the most recent inventory year

The national energy balance for 2022 in the Netherlands (as used for this submission) can be found on the following pages.

The national energy balance for other years is available online at:
StatLine - Energy balance sheet; supply, transformation and consumption (cbs.nl)

Please note that because of the size, the table underneath has been split up in 2 parts.

Energy Balance the Netherlands 2022, part 1-2

Energy balance sheet the Netherlands 2022	Anthracite	Coking coal	Steam coal	Lignite	Coke-oven cokes	BKB (Braunkohlenbriketts)	Patent fuel	Coal tar	Gas works gas	Coke oven gas	Blast furnace gas	Crude oil	Natural gas liquids	Additives	Other hydrocarbons	Residual gas	Lpg
Energy supply																	
Total Primary Energy Supply (TPES)	0.1	113.4	120.8	0.3	-0.6	0.0		-2.3				2189.3	307.5	48.5		13.5	53.1
Indigenous production												16.7	4.0	10.1		13.5	
Imports	0.1	112.2	127.0	0.3	1.3	0.0						4096.1	330.0	76.1			143.8
Exports					2.4			2.2				1845.1	14.3	29.2			91.3
Bunkers																	
Stock change		1.2	-6.2		0.5			-0.2				-78.3	-12.2	-8.6			0.6
Energy consumption																	
Net energy consumption	0.1	113.4	120.8	0.3	-0.6	0.0		-2.3				2189.3	307.5	48.5		13.5	53.1
Energy transformation																	
Total energy transformation input		113.1	120.4		47.1					2.0	23.2	2189.3	244.8	47.3		31.3	40.8
Electricity and CHP transformation input			120.4							2.0	23.2					20.6	
Other transformation input		113.1			47.1							2189.3	244.8	47.3		10.6	40.8
Total energy transformation output					52.0			3.3		15.1	36.0					202.2	62.7
Electricity/CHP transformation output																	
Other transformation output					52.0			3.3		15.1	36.0					202.2	62.7
Total net energy transformation		113.1	120.4		-4.9			-3.3		-13.1	-12.8	2189.3	244.8	47.3		-170.9	-21.8

Energy balance sheet the Netherlands 2022	Anthracite	Coking coal	Steam coal	Lignite	Coke-oven cokes	BKB (Braunkohlenbriketts)	Patent fuel	Coal tar	Gas works gas	Coke oven gas	Blast furnace gas	Crude oil	Natural gas liquids	Additives	Other hydrocarbons	Residual gas	Lpg
Net electricity/CHP transformation			120.4							2.0	23.2					20.6	
Net other transformation		113.1			-4.9			-3.3		-15.1	-36.0	2189.3	244.8	47.3		-191.5	-21.8
Energy sector own use																	
Total energy sector own use										6.7	8.7					85.0	6.7
Production of heat and power																	
Extraction of crude petroleum and gas																	
Coke-oven plants										5.7	1.5						
Blast furnaces										1.0	7.2						
Oil refineries																85.0	6.7
Electricity and gas supply																	
Distribution losses																	
Distribution losses																	
Final consumption																	
Total final consumption	0.1	0.3	0.4	0.3	4.3	0.0		0.9		6.4	4.1		62.7	1.2		99.4	68.2
Total final energy consumption	0.0	0.2	0.4	0.3	4.1	0.0				6.4	4.1					99.4	10.7
Total industry		0.2	0.4	0.0	4.1	0.0				6.4	4.1					99.4	0.9
Iron and steel		0.2			3.1					6.4	4.1						0.5
Chemical and petrochemical																99.4	0.0
Non-ferrous metals																	0.0
Non-metallic minerals		0.0			1.0												0.1
Transport equipment																	0.0

Energy balance sheet the Netherlands 2022	Anthracite	Coking coal	Steam coal	Lignite	Coke-oven cokes	BKB (Braunkohlenbriketts)	Patent fuel	Coal tar	Gas works gas	Coke oven gas	Blast furnace gas	Crude oil	Natural gas liquids	Additives	Other hydrocarbons	Residual gas	Lpg
Machinery																	0.1
Mining and quarrying				0.0													0.0
Food and tobacco			0.4														0.1
Paper, pulp and printing																	0.0
Wood and wood products																	0.0
Construction					0.0												0.0
Textile and leather																	0.0
Other industry and non-specified						0.0										0.0	0.0
Total transport																	5.2
Domestic aviation																	
Road transport																	5.2
Rail transport																	
Pipeline transport																	
Domestic navigation																	
Non-specified																	
Total other sectors	0.0			0.3		0.0											4.6
Services, waste, water and repair				0.3		0.0											1.8
Households	0.0					0.0											1.0
Agriculture																	1.8
Fishing																	
Non-specified																	
Total non-energy use	0.1	0.0			0.2			0.9					62.7	1.2			57.6

Energy balance sheet the Netherlands 2022	Anthracite	Coking coal	Steam coal	Lignite	Coke-oven cokes	BKB (Braunkohlenbriketts)	Patent fuel	Coal tar	Gas works gas	Coke oven gas	Blast furnace gas	Crude oil	Natural gas liquids	Additives	Other hydrocarbons	Residual gas	Lpg
Industry (excluding the energy sector)	0.1	0.0			0.2			0.9					62.7	1.2			57.6
Of which chemistry and pharmaceuticals													62.7	1.2			57.6
Transport																	
Other sectors																	
Statistical difference																	
Statistical differences	0.0															0.0	

Energy Balance the Netherlands 2022, part 2-2

Energy balance sheet the Netherlands 2021	Naphtha	Motor gasoline	Gasoline type jet fuel	Aviation gasoline	Kerosene type jet fuel	Other kerosene	Heating and other gasoil	Fuel oil	White spirit and industrial spirit (SBP)	Lubricants	Bitumen	Paraffin waxes	Petroleum coke	Other petroleum products	Natural gas	Municipal waste; renewable fraction	Solid and liquid biomass	Biogas	Non-rene.municipal waste + residual heat
Energy supply																			
Total Primary Energy Supply (TPES)	456.3	-710.5		-2.5	-297.9	-17.4	-592.9	-351.6	12.2	-1.8	-25.1	0.4	8.8	-50.3	977.9	37.6	156.7	18.1	41.6
Indigenous production														5.5	539.3	32.7	146.3	18.1	37.5
Imports	1042.0	321.5		0.0	167.0	11.5	540.7	1022.1	97.9	130.0	16.7	9.0	75.3	38.7	1868.7	5.8	66.1		5.0
Exports	565.4	1025.1		2.5	335.8	27.8	1017.0	992.8	82.4	128.2	41.8	8.6	64.5	92.8	1234.2	0.9	39.7		0.8
Bunkers					133.5		99.0	377.3		4.7					3.1				
Stock change	-20.3	-6.9		-0.1	4.4	-1.0	-17.6	-3.7	-3.3	1.1	0.0	0.0	-1.9	-1.7	-192.8		-15.9		
Energy consumption																			
Net energy consumption	456.3	-710.5		-2.5	-297.9	-17.4	-592.9	-351.6	12.2	-1.8	-25.1	0.4	8.8	-50.3	991.1	37.6	156.7	17.5	41.6
Energy transformation																			
Total energy transformation input	747.4	34.3		0.0	23.2	7.0	187.3	271.0	66.4	33.0	0.0	0.2		23.0	408.3	37.6	129.7	15.9	41.6
Electricity and CHP transformation input							0.4							0.1	392.3	37.6	73.1	8.6	32.0

Energy balance sheet the Netherlands 2021	Naphtha	Motor gasoline	Gasoline type jet fuel	Aviation gasoline	Kerosene type jet fuel	Other kerosene	Heating and other gasoil	Fuel oil	White spirit and industrial spirit (SBP)	Lubricants	Bitumen	Paraffin waxes	Petroleum coke	Other petroleum products	Natural gas	Municipal waste; renewable fraction	Solid and liquid biomass	Biogas	Non-rene.municipal waste + residual heat
Other transformation input	747.4	34.3		0.0	23.2	7.0	186.9	271.0	66.4	33.0	0.0	0.2		22.9	16.0		56.6	7.3	9.6
Total energy transformation output	496.8	909.0		2.6	322.9	25.7	1032.2	622.7	55.4	41.3	29.3	1.3	15.2	81.9	11.1				
Electricity/CHP transformation output																			
Other transformation output	496.8	909.0		2.6	322.9	25.7	1032.2	622.7	55.4	41.3	29.3	1.3	15.2	81.9	11.1				
Total net energy transformation	250.6	-874.8		-2.6	-299.6	-18.7	-845.0	-351.6	11.1	-8.2	-29.3	-1.2	-15.2	-58.9	397.2	37.6	129.7	15.9	41.6
Net electricity/CHP transformation							0.4							0.1	392.3	37.6	73.1	8.6	32.0
Net other transformation	250.6	-874.8		-2.6	-299.6	-18.7	-845.4	-351.6	11.1	-8.2	-29.3	-1.2	-15.2	-59.0	4.9		56.6	7.3	9.6
Energy sector own use																			
Total energy sector own use							0.0				0.0		9.3		24.7				

Energy balance sheet the Netherlands 2021	Naphtha	Motor gasoline	Gasoline type jet fuel	Aviation gasoline	Kerosene type jet fuel	Other kerosene	Heating and other gasoil	Fuel oil	White spirit and industrial spirit (SBP)	Lubricants	Bitumen	Paraffin waxes	Petroleum coke	Other petroleum products	Natural gas	Municipal waste; renewable fraction	Solid and liquid biomass	Biogas	Non-rene.municipal waste + residual heat
Production of heat and power																			
Extraction of crude petroleum and gas							0.0								17.3				
Coke-oven plants																			
Blast furnaces															0.5				
Oil refineries							0.0				0.0		9.3		5.7				
Electricity and gas supply															1.2				
Distribution losses																			
Distribution losses																			
Final consumption																			
Total final consumption	205.7	164.3		0.1	1.7	1.3	252.1		1.1	6.4	4.2	1.6	14.8	8.6	569.1		27.0	1.6	
Total final energy consumption		164.3		0.1	1.7	0.2	252.0						0.1	2.8	500.9		27.0	1.6	
Total industry						0.0	21.9						0.1	2.8	145.8		3.2	1.3	
Iron and steel							0.1						0.1	0.0	7.8				

Energy balance sheet the Netherlands 2021	Naphtha	Motor gasoline	Gasoline type jet fuel	Aviation gasoline	Kerosene type jet fuel	Other kerosene	Heating and other gasoil	Fuel oil	White spirit and industrial spirit (SBP)	Lubricants	Bitumen	Paraffin waxes	Petroleum coke	Other petroleum products	Natural gas	Municipal waste; renewable fraction	Solid and liquid biomass	Biogas	Non-rene.municipal waste + residual heat
Chemical and petrochemical						0.0	0.2							2.8	49.5				
Non-ferrous metals							0.0								2.4				
Non-metallic minerals						0.0	0.2							0.0	18.4				
Transport equipment							0.0								1.7				
Machinery						0.0	0.0							0.0	7.8				
Mining and quarrying							0.1								1.9				
Food and tobacco							0.0							0.0	39.5				
Paper, pulp and printing							0.0							0.0	8.1				
Wood and wood products							0.0								0.4				
Construction							21.1								2.5		0.2		
Textile and leather							0.0								2.0				
Other industry and non-specified							0.0							0.0	3.9				
Total transport		164.3		0.1	0.4		200.1								2.6				

Energy balance sheet the Netherlands 2021	Naphtha	Motor gasoline	Gasoline type jet fuel	Aviation gasoline	Kerosene type jet fuel	Other kerosene	Heating and other gasoil	Fuel oil	White spirit and industrial spirit (SBP)	Lubricants	Bitumen	Paraffin waxes	Petroleum coke	Other petroleum products	Natural gas	Municipal waste; renewable fraction	Solid and liquid biomass	Biogas	Non-rene.municipal waste + residual heat
Domestic aviation				0.1	0.4														
Road transport		164.3					188.8								2.6				
Rail transport							0.9												
Pipeline transport																			
Domestic navigation							10.4												
Non-specified																			
Total other sectors		0.0			1.3	0.2	30.0							0.0	352.5		23.8	0.3	
Services, waste, water and repair		0.0				0.0	5.9							0.0	94.2		1.6	0.3	
Households						0.2	0.3								237.4		16.2		
Agriculture							17.3								20.7		6.0		
Fishing							4.5												
Non-specified					1.3		2.1								0.1				
Total non-energy use	205.7					1.1	0.1		1.1	6.4	4.2	1.6	14.7	5.8	68.2				
Industry (excluding the energy sector)	205.7					1.0	0.1		1.1	2.1	4.2	1.6	14.7	5.8	68.2				

Energy balance sheet the Netherlands 2021	Naphtha	Motor gasoline	Gasoline type jet fuel	Aviation gasoline	Kerosene type jet fuel	Other kerosene	Heating and other gasoil	Fuel oil	White spirit and industrial spirit (SBP)	Lubricants	Bitumen	Paraffin waxes	Petroleum coke	Other petroleum products	Natural gas	Municipal waste; renewable fraction	Solid and liquid biomass	Biogas	Non-rene.municipal waste + residual heat
Of which chemistry and pharmaceuticals	205.7					1.0	0.1		0.6	0.0		1.1	10.8	5.8	68.2				
Transport										2.7									
Other sectors						0.0				1.5									
Statistical difference																			
Statistical differences								0.0						0.0	-13.2			0.6	

Annex 5 The Netherlands' fuel list and standard CO_2 emission factors. Version January 2024

Colophon

Project name	Annual update of fuel list for the Netherlands
Project number	113569/BL2024
Version number	January 2024
Project leader	P.J. Zijlema
Enclosures	0
Author	P.J. Zijlema

The initial version of this fuel list was approved by the Steering Committee Emission Registration (SCER) in 2004, and the list was subsequently updated on the basis of decisions of the Steering Committee concerning the CO_2 emission factor for natural gas at meetings held on 25 April 2006 and 21 April 2009. The Steering Committee Emission Registration delegated the authority for approving this list to the ER/Working Group on Emission Monitoring (WEM) on 21 April 2009.
The present document (the version of January 2024) is approved by WEM, after detailed discussions with the Dutch Emissions Authority (NEa) and several institutes that participate in the Emission Register (ER/PRTR) project, a.o:

- CBS, Statistics Netherlands,
- PBL, Netherlands Environmental Assessment Agency,
- RIVM, National Institute for Public Health and the Environment,
- RWS, Rijkswaterstaat, an agency of the Dutch Ministry of Infrastructure and the Environment responsible for the design, construction, management and maintenance of the main infrastructure facilities in the Netherlands,
- TNO, the Dutch organisation for Applied Scientific Research (TNO).

5.1 Fuel list, version of January 2024

Name (Dutch)	Name (English)	Unit	Net Calorific Value (MJ/unit)				CO_2 EF (kg/GJ)			
			2022	2023	2024	Ref 1)	2022	2023	2024	Ref 1)
	A. Liquid Fossil, Primary Fuels									
Ruwe aardolie	Crude oil	kg	42.7	42.7	42.7	CS	73.3	73.3	73.3	IPCC
Orimulsion	Orimulsion	kg	27.5	27.5	27.5	IPCC	77.0	77.0	77.0	IPCC
Aardgascondensaat	Natural Gas Liquids	kg	44.0	44.0	44.0	CS	64.2	64.2	64.2	IPCC
Fossiele additieven	Fossil fuel additives	kg	44.0	44.0	44.0	CS	73.3	73.3	73.3	IPCC
	Liquid Fossil, Secondary Fuels									
Motorbenzine 2)	Gasoline 2)	Kg	43.3	43.3	43.3	CS	72.2	72.2	72.2	CS
Vliegtuigbenzine	Aviation gasoline	kg	44.0	44.0	44.0	CS	72.0	72.0	72.0	CS
Kerosine luchtvaart 2)	Jet Kerosene 2)	kg	43.5	43.5	43.5	CS	71.5	71.5	71.5	IPCC
Petroleum	Other kerosene	kg	43.1	43.1	43.1	CS	71.9	71.9	71.9	IPCC
Leisteenolie	Shale oil	kg	38.1	38.1	38.1	IPCC	73.3	73.3	73.3	IPCC
Gas-/dieselolie 2)	Gas/Diesel oil 2)	kg	43.2	43.2	43.2	CS	72.5	72.5	72.5	CS
Zware stookolie	Residual Fuel oil	kg	41.0	41.0	41.0	CS	77.4	77.4	77.4	IPCC
LPG	Liquefied Petroleum Gas (LPG)	kg	45.2	45.2	45.2	CS	66.7	66.7	66.7	CS
Ethaan	Ethane	kg	45.2	45.2	45.2	CS	61.6	61.6	61.6	IPCC
Nafta's	Naphta	kg	44.0	44.0	44.0	CS	73.3	73.3	73.3	IPCC
Bitumen	Bitumen	kg	41.9	41.9	41.9	CS	80.7	80.7	80.7	IPCC
Smeeroliën	Lubricants	kg	41.4	41.4	41.4	CS	73.3	73.3	73.3	IPCC
Petroleumcokes	Petroleum Coke	kg	35.2	35.2	35.2	CS	97.5	97.5	97.5	IPCC
Raffinaderij grondstoffen	Refinery Feedstocks	kg	43.0	43.0	43.0	IPCC	73.3	73.3	73.3	IPCC
Raffinaderijgas	Refinery Gas	kg	45.2	45.2	45.2	CS	64.4	64.4	64.4	CS
Chemisch restgas	Chemical Waste Gas	kg	45.2	45.2	45.2	CS	61.8	61.8	61.8	CS
Overige oliën	Other oil	kg	40.2	40.2	40.2	IPCC	73.3	73.3	73.3	IPCC
Paraffine	Paraffin Waxes	kg	42.7	42.7	42.7	CS	73.3	73.3	73.3	IPCC
Terpentine	White Spirit and SBP	kg	43.6	43.6	43.6	CS	73.3	73.3	73.3	IPCC
Overige aardolie producten	Other Petroleum Products	kg	42.7	42.7	42.7	CS	73.3	73.3	73.3	IPCC
	B. Solid Fossil, Primary Fuels									
Antraciet	Anthracite	kg	29.3	29.3	29.3	CS	98.3	98.3	98.3	IPCC
Cokeskolen	Coking Coal	kg	28.6	28.6	28.6	CS	94.0	94.0	94.0	CS

Name (Dutch)	Name (English)	Unit	Net Calorific Value (MJ/unit)				CO_2 EF (kg/GJ)			
			2022	**2023**	**2024**	**Ref [1)]**	**2022**	**2023**	**2024**	**Ref [1)]**
Cokeskolen	Coking Coal (used in coke oven)	kg	28.6	28.6	28.6	CS	95.4	95.4	95.4	CS
Cokeskolen	Coking Coal (used in blast furnaces)	kg	28.6	28.6	28.6	CS	89.8	89.8	89.8	CS
Overige bitumineuze steenkool [3)]	Other Bituminous Coal [3)]	Kg	24.8	24.8 [3)]	24.8 [3)]	CS	92.7	92.7	92.7	CS
Sub-bitumineuze steenkool	Sub-Bituminous Coal	kg	18.9	18.9	18.9	IPCC	96.1	96.1	96.1	IPCC
Bruinkool	Lignite	kg	20.0	20.0	20.0	CS	101.0	101.0	101.0	IPCC
Bitumineuze Leisteen	Oil Shale	kg	8.9	8.9	8.9	IPCC	107.0	107.0	107.0	IPCC
Turf	Peat	kg	9.76	9.76	9.76	IPCC	106.0	106.0	106.0	IPCC
	Solid Fossil, Secondary Fuels									
Steenkool- en bruinkoolbriketten	BKB & Patent Fuel	kg	20.7	20.7	20.7	IPCC	97.5	97.5	97.5	IPCC
Cokesoven/ gascokes	Coke Oven/Gas Coke	kg	28.5	28.5	28.5	CS	106.8	106.8	106.8	CS
Cokesovengas	Coke Oven gas	MJ	1.0	1.0	1.0	CS	42.8	42.8	42.8	CS
Hoogovengas	Blast Furnace Gas	MJ	1.0	1.0	1.0	CS	247.4	247.4	247.4	CS
Oxystaalovengas	Oxy Gas	MJ	1.0	1.0	1.0	CS	191.9	191.9	191.9	CS
Fosforovengas	Fosfor Gas	Nm3	11.0	11.0	11.0	CS	143.9	143.9	143.9	CS
Steenkool bitumen	Coal tar	kg	41.9	41.9	41.9	CS	80.7	80.7	80.7	IPCC
	C. Gaseous Fossil Fuels									
Aardgas [4)]	Natural Gas (dry) [4)]	Nm3 ae	31.65	31.65	31.65	CS	56.5[4)]	56.3[4)]	56.2[4)]	CS
Compressed natural gas (CNG) [4)]	Compressed natural gas (CNG) [4)]	Nm3 ae	31.65	31.65	31.65	CS	56.5[4)]	56.3[4)]	56.2[4)]	CS
Liquified natural gas (LNG) [4)]	Liquified natural gas (LNG) [4)]	Nm3 ae	31.65	31.65	31.65	CS	56.5[4)]	56.3[4)]	56.2[4)]	CS
Koolmonoxide	Carbon Monoxide	Nm3	12.6	12.6	12.6	CS	155.2	155.2	155.2	CS
Methaan	Methane	Nm3	35.9	35.9	35.9	CS	54.9	54.9	54.9	CS
Waterstof	Hydrogen	Nm3	10.8	10.8	10.8	CS	0.0	0.0	0.0	CS
	Biomass [4)]									
Biomassa vast	Solid Biomass	kg	15.1	15.1	15.1	CS	109.6	109.6	109.6	IPCC

Name (Dutch)	Name (English)	Unit	Net Calorific Value (MJ/unit)				CO_2 EF (kg/GJ)			
			2022	2023	2024	Ref 1)	2022	2023	2024	Ref 1)
Houtskool	Charcoal	kg	30.0	30.0	30.0	CS	112.0	112.0	112.0	IPCC
Biobenzine 3)	Biogasoline 3)	Kg	27.9	27.9 3)	27.9 3)	CS	70.7	70.7 3)	70.7 3)	CS
Biodiesel 3)	Biodiesels 3)	Kg	38.7	38.7 3)	38.7 3)	CS	74.1	74.1 3)	74.1 3)	CS
Overige vloeibare biobrandstoffen	Other liquid biofuels	kg	36.0	36.0	36.0	CS	79.6	79.6	79.6	IPCC
Biomassa gasvormig	Gas Biomass	Nm3	21.8	21.8	21.8	CS	90.8	90.8	90.8	CS
RWZI biogas	Wastewater biogas	Nm3	23.3	23.3	23.3	CS	84.2	84.2	84.2	CS
Stortgas	Landfill gas	Nm3	19.5	19.5	19.5	CS	100.7	100.7	100.7	CS
Industrieel fermentatiegas	Industrial organic waste gas	Nm3	23.3	23.3	23.3	CS	84.2	84.2	84.2	CS
	D Other fuels									
Afval 3) 6)	Waste 3) 6)	Kg	9.4	9.4 3)	9.4 3)	CS	107.4	107.4 3)	107.4 3)	CS

1) IPCC: default value from the 2006 IPCC Guidelines; CS: country-specific
2) This concerns only the fossil part of the fuel
3) The calorific value and/or emission factor for these fuels are updated annually. Since the values for 2023 and 2024 are not yet known, they are set equal to the value for 2022. The figures in the above list may be modified in subsequent versions of the fuel list
4) The emission factors for natural gas, CNG and LNG are updated annually. The values given in this table represent the most up-to-date values for all years concerned.
5) For reporting of emissions from biomass the following rules have to be followed:
a. Under the Convention (UNFCCC) the emissions from biomass have to be reported as memo-item, using the mentioned emission factors. However, they do not count in the national total.
b. Under EU ETS the emission factor for biomass is zero, with exception of liquid biomass for which additional criteria have to be met to be allowed to use an emission factor of zero.
6) The percentage biogenic in the heating value is 54%. The percentage biogenic in the emission factor is 64%.

5.2 Notes on the fuel list

Netherlands Enterprise Agency (RVO) has been publishing the list of fuels and standard CO_2 emission factors for the Netherlands annually since 2004.
This list was completely revised in 2015 as a result of the obligation to follow the *2006 IPCC Guidelines* in all international reports compiled in or after 2015 (the first reporting year of the second Kyoto budget period). The list contains not only calorific values and emission factors taken from the *2006 IPCC Guidelines* but also a number of country-specific values. In 2021 the list has been updated again, taking into account the 2019 Refinement to the 2006 IPCC Guidelines (see Dröge et al, 2021)
The validity of values is governed by the following rules:

- *2006 IPCC* default emission factors are valid from 1990
- The country-specific calorific values and emission factors may be divided into the following three categories:
  - Most country-specific calorific values and emission factors are valid from 1990
  - A limited number of country-specific factors have an old value for the period 1990-2012 and are updated from 2013 and again updated from reporting year 2021.
  - The country-specific calorific value and/or emission factor for some fuels (natural gas, biogasoline, biodiesel, other bituminous coal and waste) are updated annually. In the present document (version January 2024) these values have been updated.

Readers are referred to the TNO reports (Dröge, 2014; Dröge et al, 2021) and the relevant factsheets for further details.
Various relevant institutes were consulted during the compilation of this list. One of the involved organisations was Statistics Netherlands (CBS), to ensure consistency with the Dutch Energy Balance Sheet.

With effect from 2015, the lists of calorific values and of emission factors will both contain columns for three successive years. In the present version of the fuel list (that for January 2024), the years in question are 2022, 2023 and 2024. The values in these columns are used for the following purposes:

1. **2022**: these values are used in 2024 for calculations concerning the calendar year 2022, which are required for international reports concerning greenhouse gas emissions pursuant to the UN Framework Convention on Climate Change (UNFCCC), the Paris Agreement and the Governance Regulation of the Energy Union (EU 2018/1999). The National Inventory Report for 2024 (NIR 2024) gives full details of greenhouse gas emissions in the Netherlands up to and including 2022. The fuel list forms an integral part of the NIR 2024.
2. **2023**: these values are used in 2024 for reports on energy consumption and CO_2 emission for the calendar year 2023 in the Electronic Environmental Annual Report (e-MJV).

2024: these values will be used in 2025 in emission reports for the calendar year 2024 by companies participating in the EU Emission Trading Scheme (ETS) that are allowed to report the emission factor and calorific value for a given source flow in accordance with Tier 2a (country-specific values), as laid down in Art. 31-1, MRR EU No. 601/2012. The country-specific values in question may be taken from those quoted in the last-published National Inventory Report, in this case NIR 2024.

Annex 6 Assessment of completeness and (potential) sources and sinks

The Netherlands' emissions inventory focuses on completeness, and accuracy in the most relevant sources. This means that for all 'NE' sources, it was investigated what information was available and whether it could be assumed that a source was really (very) small/negligible. For those sources that turned out not to be small, methods for estimating the emissions were developed during the improvement programme. As a result of this process, it was decided to keep only a very few sources as 'NE', where data for estimating emissions were not available and the source was very small. Of course, (developments in) data on NE sources that indicate any (major) increase in emissions and (new) data sources for estimating emissions are checked/re-assessed on a regular basis; most recently in a study performed by DNV GL (2020).

The Netherlands' GHG emissions inventory includes all sources identified by the 2006 IPCC Guidelines, with the exception of the following (very) minor sources:

- CO_2 from asphalt roofing (2A4d) and CO_2 from road paving (2A4d), both due to negligible amounts (below threshold) and missing activity data: information on the use of bitumen is available only in a division into two groups: the chemical industry and all others. There is no information on the amount of asphalt roofing production and no information on road paving with asphalt. The statistical information on the sales (value) of asphalt roofing and asphalt for road paving ends in 2002.
  As a follow-up to the 2008 review, information was collected from the branch organisation for roofing, indicating that the number of producers of asphalt roofing declined from about 15 in 1990 to fewer than 5 in 2008 and that the import of asphalt roofing increased during that period.
  Information has also been sourced on asphalt production (for road paving), as reported in the progress of the voluntary agreements for energy efficiency. A first estimate indicates that annual CO_2 emissions could be approximately 0.5 kton.
  On the basis of the above, it was assumed that emissions related to these two categories are very low/undetectable and that the effort expended in generating activity data would, therefore, not be cost-effective. So not only the missing activity data, but also the very limited amount of emissions were the rationale behind the decision not to estimate these emissions.
- CH_4 from Enteric fermentation: poultry (3A4), due to missing EFs: for this source category, no IPCC default EF is available.
- Direct N_2O emissions from septic tanks (5D3, septic tanks): direct emissions of N_2O from septic tanks are not calculated since they are unlikely to occur, given the anaerobic circumstances in these tanks. Indirect N_2O emissions from septic tank effluent are included (IE) in CRF category 5D3 (Indirect N_2O emission from surface water as a result of discharge of domestic and industrial effluents).

- CH_4 emissions from industrial sludge treatment (5D2): data from the survey among IWWTPs conducted by Statistics Netherlands shows that only 2 out of a total of 160 IWWTPs are equipped with anaerobic sludge digestion reactors. These data are not published on www.cbs.statline.nl for reasons of confidentiality. Forthcoming CH_4 emissions are not estimated (NE) because it is not known what sludge treatment capacity these plants have or how much sludge is digested. It is likely that these emissions are a very minor source and can be neglected.
- Precursor emissions (i.e. CO, NO_x, NMVOC and SO_2) from Memo item international bunkers (international transport) have not been included.

A number of recommendations by DNV GL, relating to the 2019 refinement of the IPCC Guidelines, will be further explored and implemented once these guidelines become mandatory for calculating greenhouse gas emissions.

Annex 7 Additional information to be considered as part of the NIR submission

List A7.1 contains the list of methodology reports that have been submitted to the UNFCCC (in a separate ZIP file) as part of the submission of 15 April 2024. These reports are to be considered as an integrated part of this NIR2024.

A7.1 List of methodology reports

ENINA (Energy, IP, Waste):
Methodology for the calculation of emissions to air from the sectors Energy, Industry and Waste
RIVM report 2024-0014
E. Honig, J.A. Montfoort, R. Dröge, B. Guis, K. Baas, B. van Huet, O.R. van Hunnik

Transport:
Methods for calculating the emissions of transport in the Netherlands
RIVM report 2024-0023
G. Geilenkirchen, M. Bolech, J. Hulskotte, S. Dellaert, N. Ligterink, E. van Eijk, K. Geertjes, M. Kosterman, M. ’t Hoen

WESP:
Methodology for the calculation of emissions from product usage by consumers, construction and services
RIVM report 2024-0016
A.J.H. Visschedijk, J.A.J. Meesters, M.M. Nijkamp, W.W.R Koch, B.I. Jansen, R. Dröge

Agriculture:
Methodology for the calculation of emissions from agriculture
RIVM report 2024-0015
Calculations for methane, ammonia, nitrous oxide, nitrogen oxides, non-methane volatile organic compounds, fine particles and carbon dioxide emissions using the National Emission Model for Agriculture (NEMA)
T.C. van der Zee, A. Bleeker, C. van Bruggen, W. Bussink, H.J.C. van Dooren, C.M. Groenestein, J.F.M. Huijsmans, H. Kros, L.A. Lagerwerf, K. Oltmer, M. Ros, M. van Schijndel, L. Schulte-Uebbing, G.L. Velthof

LULUCF:
Greenhouse gas reporting of the LULUCF sector in the Netherlands
Methodological background, update 2024, WOt-technical report 255
S.A. van Baren, E.J.M.M. Arets, C.M.J. Hendriks, H. Kramer, J.P. Lesschen, M.J. Schelhaas

These reports are also available at the website http://english.rvo.nl/nie

Annex 8 Chemical compounds, GWP, units and conversion factors

A8.1 Chemical compounds

CF_4	Perfluoromethane (tetrafluoromethane)
C_2F_6	Perfluoroethane (hexafluoroethane)
CH_4	Methane
CO	Carbon monoxide
CO_2	Carbon dioxide
HCFCs	Hydrochlorofluorocarbons
HFCs	Hydrofluorocarbons
HNO_3	Nitric acid
NF_3	Nitrogen trifluoride
NH_3	Ammonia
NO_x	Nitrogen oxide (NO and NO_2), expressed as NO_2
N_2O	Nitrous oxide
NMVOC	Non-methane volatile organic compounds
PFCs	Perfluorocarbons
SF_6	Sulphur hexafluoride
SO_2	Sulphur dioxide
VOC	Volatile organic compounds (may include or exclude methane)

A8.2 GWP of selected GHGs

Table A8.1 lists the 100-year GWP of selected GHGs. Gases shown in italics are not emitted in the Netherlands.

Table A8.1 100-year GWP of selected GHGs

Gas	**100-year GWP 1)**
CO_2	1
CH_4 2)	28
N_2O	265
HFCs 3):	
HFC-23	12,400
HFC-32	677
HFC-41	116
HFC-43-10mee	1,650
HFC-125	3,170
HFC-134	1120
HFC-134a	1,300
HFC-143	328
HFC-143a	4,800
HFC-152	16
HFC-152a	138
HFC-161	4
HFC-227ea	3,350
HFC-236cb	1,210
HFC-236ea	1,330
HFC-236fa	8,060
HFC-245ca	716
HFC-245fa	858
HFC-365mfc	804
PFCs 3):	
CF_4	*6,630*
C_2F_6	*11,100*
C_3F_8	*8,900*
C_4F_{10}	*9,200*
c-C_4F_8	*9,540*
C_5F_{12}	*8,550*
C_6F_{14}	*7,910*
$C_{10}F_{18}$	*7,190*
c-C_3F_6	*9,200*
SF_6	23,500
NF_3	16,100

1) GWPs calculated using a 100-year time horizon in compliance with the UNFCCC Guidelines for reporting (UNFCCC, 2013).
2) The GWP of methane includes the direct effects and the indirect effects due to the production of tropospheric ozone and stratospheric water vapour; the indirect effect due to the production of CO_2 is not included.
3) The GWP-100 of emissions reported as 'HFC-unspecified' and 'PFC-unspecified' differ per reported year. They are in the order of magnitude of 3,000 and 8,400, respectively.

Source: IPCC 5th assessment report (2013).

A8.3 Units

MJ Mega Joule (10^6 Joule)
GJ Giga Joule (10^9 Joule)
TJ Tera Joule (10^{12} Joule)
PJ Peta Joule (10^{15} Joule)
Mg Mega gramme (10^6 gramme)
Gg Giga gramme (10^9 gramme)
Tg Tera gramme (10^{12} gramme)
Pg Peta gramme (10^{15} gramme)
ton metric ton (= 1,000 kilogramme = 1 Mg)
kton kiloton (= 1,000 metric ton = 1 Gg)
Mton Megaton (= 1,000,000 metric ton = 1 Tg)
ha hectare (= 10^4 m^2)
kha kilo hectare (= 1,000 hectare = 10^7 m^2 = 10 km^2)
mln million (= 10^6)

A8.4 Conversion factors for emissions

From element basis to full molecular mass:		**From full molecular mass to element basis**	
C → CO_2:	x 44/12 = 3.67	CO_2 →C:	x 12/44 = 0.27
C → CH_4:	x 16/12 = 1.33	CH_4 →C:	x 12/16 = 0.75
C → CO:	x 28/12 = 2.33	CO → C:	x 12/28 = 0.43
N → N_2O:	x 44/28 = 1.57	N_2O → N:	x 28/44 = 0.64
N → NO:	x 30/14 = 2.14	NO → N:	x 14/30 = 0.47
N → NO_2:	x 46/14 = 3.29	NO_2 → N:	x 14/46 = 0.30
N → NH_3:	x 17/14 = 1.21	NH_3 → N:	x 14/17 = 0.82
N → HNO_3:	x 63/14 = 4.50	HNO_3 → N:	x 14/63 = 0.22
S → SO_2:	x 64/32 = 2.00	SO_2 → S:	x 32/64 = 0.50

Annex 9 List of abbreviations

AD	Activity Data
AER	Annual Environmental Reports
AGB	Above-Ground Biomass
AR	Afforestation and Reforestation
AER	Annual Environmental Report
BCEF	Biomass Expansion Function
BF	Blast Furnace Gas
BGB	Below-Ground Biomass
BOD	Biological Oxygen Demand
C	Carbon or Confidential information(notation code in CRF)
CO	Coke Oven Gas
COD	Chemical Oxygen Demand
CBS	Statistics Netherlands
CDM	Clean Development Mechanism
CHP	Combined Heat and Power
CLRTAP	Convention on Long-Range Transboundary Transport of Air Pollutants
COD	Chemical Oxygen Demand
CPR	Commitment Period Reserve
CRF	Common Reporting Format (of emissions data files, annexed to an NIR)
CSC	Carbon Stock Changes
D	Deforestation
DM	Dry matter
DOC	Degradable Organic Carbon
DOCf	Degradable Organic Carbon Fraction
DOM	Dead Organic Matter
DW	Dead Wood
e-AER	electronic Annual Environmental Report
EEA	European Environment Agency
EF	Emission Factor
ENINA	Task Group Energy, Industry and Waste Handling
ER	Emission Registration (system)
ERT	Expert Review Team
ERU	Emission Reduction Unit
ETS	Emission Trading System
EU	European Union
EWL	European Waste List
EZ	Ministry of Economic Affairs
EZK	Ministry of Economic Affairs and Climate Policy (EZK)
FAO	Food and Agricultural Organization (UN)
F-gases	group of fluorinated compounds comprising HFCs, PFCs and SF_6
FGD	Flue Gas Desulphurisation
FM	Forest Management
FMRL	Forest Management Reference Level
GE	Gross Energy
GHG	Greenhouse Gas
GWP	Global Warming Potential

HOSP	Timber Production Statistics and Forecast (in Dutch: 'Hout Oogst Statistiek en Prognose oogstbaar hout')
HWP	Harvested wood products
IE	Included Elsewhere (notation code in CRF)
IEA	International Energy Agency
IEF	Implied Emission Factor
IPPU	Industrial Processes and Product Use (sector)
IWWTP	Industrial Wastewater Treatment Plant
IPCC	Intergovernmental Panel on Climate Change
LDAR	Leak Detection and Repair
LEI	Agricultural Economics Institute
LPG	Liquefied Petroleum Gas
LULUCF	Land use, land Use Change and Forestry (sector)
MCF	methane conversion factor
MFV	Measuring Network Functions (in Dutch: 'Meetnet Functievervulling')
MR	Methane Recovery
MSW	Municipal Solid Waste
MW	Mega Watt
N	Nitrogen
NA	Not Available/Not Applicable (notation code in CRF)
NAV	Dutch Association of Aerosol Producers
NE	Not Estimated (notation code in CRF)
NEa	Netherlands Emissions Authority (Dutch Emissions Authority)
NFI	National Forest Inventory
NIC	National Inventory Compiler
NIE	National Inventory Entity
NIR	National Inventory Report (annual GHG inventory report to UNFCCC)
NL-PRTR	Netherlands'Pollutant Release and Transfer Register
NMVOC	Non-Methane Volatile Organic Compound
NO	Not Occurring (notation code in CRF)
NRMM	Non-Road Mobile Machinery
ODS	Ozone Depleting Substances
ODU	Oxidation During Use (of direct non-energy use of fuels or of petrochemical products)
OECD	Organisation for Economic Co-operation and Development
OX	OXygen furnace gas
PA	Paris Agreement
PBL	PBL Netherlands Environmental Assessment Agency (formerly MNP)
PE	Pollution Equivalent
PRTR	Pollutant Release and Transfer Register
QA	Quality Assurance
QC	Quality Control
RA	Reference Approach (vs. sectoral or national approach)
RIVM	National Institute for Public Health and the Environment
RVO	Netherlands Enterprise Agency
SA	Sectoral Approach
SCR	Selective Catalytic Reduction
SEF	Standard Electronic Format
SNCR	Selective Non-Catalytic Reduction
SWDS	Solid Waste Disposal Site

TNO	Netherlands Organisation for Applied Scientific Research
TOF	Trees Outside Forest
TOW	Total Organics in Wastewater
UN	United Nations
UNECE	United Nations Economic Commission for Europe
UNFCCC	United Nations Framework Convention on Climate Change
UWWTP	Urban WasteWater Treatment Plant
VOC	Volatile Organic Compound
VS	Volatile Solids
WAR	Working Group for Waste Registration
WBCSD	World Business Council for Sustainable Development
WEM	Working Group Emission Monitoring
WRI	World Resources Institute
WUR	Wageningen University and Research Centre (or: Wageningen UR)
WenR	Wageningen Environmental Research
WecR	Wageningen Economic Research
WWTP	WasteWater Treatment Plant

Annex 10 Improvements made in response to the in-country UNFCCC review of October 2022

The ERT's provisional views on the issues raised in the previous review report

Sector	**Energy**
ID# concept ARR	E.2
Addressing/Not resolved/ New from 2022 review	Not resolved
Issue and/or problem classificationa[, b]	1.A.2.c Chemicals – all fuels – CO2 (E.6, 2021) (E.27, 2019) Comparability
Recommendation made in previous review report	Allocate the non-energy use emissions to the IPPU category where they occur, if applicable, and provide in the NIR information on emissions resulting from the use of fossil fuels as feedstocks for the production of silicon carbide, carbon black, ethylene and methanol.
ERT assessment and rationale	Not resolved. The Party reported in CRF table 1.A(a)s2 the emissions resulting from the use of fossil fuels as feedstocks for the production of silicon carbide, carbon black, ethylene and methanol. As explained in the NIR (sections 3.2.5.2, p.98, and 4.3, p.138), the AD provided by the energy balance cannot be separated into combustion- and process-related data. During the review, the Party confirmed that it will continue reporting the GHG emissions from the production of silicon carbide, carbon black, ethylene and methanol in the energy sector under category 1.A.2.c (chemicals), although these emissions are process-related. The ERT noted that this approach is not in accordance with the 2006 IPCC Guidelines (vol. 3, chap. 3.9.4.2, p.3.88, and vol. 3, chap. 1, box 1.1, p.1.8, and vol. 2, chap. 1.2, p.1.5), particularly in terms of the allocation of fuels between energy and non-energy uses, and it therefore considers that the recommendation has not yet been implemented.
Updated NLD Response in NIR/CRF 2024	Emissions from the combustion of waste gases have been reallocated to the IPPU sector (in cases where these waste gases are combusted in the same sector as where they are produced). Emissions from the combustion of waste gas by the chemical industry are reallocated from 1A2c to 2B10.

Sector	**Energy**
Updated paragraph or table number in: NIR, CRF and or Methodology Report (MR) for NIR/CRF 2024	-

Sector	**Energy**
ID# concept ARR	E.4
Addressing/Not resolved/ New from 2022 review	Not resolved
Issue and/or problem classificationa[, b]	1.A.3.e.i Pipeline transport – gaseous fuels – CH4 (E.7, 2021]) (E.15, 2019) (E.21, 2017) Comparability
Recommendation made in previous review report	Allocate combustion emissions of CH4 from the natural gas transport network to subcategory 1.A.3.e.i (pipeline transport).
ERT assessment and rationale	Not resolved. The Party reported in its NIR (sections 3.2.6.1, p.107, and 3.3.2.1, p.125) that energy consumption for pipeline transport is not recorded separately in the national energy statistics, but that CO2 and N2O combustion emissions for gas transport are included in category 1.A.3.e (other transportation). The CH4 emissions for gas transport are reported under subcategory 1.B.2.b.4 (natural gas transmission and storage) instead of under category 1.A.3.e. During the review, the Party clarified that it has no plan to investigate moving the allocation of CH4 combustion emissions from the natural gas transport network to category 1.A.3.e. The ERT noted that the approach used by the Party is not in accordance with the 2006 IPCC Guidelines (vol. 2, table 3.1.1).
Updated NLD Response in NIR/CRF 2024	The NIR and Methodology report (Honig et al 2024) mention that total emissions of CH4 from gas transmission are included in 1B2b. Also the Methodology report mentions that there are no plans to investigate this further (for comparability), because no specific data for these early years is available and that this is a minor allocation issue, i.e. no missing emissions (no underestimation).

Sector	Energy
Paragraph or table number in: NIR, CRF and or Methodology report (MR)	See paragraph 3.3.2.1 Source category description NIR and paragraph 2.4.2.2 Oil and Gas transport MR (Honig et al., 2024).

Sector	Energy
ID# concept ARR	E.5
Addressing/Not resolved/ New from 2022 review	Not resolved
Issue and/or problem classificationa[, b]	1.A.4.a Commercial/institutional – biomass – CO_2 and CH_4 (E.14, 2021) Transparency
Recommendation made in previous review report	Include the AD for landfill gas in the CRF tables and present transparently the different reasons affecting the recalculations for each subcategory, as well as the impact of the recalculations separately along with the aggregated category-level information.
ERT assessment and rationale	Not resolved. The Party did not provide transparent information on the AD for landfill gas or transparent information related to the biomass recalculations. Regarding the GHG emissions from landfill gas flaring, during the review the Party provided the following information: (1) CH_4 emissions have been reallocated from subcategory 1.A.4.a.i (commercial/institutional – stationary combustion) to category 5.A.1.a (managed waste disposal sites – anaerobic) and amount to 9.7 t CH_4 for 2018 and 9.1 t CH_4 for 2019; (2) CO_2 emissions have been removed from subcategory 1.A.4.a.i but are not reported elsewhere, since these emissions are generated by a biofuel and amount to 48.7 kt CO_2 for 1998, 104.4 kt CO_2 for 2003, 47.5 kt CO_2 for 2018 and 44.7 kt CO_2 for 2019; and (3) N_2O emissions were not calculated because they are very small. At the same time, the Party mentioned that it is not required to report N_2O and CH_4 emissions from landfill gas flaring. Regarding biomass, the Party reported recalculations in CRF table 1.A(a)s4 for the entire time series for CO_2 and CH_4 emissions, as well as for 2015–2019 for biomass consumption and N_2O emissions, but it did not provide any related information in its NIR. During the review, the Party specified that the small changes to the N_2O emissions in subcategory 1.A.4.a.i are the result of corrections to the energy statistics on biofuels, but it did not specify what type of biofuel and in what way they were corrected by the energy

Sector	Energy
	balance. It also explained that an unnumbered table in the NIR (section 3.2.7.5, p.122) contains the recalculations for both fossil fuel and biogenic emissions. By error, the text in the NIR explains only that the recalculation was for CO2 emissions, but it should have mentioned that it contained both the fossil and biogenic fuels. The ERT noted that, compared with the values reported in the previous submissions, in subcategory 1.A.4.a.i biomass consumption decreased by 13.59 TJ for 2019, and smaller differences occur for 2015–2018. As a consequence, the overall impact of the corresponding recalculations for CO2, CH4 and N2O emissions for 2019 amounts to a decrease of 0.26 per cent (0.26 kt CO2 eq) compared with the previous submissions, excluding CO2 emissions. The ERT considers that the Party did not present the different reasons affecting the recalculations transparently and did not present the impact of the recalculations separately along with the aggregated category-level information.
Updated NLD Response in NIR/CRF 2024	The notations key NA for the category 1.B.2.b.6 AD are changed to NO
Paragraph or table number in: NIR, CRF and or Methodology report (MR)	CRF category 1.B.2.b.6

Sector	Energy
ID# concept ARR	E.6
Addressing/Not resolved/ New from 2022 review	Not resolved
Issue and/or problem classificationa[, b]	1.A.4.b Residential – biomass – CO2, CH4 and N2O (E.15, 2021) Transparency
Recommendation made in previous review report	Transparently present the different reasons affecting the recalculations for each subcategory, as well as the impact of the recalculations separately along with the aggregated category-level information in future annual submissions.
ERT assessment and rationale	Not resolved. The Party explained in its NIR (section 3.2.7.5, p.121) that it took into consideration the recalculations provided by the energy balance for natural gas for 2015–2019, but it did not provide any information related to the biomass recalculations that are

Sector	Energy
	reported in CRF table 1.A(a)s4 for biomass consumption and the corresponding CO2, CH4 and N2O emissions reported under subcategory 1.A.4.b.i (residential – stationary combustion). The ERT noted that, according to the CRF tables, there were recalculations for biomass, particularly for 2019. During the review, the Party explained that an unnumbered table in the NIR (section 3.2.7.5, p.122) contains the recalculations for both fossil fuel and biogenic emissions. By error, the text in the NIR explains only that the recalculation was for CO2 emissions, but it should have mentioned that it contained both the fossil and biogenic fuels. The ERT noted that subcategory 1.A.4.b.i (biomass consumption) increased by 21.28 TJ for 2019, and smaller differences occur for 2015–2018 compared with the values reported in the previous submission. As a consequence, the overall impact of the corresponding recalculations for the CO2, CH4 and N2O emissions for 2019 amounts to an increase of 0.02 kt CO2-eq compared with the previous submission, excluding CO2 emissions.
Updated NLD Response in NIR/CRF 2024	Information on the methods, EFs and verification of the estimation of CH4 emissions from natural gas can be found in the NIR and in more detail in the Methodology report (Honig et al., 2024).
Paragraph or table number in: NIR, CRF and or Methodology report (MR)	See paragraph 3.3.2. NIR and paragraph 2.4. Oil and Gas MR (Honig et al., 2024).

Sector	Energy
ID# concept ARR	E.7
Addressing/Not resolved/ New from 2022 review	Addressing
Issue and/or problem classificationa[, b]	1.B.2.b Natural gas – gaseous fuels – CO2 and CH4 (E.12, 2021) (E.21, 2019) (E.27, 2017) Comparability
Recommendation made in previous review report	Report the appropriate notation keys in CRF table 1.B.2 for AD and CO2 and CH4 emissions, ensuring time-series consistency.
ERT assessment and rationale	Addressing. The Party reported “NA” for the AD and “NO” for CH4 and CO2 emissions in CRF table 1.B.2 for the entire time series for subcategory 1.B.2.b.6. (natural gas – other). In

Sector	Energy
	previous submissions the Party had reported "IE" for AD and "NO" for CH_4 and CO_2 emissions. During the review, the Party explained that it had reported "NA" for AD because there are no emissions in this category. The ERT noted that, according to the 2006 IPCC Guidelines (vol. 1, chap. 8, p.8.7), "NA" is to be used for activities under a given category that occur within the Party but do not result in emissions or removals of a specific gas. Where "NA" is reported for AD and there is a method and an EF in the 2006 IPCC Guidelines (according to the 2006 IPCC Guidelines, vol. 1, chap. 8) for the particular category–gas combination, then "NE" should be used (in this case, for CH_4 and CO_2 emissions). The same chapter of the 2006 IPCC Guidelines notes that activities under subcategory 1.B.2.b.6 (natural gas – other) could be represented by the fugitive emissions from natural gas systems (excluding venting and flaring) if not otherwise accounted for in the other categories (exploration, production, processing, transmission and storage, distribution) and may include emissions from well blowouts and pipeline ruptures or dig-ins. Considering the above information, the Party informed the ERT during the review that the situations referenced above do not appear to be the case within the Party and consequently the appropriate notation key for the AD for subcategory 1.B.2.b.6 (natural gas – other) would be "NO". The ERT considers that the issue will be resolved if the Party uses the appropriate notation keys for subcategory 1.B.2.b.6 (natural gas – other).
Updated NLD Response in NIR/CRF 2024	The notations key NA for the category 1.B.2.b.6 AD are changed to NO
Paragraph or table number in: NIR, CRF and or Methodology report (MR)	CRF category 1.B.2.b.6

Sector	Energy
ID# concept ARR	E.8
Addressing/Not resolved/ New from 2022 review	Not resolved
Issue and/or problem classificationa[, b]	1.B.2.b Natural gas – gaseous fuels – CH4 (E.17, 2021) Comparability
Recommendation made in previous review report	(a) Include in the next NIR further information on the methods and EFs used to estimate fugitive emissions of CH4 from natural gas (category 1.B.2.b), as well as the verification processes used by the Party; (b) Report in the CRF tables disaggregated estimates to the extent possible while maintaining confidentiality (e.g. for the following subcategories: 1.B.2.b.1 natural gas: exploration; 1.B.2.b.2 natural gas: production; and 1.B.2.b.3 natural gas: processing) in order to increase the transparency and comparability of its reporting under this category.
ERT assessment and rationale	Not resolved. (a) The Party did not report in the NIR further information on the methods and EFs used or on the verification processes for estimating CH4 emissions from natural gas (category 1.B.2.b). During the review the Party described the explanation provided in the methodology report (Honig et al., 2022), according to which CH4 emissions are reported aggregated consistently with the information received from the companies. The ERT noted that the transparency of the report will be increased by implementing the recommendation made by the previous ERT that the Party include in the NIR information on the methods and EFs used to estimate fugitive emissions of CO2 and CH4 from natural gas (category 1.B.2.b), as well as on the verification processes used by the Party. (b) The Party continued to report in CRF table 1.B.2 aggregated estimates based on plant-specific data provided by relevant companies for the subcategories 1.B.2.b.1 (natural gas exploration), 1.B.2.b.2 (natural gas production) and 1.B.2.b.3 (natural gas processing) by using “IE” for the corresponding CO2 and CH4 emissions. During the review, the Party explained that in their reports the companies did not consistently provide the AD and GHG emissions disaggregated by activity for this category and the companies are not planning to disaggregate their data in the future. According to

Sector	Energy
	the explanations provided in CRF table 9, the combustion and fugitive emissions cannot be separated between oil and gas exploration and production, and the fugitive emissions from processing cannot be separated from the total fugitive emissions from natural gas activities. For this reason, emissions from oil exploration and production and from natural gas exploration and production are included in subcategory 1.A.1.c.ii (oil and gas extraction); fugitive emissions from natural gas processing are reported under subcategories 1.B.2.c.1.iii (venting, combined) and 1.B.2.c.2.iii (flaring, combined); venting emissions from gas and oil are included under subcategory 1.B.2.c.1.iii (venting, combined); and flaring emissions from gas and oil are included under subcategory 1.B.2.c.2.iii (flaring, combined). The ERT noted that it is good practice under the 2006 IPCC Guidelines (vol. 2, p.4.36, and table 4.2.2, p.4.42) to estimate the fugitive emissions at a disaggregated level and transparently report them in the CRF tables. In this regard, the Party could explore a way to use the disaggregated information from the detailed reports communicated to the ERT during the review that were provided by three companies from a total of 11, then extend the separation of the GHG emissions by CRF categories of the total emissions reported from natural gas activities.
Updated NLD Response in NIR/CRF 2024	Information on the methods, EFs and verification of the estimation of CH4 emissions from natural gas can be found in the NIR and in more detail in the Methodology report (Honig et al., 2024). According to the European Pollutant Release and Transfer Register, it is expected that more detailed reporting data will become available. Therefore, no actions are planned to make this separation until these data become available.
Paragraph or table number in: NIR, CRF and or Methodology report (MR)	See paragraph 3.3.2. NIR and paragraph 2.4. Oil and Gas MR (Honig et al., 2024).

Sector	IPPU
ID# concept ARR	I.1
Addressing/Not resolved/ New from 2022 review	Not resolved
Issue and/or problem classificationa[, b]	2.A.1 Cement production – CO2 (I.17, 2021) Consistency
Recommendation made in previous review report	Provide more information in the NIR on time-series consistency, including an explanation for why the IEF is constant for 2002–2004, considering that the same detailed methodology is applied for the monthly testing of every batch.
ERT assessment and rationale	Not resolved. The Party did not implement changes in the IEF used and did not provide additional information on the time-series consistency in the NIR. In the NIR (p.452) and during the review, the Party clarified that the issue is not prioritised among the pending issues/recommendations.
Updated NLD Response in NIR/CRF 2024	The Party did not implement in its NIR the recommendation made in the previous review report. During the review, the Party clarified that it has set their priorities for other important issues/recommendations. Because the is an issue of the past, Netherlands has set priorities for other important issues/recommendations. Furthermore, cement production does not occur anymore in the Netherlands because the only important producer closed in 2020.
Paragraph or table number in: NIR, CRF and or Methodology report (MR)	-

Sector	IPPU
ID# concept ARR	I.2
Addressing/Not resolved/ New from 2022 review	Not resolved
Issue and/or problem classificationa[, b]	2.A.1 Cement production – CO2 (I.17, 2021) Consistency

Sector	IPPU
Recommendation made in previous review report	Provide information on the changes in the raw materials used or the process followed that led to the increase in the variability of the IEF for 2005 onward.
ERT assessment and rationale	Not resolved. The Party did not provide additional information in the NIR. In the NIR (p.452) and during the review, the Party clarified that the issue is not a priority for the inventory team.
Updated NLD Response in NIR/CRF 2024	The Party did not implement in its NIR the recommendation made in the previous review report. During the review, the Party clarified that it has set their priorities for other important issues/recommendations. Because the is an issue of the past, Netherlands has set priorities for other important issues/recommendations. Futhermore, cement production does not occur anymore in the Netherlands because the only important producer closed in 2020.
Paragraph or table number in: NIR, CRF and or Methodology report (MR)	-

Sector	IPPU
ID# concept ARR	I.3
Addressing/Not resolved/ New from 2022 review	Not resolved
Issue and/or problem classificationa[, b]	2.A.2 Lime production – CO2 (I.18, 2021) Transparency
Recommendation made in previous review report	Provide information on the source of the AD in the NIR, including a discussion on time-series consistency.
ERT assessment and rationale	Not resolved. The Party reported in the NIR (section 4.2.2, p.134) a description of two sugar industry plants in which limestone was used to produce lime for sugar juice purification. The Party also reported the data source for EFs; however, the data source for the AD is missing. The AD are only available for 1990 and from 2003 onward. The Party did not provide an explanation of why the AD between 1990 and 2003 were not reported. The last ERT asked for an explanation of the significant decrease in the AD between 1990 and 2004, followed by a fluctuating but increasing trend. This was not explained in the NIR.

Sector	IPPU
Updated NLD Response in NIR/CRF 2024	Activity data is obtained from the sugar company's annual reports. This is available from 2003 onwards.
Paragraph or table number in: NIR, CRF and or Methodology report (MR)	NIR 4.2.2

Sector	IPPU
ID# concept ARR	I.4
Addressing/Not resolved/ New from 2022 review	Not resolved
Issue and/or problem classificationa[, b]	2.A.3 Glass production – CO2 (I.19, 2021) Consistency
Recommendation made in previous review report	Provide more information in the NIR on time-series consistency for glass production, including on the decision to interpolate emissions rather than EFs and the rationale for not applying available plant-specific data.
ERT assessment and rationale	Not resolved. The Party did not report more information in the NIR as requested in the previous review report. In the NIR (p.454) and during the review, the Party clarified that this is not a priority for the inventory team owing to the considerable effort required to resolve the issue; instead, the Party will concentrate resources on improving the most recent and future emission data, including for key sources.
Updated NLD Response in NIR/CRF 2024	Because this is an issue of the past, Netherlands has set priorities for other important issues/recommendations.
Paragraph or table number in: NIR, CRF and or Methodology report (MR)	-

Sector	IPPU
ID# concept ARR	I.5
Addressing/Not resolved/ New from 2022 review	Not resolved
Issue and/or problem classificationa[, b]	2.A.4 Other process uses of carbonates – CO2 (I.20, 2021) Comparability
Recommendation made in previous review report	Include the process emissions associated with mineral wool production in the IPPU sector as per the 2006 IPCC Guidelines (vol. 3, chap. 2, p.2.27).
ERT assessment and rationale	Not resolved. The Party continues to report all emissions linked to mineral wool production under the energy sector. During the review and in the NIR (p.455), the Party clarified that it plans to implement this recommendation in its next annual submission.
Updated NLD Response in NIR/CRF 2024	For this submission, unfortunately it was not possible to separate the mineral wool production emissions. Although below threshold, Netherlands will investigate possibilities for next submissions.
Paragraph or table number in: NIR, CRF and or Methodology report (MR)	NIR 4.2.6

Sector	IPPU
ID# concept ARR	I.6
Addressing/Not resolved/ New from 2022 review	Not resolved
Issue and/or problem classificationa[, b]	2.A.4 Other process uses of carbonates – CO2 (I.21, 2021) Accuracy
Recommendation made in previous review report	Investigate the reporting for 2017 and explain the slightly higher IEF for ceramics in that year compared with all other years of the time series.
ERT assessment and rationale	Not resolved. The Party did not report the information in the NIR as requested in the previous review report. In the NIR (p.456) and during the review, the Party clarified that this is not a priority for the inventory team owing to the considerable effort required to

Sector	IPPU
	resolve the issue; instead, the Party will concentrate resources on improving the most recent and future emission data, including for key sources.
NLD Response in NIR /CRF 2023	Because the is an issue of the past, Netherlands has set priorities for other important issues/recommendations.
Updated NLD Response in NIR/CRF 2024	Because the is an issue of the past, Netherlands has set priorities for other important issues/recommendations.
Paragraph or table number in: NIR, CRF and or Methodology report (MR)	NIR 4.2.6

Sector	IPPU
ID# concept ARR	I.7
Addressing/Not resolved/ New from 2022 review	Not resolved
Issue and/or problem classificationa[, b]	2.A.4 Other process uses of carbonates – CO2 (I.21, 2021) Transparency
Recommendation made in previous review report	Provide a comparison in the NIR between the process emissions reported for ceramics producers under the EU ETS and the current inventory estimates.
ERT assessment and rationale	Not resolved. The Party did not report the information in the NIR as requested in the previous review report. In the NIR (p.456) and during the review, the Party clarified that this is not a priority for the inventory team owing to the considerable effort required to resolve the issue; instead, the Party will concentrate resources on improving the most recent and future emission data, including for key sources.
Updated NLD Response in NIR/CRF 2024	Because this is not a key source, Netherlands has set priorities for other important issues/recommendations
Paragraph or table number in: NIR, CRF and or Methodology report (MR)	-

Sector	IPPU
ID# concept ARR	I.8
Addressing/Not resolved/ New from 2022 review	Not resolved
Issue and/or problem classificationa[, b]	2.A.4 Other process uses of carbonates – (2.A.4.b soda ash) – CO2 (I.1, 2021) (I.6, 2019) (I.7, 2017) (I.13, 2016) (I.13, 2015) Accuracy
Recommendation made in previous review report	Conduct further research and consultation with industry and/or statistical agencies on other process uses of carbonates to either access additional AD and EFs or seek verification of the current method and emission estimates in order to ensure the completeness and accuracy of the estimates.
ERT assessment and rationale	Not resolved. The Party reported in its NIR (section 4.2.2, p.135) that the domestic consumption of soda ash for 2001 and 2002 was estimated based on the quantity produced and its imports and exports. For 1990–2000 and 2003 onward, these figures were estimated by extrapolating from the 2001 and 2002 values. The previous ERT suggested investigating the use of EU ETS data to resolve this issue. During the review the Party clarified that it tried to develop a new methodology, but that it did not succeed in its implementation. The Party mentioned that this is also described in the NIR (section 4.2.2, p.135) and in the methodology report (Honig et al., 2022, section 2.2.3.1). However, the NIR did not include this explanation and the referenced section in the methodology report was incorrect. During the review, the Party further clarified that the description is provided in the methodology report (Honig et al., 2022, section 2.2.3.2, p.52). Since soda ash is also used in glass production, in order to prevent double counting the CO2 emissions from soda ash used for glass production should be subtracted from the emissions from total soda ash use, because these are integrally reported. However, this procedure has not been used for the figures produced so far, owing to a lack of data and because the small quantity of CO2 emissions estimated as being associated with soda ash use contain a considerable margin of uncertainty. Taking this explanation into account, the Party identified a number of emissions that are double counted. However, the methodology has still not been improved. There are no data for 1990–2000 and 2003 onward and the Party has not delivered an explanation of why EU ETS data were not used. The ERT considers that the Party has not implemented the previous recommendation.

Sector	IPPU
Updated NLD Response in NIR/CRF 2024	Because the emissions are below threshold, Netherlands has set priorities for other important issues/recommendations.
Paragraph or table number in: NIR, CRF and or Methodology report (MR)	NIR 4.2.6

Sector	IPPU
ID# concept ARR	I.9
Addressing/Not resolved/ New from 2022 review	Not resolved
Issue and/or problem classificationa[, b]	2.B Chemical industry – CO_2, CH_4 and N_2O (I.22, 2021) Transparency
Recommendation made in previous review report	Implement the planned update and consider the possibility of reporting in CRF table 2(I).A-Hs1 more detailed AD and emissions (e.g. for ethylene production, for which AD are available from Eurostat).
ERT assessment and rationale	Not resolved. The AD for the category continues to be reported using notation keys “C” (including for ethylene production) and “IE”. In its NIR (section 4.3.1), the Party provided general information on AD for the Dutch chemical industry. For ethylene production, the Party reported that emissions are estimated on the basis of capacity data by using a default capacity utilisation rate of 86 per cent (based on Neelis et al., 2005) and applying the default EF of 0.86 t/t ethylene oxide. For 2020, EU petrochemistry data were used as a new source. The Party further clarified that it cannot supply AD as it is not possible to find current AD for ethylene production in the Eurostat Prodcom database. During the review, the Party provided further information on the AD, EFs and emissions for the chemical industry, which contained confidential plant-specific data. The ERT considers that since information is still missing from the CRF table, the Party has not implemented the previous recommendation.
Updated NLD Response in NIR/CRF 2024	Confidential plant-specific data cannot be included in the CRF, and are available to reviewers upon request. The number of plants per sector is mentioned in section 4.3.1

Sector	IPPU
Paragraph or table number in: NIR, CRF and or Methodology report (MR)	NIR 4.3.1

Sector	IPPU
ID# concept ARR	I.10
Addressing/Not resolved/ New from 2022 review	Addressing
Issue and/or problem classificationa[, b]	2.B Chemical industry – CO2, CH4 and N2O (I.22, 2021) Transparency
Recommendation made in previous review report	Include more information in the NIR on the chemical industry, such as the number of plants in operation and the overall production capacity for each chemical industry subsector (caprolactam, silicon carbide, titanium dioxide production, methanol, ethylene, ethylene oxide, acrylonitrile, carbon black, industrial gas, carbon electrodes, activated carbon, ethylene dichloride and vinyl chloride monomer).
ERT assessment and rationale	Addressing. The Party reported in its NIR (section 4.3.1, p.137) the number of plants for the different subsectors. Furthermore, the Party reported “C” in CRF table 2(I).A-Hs1 for AD in the chemical industries in which emissions occur. During the review, the Party provided further information on the AD, EFs and emissions for the chemical industry, which contained confidential plant-specific data. The ERT considers that information is still missing in the NIR, such as the number of plants in operation and the overall production capacity of each chemical industry subsector (caprolactam, silicon carbide, titanium dioxide production, methanol, ethylene, ethylene oxide, acrylonitrile, carbon black, industrial gas, carbon electrodes, activated carbon, ethylene dichloride and vinyl chloride monomer).
Updated NLD Response in NIR/CRF 2024	The number of plants is mentioned in section 4.3.1
Paragraph or table number in: NIR, CRF and or Methodology report (MR)	4.3.1

Sector	IPPU
ID# concept ARR	I.11
Addressing/Not resolved/ New from 2022 review	Not resolved
Issue and/or problem classificationa[, b]	2.B.8 Petrochemical and carbon black production – CO2 and CH4 (I.23, 2021) Completeness
Recommendation made in previous review report	Report AD and emissions under category 2.B.8.c (ethylene dichloride and vinyl chloride monomer) or, if this is not possible for confidentiality reasons, change the reporting from “NO” to “IE”.
ERT assessment and rationale	Not resolved. The Party did not report AD and emissions under category 2.B.8.c for ethylene dichloride and vinyl chloride monomer and did not change its reporting from “NO” to “IE”. In its NIR (p.458) the Party clarified that an update on general AD for the Dutch chemical industry is included in the NIR (section 4.3.1). However, the ERT did not find an explanation for the reporting of ethylene dichloride and vinyl chloride monomer in the referred section of the NIR. During the review, the Party explained that the emissions were included under category 2.B.8.c, hence the ERT did not consider this as an underestimation of emissions. Furthermore, the Party noted that it will change the reporting from “NO” to “IE” in the next submission and progress was being made in terms of updating information on AD.
Updated NLD Response in NIR/CRF 2024	Not all AD data is available, therefore notations keys are changed to IE
Paragraph or table number in: NIR, CRF and or Methodology report (MR)	NIR 4.3.2

Sector	IPPU
ID# concept ARR	I.12
Addressing/Not resolved/ New from 2022 review	Addressing
Issue and/or problem classificationa[, b]	2.B.8 Petrochemical and carbon black production – CO2 (I.4, 2021) (I.10, 2019) (I.10, 2017) (I.16, 2016) (I.16, 2015) Transparency
Recommendation made in previous review report	Document the QA/QC activities and outcomes for the chemical and petrochemical sources in the IPPU sector.
ERT assessment and rationale	Addressing. The Party reported in its NIR (section 4.3.4, p.146) the information on the QA/QC activities and outcomes for the chemical and petrochemical sources. However, the NIR provided no information on the analysis of data reported under the EU ETS. During the review, the Party clarified that the information on QA/QC activities could not be reported in the 2022 NIR because the EU ETS reports for these companies were not available on time and it received them only during the review week. The ERT considers that the issue will be resolved if the Party includes information from EU ETS reports in the NIR.
Updated NLD Response in NIR/CRF 2024	Following the request for EU-ETS reports, it turned out that emissions from petrochemical and carbon black production are either not included in the ETS, or situated on the Chemelot estate (reporting only the total). Therefore no emission verification to ETS reports can be made.
Paragraph or table number in: NIR, CRF and or Methodology report (MR)	NIR 4.3.4

Sector	IPPU
ID# concept ARR	I.13
Addressing/Not resolved/ New from 2022 review	Not resolved
Issue and/or problem classificationa[, b]	2.B.9 Fluorochemical production – HFCs (I.6, 2021) (I.15, 2019) (I.21, 2017) Transparency

Sector	IPPU
Recommendation made in previous review report	Report the HFC-23 load in the untreated flow based on flow meter results and stream composition in the NIR or in the energy, industry and waste management report, and report the type of HFCs separately in the CRF tables, or, if it is difficult to implement this recommendation soon, investigate ways to present information on AD in the NIR that demonstrate the completeness of reporting until the recommendation can be implemented.
ERT assessment and rationale	Not resolved. The Party did not report the information in its NIR as requested in the previous review report. In its NIR (p.445) and during the review, the Party clarified that the flow meter results were not available, so this issue cannot be resolved. The emission data are obtained from the AER of the only company in the Netherlands. The Party further clarified that the AER is checked annually by the competent authority; hence these data are considered to be of the highest quality. The ERT considers that the issue will be resolved if the Party reports information on AD.
Updated NLD Response in NIR/CRF 2024	Flow meter results are not available. The emissions data is obtained from the Annual Emission Report of the only company in the Netherlands. This Annual Emissions Report is annually checked by the competent authority, hence these data are considered to be of the highest quality.
Paragraph or table number in: NIR, CRF and or Methodology report (MR)	NIR 4.3.4

Sector	IPPU
ID# concept ARR	I.14
Addressing/Not resolved/ New from 2022 review	Not resolved
Issue and/or problem classificationa[, b]	2.C.1 Iron and steel production – CO2 (I.8, 2021) (I.17, 2019) (I.23, 2017) Transparency
Recommendation made in previous review report	(1) Assess the carbon flow and carbon balance in each process in the iron and steel industry in order to ensure the completeness and transparency of reporting;

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	(2) Conduct QA/QC activities for the AD, as described in the 2006 IPCC Guidelines (vol. 3, chap. 4.2.4.1), provide a quantitative summary of QA/QC activities in order to demonstrate that the reporting is correct (e.g. QA/QC procedure for subcategories 2.C.1.d (sinter) and 2.C.1.e (pellet) (see document FCCC/ARR/2017/NLD, ID# I.24) and for reporting the allocation to the energy sector subcategories 1.B.1.b, 1.A.1.a, 1.A.2.a and 1.A.1.c) and report a summary of the results of QA/QC activities (see document FCCC/ARR/2017/NLD, ID# I.25).
ERT assessment and rationale	Not resolved. (1) The Party did not provide in its NIR an assessment of the carbon flow and carbon balance for each process in the iron and steel industry. During the previous review, the Party clarified that the emissions relevant for iron and steel production were reported in CRF subcategories 1.A.1.c, 1.A.2.a, 1.B.1.b and 2.C.1 and partly in category 2.A.4.d and the sum of emissions reported for these categories was consistent with the total reported under the EU ETS. In its NIR (p.446) and during the review, the Party clarified that the explanation was incorporated in the NIR (section 4.4.2). However, the ERT noted that neither this explanation nor additional information were included in the NIR. (2) The Party reported in its NIR (section 4.4.4, p.150) that in addition to the general QA/QC procedure for category 2.C.1, the AD and emission data of the producers' AERs were compared with the EU ETS monitoring reports and no differences were found. The Party also did not report in its NIR information on conduct of the QA/QC activities for the AD. During the review, the Party clarified that the requested information is included in the NIR (section 4.4.2). The ERT noted that the NIR (section 4.4.2) did not contain any additional information compared with the previous NIR.
Updated NLD Response in NIR/CRF 2024	The Netherlands needs more information on how to perform an QA/QC and assessment on carbon balance, which is obtained from the company. This could be an issue for further submissions.
Paragraph or table number in: NIR, CRF and or Methodology report (MR)	NIR 4.3.4

Sector	IPPU
ID# concept ARR	I.15
Addressing/Not resolved/ New from 2022 review	Addressing
Issue and/or problem classificationa[, b]	2.C.1 Iron and steel production – CO2 and CH4 (I.9, 2021) (I.18, 2019) (I.24, 2017) Comparability
Recommendation made in previous review report	Ensure that all emissions are reported under iron and steel production subcategories in the IPPU sector, in accordance with the 2006 IPCC Guidelines.
ERT assessment and rationale	Addressing. The Party reported "IE" for CO2 emissions from pig iron, sinter and pellet production and "IE" for CH4 emissions from pellet production in CRF table 2(I)A- Hs2. According to CRF table 9 all emissions from the subcategories were reported under subcategory 2.C.1.f. According to the NIR (p.447) all process emissions are reported in the IPPU sector, in CRF category 2.C.1 and partly in subcategory 2.A.4.d, and combustion emissions are reported in subcategories 1.A.1.c (flaring), 1.A.2.a and 1.B.1.b. During the review, the ERT requested (1) a clear presentation of the iron and steel production processes used in 2020; (2) the calculation data sheets for the total GHG emissions associated with iron and steel production (included for categories 2.C.1, 2.A.4.d, 1.A.1.c (flaring), 1.A.2.a and 1.B.1.b) for 2020; and (3) a comparison with the EU ETS data (2020). The Party provided the ERT with a confidential document, "Specification of the Dutch emission figures in the iron and steel category 2015.xls", which includes a schematic presentation of the flows in the iron and steel sector, as well as the CO2 emissions and allocations to CRF categories for 2015. The Party explained that this schematic presentation was a result of an in-depth discussion with the ERT during the in-country review in 2017. The ERT noted from the presentation that the iron and steel production processes are basic oxygen furnace steel, electric arc furnace steel and direct reduction. The Party also provided the ERT with a confidential data calculation spreadsheet ("Confidential review data calculation 2A4d 2C1.xls") for the processes in one of the iron and steel plants for 2021 (including calculations for categories 2.A.4.d and 2.C.1). The ERT commends the Party for providing the information, but the ERT was not able to verify the 2020 CO2 emissions from the data provided because the data were from 2015 and 2021. Regarding the comparison with the EU ETS data, the Party informed the ERT that the Dutch Emissions Authority is the independent national authority appointed to implement and monitor

Sector	IPPU
	the EU ETS, and the necessary confidential data would have to be requested from it. The Party also stated that previous ERTs (for its 2021 and 2019 submissions) had noted that the sum of the emissions related to iron and steel production as reported under CRF categories 1.A.1.c, 1.A.2.a, 1.B.1.b, 2.C.1 and 2.A.4.d is consistent with the total reported under the EU ETS. The current ERT was not able to verify the consistency of the reporting with the EU ETS data. The ERT could not check whether all emissions are reported under the iron and steel production subcategories in the IPPU sector because the data provided were for 2015 and 2021, instead of for 2020, and as such could not compare the data with the EU ETS. However, the ERT carried out a verification based on public data from the EU ETS portal and on production data provided by the International Steel Association and discovered that the data were consistent. The ERT therefore continues to consider the issue as an issue of comparability rather than an issue of accuracy.
Updated NLD Response in NIR/CRF 2024	Confidential plant-specific data cannot be included in the CRF and NIR, and are available to reviewers upon request.
Paragraph or table number in: NIR, CRF and or Methodology report (MR)	-

Sector	IPPU
ID# concept ARR	I.16
Addressing/Not resolved/ New from 2022 review	Addressing
Issue and/or problem classificationa[, b]	2.C.1 Iron and steel production – CO2 and CH4 (I.24, 2021) Completeness
Recommendation made in previous review report	Justify why CH4 emissions from sinter production do not occur or estimate and report these emissions or change the reporting to “NE” and provide information in the NIR to justify the likely level of emissions in accordance with paragraph 37(b) of the UNFCCC Annex I inventory reporting guidelines.
ERT assessment and rationale	Addressing. The Party reported “NO” for CH4 emissions from sinter production in CRF table 2(I)A-Hs2 and in its NIR (section 4.4.6, p.150) and explained that estimates for CH4 process

Sector	IPPU
	emissions from sinter production will be reported in its next annual submission. In the NIR (p.150) and during review, the Party clarified that the preliminary assessment of CH4 process emissions from sinter production is 0.02 kt CH4 (0.5 kt CO_2-eq). This value is below the threshold of significance for the application of an adjustment in accordance with decision 22/CMP.1, annex, paragraph 80(b), in conjunction with decision 4/CMP.11, and therefore this issue was not included in the list of potential problems and further questions raised by the ERT. The ERT considers that the recommendation has not yet been fully addressed because the Party has not yet provided the methodology, AD and EF used for estimating CH4 emissions for the entire time series and has not changed the notation key to “NE”.
Updated NLD Response in NIR/CRF 2024	Because the emissions are below threshold, Netherlands has set priorities for other important issues/recommendations.
Paragraph or table number in: NIR, CRF and or Methodology report (MR)	NIR 4.4.6

Sector	IPPU
ID# concept ARR	I.17
Addressing/Not resolved/ New from 2022 review	Not resolved
Issue and/or problem classificationa[, b]	2.C.1 Iron and steel production – CO2 and CH4 (I.24, 2021) Completeness
Recommendation made in previous review report	Explain the reporting of “NO” for CO2 emissions for subcategory 2.C.1.f, given that sinter and pellet production are reported as “IE”; and check and correct the use of notation keys for all subcategories of category 2.C.1.
ERT assessment and rationale	Not resolved. The Party continued to report “IE” for CO2 emissions from sinter and pellet production and “NO” for subcategory 2.C.1.f in CRF table 2(I)A-Hs2 without an explanation of the reporting in the NIR.

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Updated NLD Response in NIR/CRF 2024	As this only refers to allocation of emissions, this has not yet been prioritised.
Paragraph or table number in: NIR, CRF and or Methodology report (MR)	-

Sector	IPPU
ID# concept ARR	I.18
Addressing/Not resolved/ New from 2022 review	Not resolved
Issue and/or problem classificationa[, b]	2.C.3 Aluminium production – CO2 (I.25, 2021) Convention reporting adherence
Recommendation made in previous review report	Include a check of the IEFs as part of its QC procedures prior to reporting.
ERT assessment and rationale	Addressing. The Party did not describe in the NIR a check of the IEFs as part of its QC procedures. During the review, the Party clarified that the figures for CO2 and PFC emissions are taken directly from AERs and EU ETS reports, which are themselves subject to stringent QA/QC procedures. (A description of the verification process for EU ETS reports is available at https://www.emissionsauthority.nl/topics/year-end-closing-ets/emissions-report-verification.) The ERT agrees with the Party that these processes have already been through a QA/QC system and considers that the issue will be resolved when the Party includes information in the NIR on any follow-up checks of the IEF before submitting the inventory.
Updated NLD Response in NIR/CRF 2024	The emissions data is obtained from the Annual Emission Report of the only company in the Netherlands. This Annual Emissions Report is annually checked by the competent authority, hence these data are considered to be of the highest quality. It is also compared with the company's ETS report, that contains the same emission data.

Sector	IPPU
Paragraph or table number in: NIR, CRF and or Methodology report (MR)	-

Sector	IPPU
ID# concept ARR	I.21
Addressing/Not resolved/ New from 2022 review	Addressing
Issue and/or problem classificationa[, b]	2.D.1 Lubricant use – CO_2 (I.27, 2021) Transparency
Recommendation made in previous review report	Report the AD in CRF table 2(I).A-Hs2 in the annual submission.
ERT assessment and rationale	Addressing. The Party reported “C” for AD in CRF table 2(I).A-Hs2. However, the Party did not explain in its NIR (section 4.5.2, p.151) why the AD are confidential. During the review, the Party clarified that the AD are no longer confidential and provided a table containing the data and confirmed that it plans to include the AD in its next annual submission.
Updated NLD Response in NIR/CRF 2024	The activity data are now made available and will be included in the CRF.
Paragraph or table number in: NIR, CRF and or Methodology report (MR)	-

Sector	IPPU
ID# concept ARR	I.23
Addressing/Not resolved/ New from 2022 review	Addressing
Issue and/or problem classificationa[, b]	2.F.1 Refrigeration and air conditioning – HFCs (I.14, 2021) (I.27, 2019) Consistency
Recommendation made in previous review report	(1) Report HFC emissions for subcategories 2.F.1.a (commercial refrigeration), 2.F.1.d (transport refrigeration) and 2.F.1.f (stationary air conditioning) for 1990–2012 in the country in order to improve time-series consistency; (2) Revise the description in the NIR of the data-collection methods such that clear information on the method currently being used is provided.
ERT assessment and rationale	Addressing. (1) Not resolved. The data reported in the NIR for 1990–2012 are still aggregated for subcategories 2.F.1.a, 2.F.1.d and 2.F.1.f. During the review, the Party clarified that it was not possible to disaggregate data for the years before 2013 owing to the unavailability of data. (2) Resolved. The Party provided in its NIR (section 4.7.2, p.155) and the methodology report (Honig et al., 2022, chap. 2.2.3.9, p.65) a description of the current data-collection methods.
Updated NLD Response in NIR/CRF 2024	It is not possible to disaggregate data for the years prior to 2013 owing to unavailability of data.
Paragraph or table number in: NIR, CRF and or Methodology report (MR)	-

Sector	IPPU
ID# concept ARR	I.24
Addressing/Not resolved/ New from 2022 review	Addressing
Issue and/or problem classificationa[, b]	2.F.1 Refrigeration and air conditioning – HFCs (I.15, 2021) (I.28, 2019) Comparability
Recommendation made in previous review report	Report emissions from operating stock and disposal separately in CRF table 2(II).B-Hs2, or report "IE" rather than "NA" for years in which emissions occurred and "NO" for years in which emissions were not occurring, if reporting separate emissions from disposal is not possible owing to confidentiality concerns of the operators.
ERT assessment and rationale	Addressing. The last ERT recommended reporting emissions from stocks and disposal separately and that if these are confidential then the Party should use notation keys. The Party reported "NO" for 1990–2012 and "IE" for 2013–2020 in CRF table 2(II).B-Hs2 for manufacturing and disposal emissions from refrigeration and air conditioning for HFC-23, HFC-32, HFC-125, HFC-134a and HFC-143a. The Party explained in its NIR (p.450) that the stocks are the pivotal data for the emissions calculation, but did not explain that these emissions are confidential. During the review, the Party clarified that it had reported "IE" because the data on manufacturing and disposal are already reported in the emissions from the stocks. During the review, the Party further clarified that emissions from leakages, filling of installations (new and as a result of leakage during operation) and dismantling are calculated by using data directly from the refrigerant registration system, as follows: (a) The volume of refrigerant used in new installations; (b) The volume of refrigerant to fill operating installations (as a result of leakage); (c) The volume of refrigerant gained back from retrofitting or maintenance; (d) The volume of dismantled installations. The Party also explained that it used the default EFs from the 2006 IPCC Guidelines for calculating emissions from refrigerant management of containers. Disposed refrigerants are also registered, but the Party has assumed that disposal is carried out in a responsible way without further losses apart from those occurring during dismantling. The ERT was unable to understand why there are no emissions of fluorinated gases during

Sector	IPPU
	the disposal of the refrigeration and air-conditioning systems and noted that the Party collects data on the volume of refrigerant used in new installations and the volume of refrigerant to fill operating installations. As such, all necessary data are available to calculate and report emissions from filling and disposal separated by usage. However, during the review the Party clarified that all types of emission are taken into account (i.e. refilling, dismantling, re-use, leakage), but as these cannot be separately distinguished in the columns of CRF table 2(II)B-Hs2, it has reported "IE" as follows: (a) 'Manufacturing' is indicated as "IE" because data on new filling and refilling cannot be disaggregated (and there is no HFC production in the Netherlands); (b) 'From disposal' should be "IE", because data cannot be disaggregated. The Party does not calculate emissions from the incineration of disposed HFCs; (c) 'Recovery' should remain "IE" because the Party calculates emissions from leakage from working systems using the amount that is filled yearly (i.e. this is a combination of new and recovered refrigerants and the Party does not make a distinction). The column 'From stock' contains the total emissions. Furthermore, the Party clarified that is has implemented a new method in which it is using data collected from the refrigerants registration system for the Netherlands' Pollutant Release and Transfer Register, with the threshold for registration of systems being HFC content ≥5,000 kg CO_2-eq. The new method applied using this data source resulted in lower emission estimates than those calculated using the old stock-model method. The ERT assumes that the lower emissions are because of the threshold of HFC content ≥5,000 kg CO_2-eq. The ERT still recommends reporting the emissions differentiated from 'Manufacturing', 'From stock' and 'From disposal'. However, if these emissions are confidential the ERT recommends reporting the notation key "IE". The ERT assumes that the new model is omitting some emissions, because of the low threshold for registration, but assumes that these are below the threshold of significance.
Updated NLD Response in NIR/CRF 2024	Emission cannot be split, therefore notation key IE is used. The emissions calculated with this new method are lower than those calculated with the old stock-model method probably due to the assumption in the stock model method that the usage figures were the same as the sales figures and that a fixed leakage percentage of 5.8% was used. According to the new method the average leakage rate for example during the period 2013-2015 was approximately 4%.

Sector	IPPU
Paragraph or table number in: NIR, CRF and or Methodology report (MR)	-

Sector	IPPU
ID# concept ARR	I.26
Addressing/Not resolved/ New from 2022 review	Not resolved
Issue and/or problem classificationa[, b]	2.F Product uses as substitutes for ozone-depleting substances – HFCs(I.30, 2021) Transparency
Recommendation made in previous review report	Improve the transparency of the reporting of emissions for categories 2.F.2–2.F.5 as a matter of urgency by disaggregating the data for each gas and subcategory as far as possible.
ERT assessment and rationale	Not resolved. The Party did not disaggregate the emissions for categories 2.F.2–2.F.5. During the review the Party clarified that it is not possible to report disaggregated data from 2015 onward owing to the lack of AD. The ERT noted that the new method (see ID# I.27 below) is not delivering the necessary data to report the emissions differentiated in accordance with the subsectors required in the CRF tables.
Updated NLD Response in NIR/CRF 2024	It is not possible to disaggregate the data from 2015 onwards
Paragraph or table number in: NIR, CRF and or Methodology report (MR)	NIR 4.7.3

Sector	IPPU
ID# concept ARR	1.27
Addressing/Not resolved/ New from 2022 review	Not resolved
Issue and/or problem classificationa[, b]	2.F Product uses as substitutes for ozone-depleting substances – HFCs(I.30, 2021) Transparency
Recommendation made in previous review report	Include the following information in the NIR to allow a better understanding of the reporting: (a) The number of companies producing hard foam in the Netherlands; (b) Information on whether production of open-cell foam occurs or has previously occurred in the Netherlands; (c) Information about whether hard foam is currently or has previously been exported (e.g. by obtaining data from the Netherlands association of polyurethane hard foam manufacturers); (d) Information on the importation of hard foam that will lead to emissions during use and decommissioning; (e) Information on the number of fire extinguishing systems using HFCs in operation in the Netherlands and the rationale for reporting as confidential the corresponding AD and emissions; Not resolved. The Party did not provide detailed information on items (a–i) listed in the previous review report about hard foam, open-cell foam, fire extinguishers, methylene diphenyl diisocyanates, aerosols and solvents. During the review, the Party clarified that it developed a new methodology, which is described in the methodology report (Honig et al., 2022), and new emission estimates are presented in the NIR (section 4.7.2) and methodology report (Honig et al., 2022, chap. 2.2.3.11). However, the ERT noted that the referenced documents do not contain the information addressing the recommendation made in the previous review report. The ERT considers that the issue will be resolved if the Party makes a detailed investigation to check the quality of the inventory and develop a method for reporting the emissions differentiated at the subsector level and delivers the necessary information for a transparent and comparable (f) Information on the number of importers of methylene diphenyl diisocyanates in the Netherlands and a justification for reporting these data as confidential;

Sector	IPPU
	(g) Information on the number of companies using HFCs in aerosols; (h) Information on how imports and exports are considered in estimating emissions from aerosols; (i) Information on the number of companies using HFCs as solvents and the rationale for reporting these emissions as confidential.
ERT assessment and rationale	Not resolved. The Party did not provide detailed information on items (a–i) listed in the previous review report about hard foam, open-cell foam, fire extinguishers, methylene diphenyl diisocyanates, aerosols and solvents. During the review, the Party clarified that it developed a new methodology, which is described in the methodology report (Honig et al., 2022), and new emission estimates are presented in the NIR (section 4.7.2) and methodology report (Honig et al., 2022, chap. 2.2.3.11). However, the ERT noted that the referenced documents do not contain the information addressing the recommendation made in the previous review report. The ERT considers that the issue will be resolved if the Party makes a detailed investigation to check the quality of the inventory and develop a method for reporting the emissions differentiated at the subsector level and delivers the necessary information for a transparent and comparable inventory.
Updated NLD Response in NIR/CRF 2024	Netherlands used a method as described in the Methodology report since the 2022 submission. This method is based on using emissions data from adjacent countries. However, Netherlands would like to develop a better method, but unfortunately no data is available.
Paragraph or table number in: NIR, CRF and or Methodology report (MR)	NIR 4.7.3

Sector	IPPU
ID# concept ARR	I.29
Addressing/Not resolved/ New from 2022 review	Not resolved
Issue and/or problem classificationa[, b]	2.G.2 SF6 and PFCs from other product use – SF6 (I.32, 2021) Completeness

Sector	IPPU
Recommendation made in previous review report	Verify any potential uses of SF6 in particle accelerators in universities, industry and medical facilities and in magnesium production, referred to in DHV (2000), across the time series and include any related emissions in future annual submissions.
ERT assessment and rationale	Not resolved. The Party did not report on potential uses of SF6 in particle accelerators in universities, industry and medical facilities and in magnesium production. During the review, the Party clarified that so far there are no new research results on further sources of SF6 emissions, but it plans to check emissions from particle accelerators and magnesium production. The ERT made an estimation of SF6 emissions from particle accelerators and magnesium production, on the basis of SF6 emissions for these activities reported in Germany's 2022 submission, scaled to reflect population numbers. On this basis, the ERT considers that SF6 emissions from these activities might be considered below the significance threshold for the application of an adjustment in accordance with decision 22/CMP.1, annex, paragraph 80(b), in conjunction with decision 4/CMP.11. Therefore, the ERT did not include this issue in the list of potential problems and further questions raised by the ERT. The ERT considers that the issue will be resolved if the Party verifies any potential uses of SF6 in particle accelerators in universities, industry and medical facilities and in magnesium production and includes information on related emissions in the NIR.
Updated NLD Response in NIR/CRF 2024	Due to lack of time, it will be tried to perform this check for a later submission
Paragraph or table number in: NIR, CRF and or Methodology report (MR)	-

Sector	IPPU
ID# concept ARR	I.31
Addressing/Not resolved/ New from 2022 review	Not resolved
Issue and/or problem classificationa[, b]	2.G.3 N2O from product uses – N2O (I.16, 2021) (I.29, 2019) Comparability

Sector	IPPU
Recommendation made in previous review report	Report the AD for category 2.G.3.b (other (N2O from aerosol cans)) in kt in the next submission.
ERT assessment and rationale	Not resolved. The Party did not report the AD for category 2.G.3.b (other – N2O from aerosol cans) in kt, rather than the number of cans. During the review, the Party clarified that it plans to include this information in the next annual submission.
Updated NLD Response in NIR/CRF 2024	Planned to implement in CRF for the 2025 submission
Paragraph or table number in: NIR, CRF and or Methodology report (MR)	CRF 2(I).A-Hs2

Sector	IPPU
ID# concept ARR	I.32
Addressing/Not resolved/ New from 2022 review	Addressing
Issue and/or problem classificationa[, b]	2.H Other (IPPU) – CO2 (I.33, 2021) Transparency
Recommendation made in previous review report	Provide further information in the NIR on the non-energy use of fuels in this sector and the processes leading to CO2 emissions.
ERT assessment and rationale	Addressing. The Party reported in its methodology report (Honig et al., 2022, section 2.2.3.1, p.47) that this category comprises CO2 emissions related to food and drink production (category 2.H.2) in the Netherlands. CO2 emissions in this source category are related to the non-energy use of fuels. Carbon is oxidised during these processes, resulting in CO2 emissions. The ERT was unable to understand why carbon is oxidised in the process. During the review, the Party clarified that this information was inserted in the wrong section of the methodology report: it is about CO2 emissions produced by using lime in sugar production, which are reported under category 2.A.2 (lime production). These emissions had been previously reported under category 2.H.2, but when those emissions were moved to

Sector	IPPU
	category 2.A.2 it had forgotten to move the corresponding text. The Party plans to amend this in its next annual submission.
Updated NLD Response in NIR/CRF 2024	This is better explained now in the Methodology report, and also in the NIR.
Paragraph or table number in: NIR, CRF and or Methodology report (MR)	MR 2.2.3.7

Sector	Agriculture
ID# concept ARR	A.2
Addressing/Not resolved/ New from 2022 review	Addressing
Issue and/or problem classificationa[, b]	3. General (agriculture) – CH4 and N2O (A.6, 2021) (A.17, 2019) Transparency
Recommendation made in previous review report	Investigate whether alpacas and llamas exist in the country and, if relevant, estimate emissions or, in accordance with paragraph 37(b) of the UNFCCC Annex I inventory reporting guidelines, justify that the emissions are insignificant.
ERT assessment and rationale	Addressing. The Party did not report emissions from alpacas and llamas in the CRF tables and stated in its NIR (section 5.1.2, p.169) that emissions from alpacas in the Netherlands were not estimated owing to the lack of detailed information on the number of these animals and that they are mostly kept as pets or as a tourist attraction. Changes to the European Union regulation on animal health in 2022 could make the registration of alpacas mandatory, thereby making it possible to calculate corresponding emissions in the future. During the review, the Party clarified that emissions relating to alpacas are negligible. The ERT considers that the issue will be resolved if the Party provides specific evidence that there are no alpaca farms in the country or, if relevant, estimates emissions or justifies that the emissions are insignificant.

Sector	Agriculture
Updated NLD Response in NIR/CRF 2024	To reach the threshold for inclusion (significance), over 100000 alpacas would have to be present in the Netherlands, the highest estimates we could find are for a couple of thousand alpacas.
Updated paragraph or table number in: NIR, CRF and or Methodology Report (MR)	5.2

Sector	Agriculture
ID# concept ARR	A.3
Addressing/Not resolved/ New from 2022 review	Addressing
Issue and/or problem classificationa[, b]	3. General (agriculture) – CH4 and N2O (A.7, 2021) (A.18, 2019) Comparability
Recommendation made in previous review report	Investigate whether representative averages of cattle weight can be estimated and, if so, provide these estimates in the NIR and in CRF table 3.As2 in order to improve comparability.
ERT assessment and rationale	Addressing. The Party reported the values for average cattle weights in CRF tables 3.B(a)s1 and 3.B(b). The ERT noted that the Party reported “NA” for the weight of mature dairy cattle in CRF table 3.As2 even though the weights of growing and other mature cattle were reported in CRF table 3.B(b). During the review, the Party clarified that the weights of cattle are not used for estimating GHG emissions so “NE” is not appropriate, which is why it reported “NA” in CRF table 3.As2. The ERT considers that the recommendation has not yet been fully addressed because the Party reported “NA” and did not provide the values for average weights of mature dairy cattle in CRF table 3.As2.
Updated NLD Response in NIR/CRF 2024	Provided in CRF
Paragraph or table number in: NIR, CRF and or Methodology report (MR)	-

Sector	Agriculture
ID# concept ARR	A.6
Addressing/Not resolved/ New from 2022 review	Addressing
Issue and/or problem classificationa[, b]	3.B Manure management – CH4 and N2O (A.12, 2021) (A.4, 2019) (A.1, 2017) (A.2, 2016) (A.2, 2015) (41, 2014) (52, 2013) Accuracy
Recommendation made in previous review report	Continue and enhance efforts to improve the consistency between the CH4 and N2O emission estimates and report correct values for the fractions of the different MMS in the NIR and the CRF tables.
ERT assessment and rationale	Addressing. The Party reported in its NIR (section 5.3.2, pp.179–180) that a tier 2 approach was used for estimating CH4 emissions from manure management for the key categories cattle, swine and poultry. The emissions were estimated using a tier 1 approach for all other animal categories. Detailed descriptions of the methods are given in the methodology report (Van der Zee et al., 2022, p.53). During the review, the Party explained that a tier 1 method was used for estimating emissions from fur-bearing animals, rabbits, horses, goats, and mules and asses; therefore, no further information was required in the CRF tables. The ERT noted that CRF table 3.B(b) contains information on the MMS for fur-bearing animals (liquid manure), rabbits (solid manure), horses (solid manure; pasture, range and paddock), goats (solid manure), and mules and asses (solid manure; pasture, range and paddock). However, the Party reported “NO” and “NA” in CRF table 3.B(a)s2 for the allocation of MMS, except for mules and asses (reported values). The ERT noted that the inconsistent reporting on MMS used for fur-bearing animals, rabbits, horses, goats, and mules and asses between the CH4 and N2O emission estimates has not been resolved.
Updated NLD Response in NIR/CRF 2024	The calculation of N emissions is more detailed than the calculation of CH4. As a Tier one method is used for the CH4 emissions from manure management the applied MMS does not affect the CH4 emissions. However, we do acknowledge that the different notation keys can be confusing. Therefore, changed the notation keys to match the notation keys of N2O from manure management.

Sector	Agriculture
Paragraph or table number in: NIR, CRF and or Methodology report (MR)	-

Sector	Agriculture
ID# concept ARR	A.7
Addressing/Not resolved/ New from 2022 review	Not resolved
Issue and/or problem classificationa[, b]	3.B Manure management – CH4 and N2O (A.17, 2021) (A.27, 2019) Transparency
Recommendation made in previous review report	Include in the NIR a description of each of the MMS used in the country, those being manure separation, nitrification or denitrification, the creation of mineral concentrates, the incineration of manure, and the drying and digesting of manure.
ERT assessment and rationale	Not resolved. The Party did not report in its NIR the description of each of the MMS used in the country. During the review, the Party explained that the common manure treatments in the Netherlands are manure separation, nitrification/denitrification, creation of mineral concentrates, incineration of manure, drying of manure and/or digesting of manure. This information was supposed to be included in the NIR (section 5.3.2), but the paragraph was accidentally omitted during the final stages of drafting the NIR. The Party clarified that this information will be included in the NIR of its next annual submission.
Updated NLD Response in NIR/CRF 2024	provided in NIR 5.3.2
Paragraph or table number in: NIR, CRF and or Methodology report (MR)	NIR 5.3.2

Sector	Agriculture
ID# concept ARR	A.12
Addressing/Not resolved/ New from 2022 review	Not resolved
Issue and/or problem classificationa[, b]	3.D Direct and indirect N2O emissions from agricultural soils – N2O (A.24, 2021) (A.8, 2019) (A.5, 2017) (A.8, 2016) (A.8, 2015) Transparency
Recommendation made in previous review report	Include in the NIR numeric data on annual removal of agricultural crop residues.
ERT assessment and rationale	Not resolved. The Party did not report in its NIR numerical data on annual removal of agricultural crop residues. During the review, the Party explained that the methodology for estimating emissions from crop residues is based on the methodology in Ruijter et al. (2019) and it provided a summary of the methodology. However, the ERT noted that a description of this method and the underlying numerical data are not included in the NIR or the methodology report Van der Zee et al., 2022). The ERT considers that this issue would be resolved if the Party includes a summary of the methodology for estimating emissions from crop residues and associated key data sets in the NIR or the relevant methodology report.
Updated NLD Response in NIR/CRF 2024	more detailed references are provided in section 5.4.1 of the NIR. The methodology to calculate N2O emissions from crop residues is provided in section 12.7 of Van der Zee et al. (2024). Activity data can be found in Annex 21 of Van Bruggen et al. (2024).
Paragraph or table number in: NIR, CRF and or Methodology report (MR)	Chapter 12.7 of the MR, NIR 5.4.1

Sector	**Agriculture**
ID# concept ARR	A.16
Addressing/Not resolved/ New from 2022 review	Not resolved
Issue and/or problem classificationa[, b]	3.D.a.3 Urine and dung deposited by grazing animals – N2O (A.29, 2021) (A.36, 2019) Accuracy
Recommendation made in previous review report	Noting that the Party has drained much of its soils over the years, resulting in a potentially very low groundwater level, review the research on the EF3 for urine and dung deposited by grazing animals to determine if the current EF3 is still applicable to the Party's agricultural systems, and, until such time as this review and any further research has been carried out, improve transparency by explaining in the NIR how research results were used to calculate the current EF3.
ERT assessment and rationale	Not resolved. There were no recalculations to the emissions since the 2021 submission. The Party reported in its NIR (section 5.4.2, table 5.9, p.186) country-specific EFs for subcategory 3.D.a.3 by soil type. During the review, the Party clarified that groundwater levels had already been reduced in the 1990s and referred to the methodology report (Van der Zee et al., 2022) based on Velthof et al. (1996). The ERT considers that the Party did not improve transparency by explaining in the NIR how research results were used to calculate the current EF3. The ERT noted that this issue could be addressed by the Party adding an overview of the methodology in Velthof et al. (1996) to the NIR with supporting data and justifying why the EF3 values used are still applicable.
Updated NLD Response in NIR/CRF 2024	Reference is included.
Paragraph or table number in: NIR, CRF and or Methodology report (MR)	The correct reference is included in section 5.4.2 of the NIR.

Sector	LULUCF
ID# concept ARR	L.2
Addressing/Not resolved/ New from 2022 review	Not resolved
Issue and/or problem classificationa[, b]	4.A Forest land – CO_2 (L.15, 2021) Transparency
Recommendation made in previous review report	Include information in the NIR on forest age structure that justifies the trend in removals.
ERT assessment and rationale	Not resolved. The Party did not provide information in its NIR on forest age structure. However, the NIR (section 6.4.2.1, p.218) includes a reference to Schelhaas et al. (2022a). This report provides information on age class distribution (chap. 7), harvesting (chap. 15) and growing stock (chap. 16). A summary of the forest age structure is not available in English. Therefore, the ERT considers that the recommendation has not been addressed.
Updated NLD Response in NIR/CRF 2024	Reference to Schelhaas et al 2022 has been included with explanation on where to find the information on age class distribution, harvesting and growing stock. Additionally a link to a flyer with key figures from the NFI7, including information on age class structure, growing stock and harvests, has been included in the text (NIR section 6.4.2.1).
Paragraph or table number in: NIR, CRF and or Methodology report (MR)	NIR section 6.4.2

Sector	LULUCF
ID# concept ARR	L.6
Addressing/Not resolved/ New from 2022 review	Not resolved
Issue and/or problem classificationa[, b]	4.C Grassland – CO_2 (L.16, 2021) Transparency
Recommendation made in previous review report	Report information in the NIR on the exact methodology applied in the estimation of CSCs in orchards.

Sector	LULUCF
ERT assessment and rationale	Not resolved. The Party did not update the methodological description for orchards in its NIR. During the review, the Party clarified that additional information should have been included in the NIR regarding the change in statistical survey classification, which resulted in a small increase in orchard area between 2014 and 2015 (about 1 kha). CBS confirmed that an average of 700 ha high-quality fruit trees was included in the most recent time series. The Party expects this to have a small impact on net removals (approximately 4 kt CO2) and therefore decided not to make a correction in this inventory cycle. The ERT considers that the issue will be resolved if the Party includes information in the NIR of its next annual submission on the exact methodology applied in the estimation of CSCs in orchards.
Updated NLD Response in NIR/CRF 2024	This issue now has been explicitly indicated in the NIR, section 6.6.2
Paragraph or table number in: NIR, CRF and or Methodology report (MR)	NIR section 6.6.2

Sector	LULUCF
ID# concept ARR	L.7
Addressing/Not resolved/ New from 2022 review	Not resolved
Issue and/or problem classificationa[, b]	4.C.1 Grassland remaining grassland – CO2 (L.8, 2021) (L.13, 2019) (L.10, 2017) (L.10, 2016) (L.10, 2015) Accuracy
Recommendation made in previous review report	Correct the errors in the allocation of areas and the estimates of emissions/removals between grassland remaining grassland and land converted to grassland, and enhance the QA/QC procedures to ensure accurate reporting on this issue in the NIR and the CRF tables.
ERT assessment and rationale	Not resolved. The Party reported in its NIR (sections 6.6, p.235, and 6.6.1, p.230) that the correction of the misallocation of land converted to grassland, which changes within the 20-year transition period from one grassland category (non-trees outside forest) to another, has not yet been implemented and the Party plans to update the LULUCF model for the 2023 NIR.

Sector	LULUCF
	The ERT agrees with the Party's conclusion that this is a low-priority improvement as it will only impact the allocation of areas between land remaining and land converted categories and will not impact emission/removal calculations. The ERT considers that the issue will be resolved if the Party includes this information in the NIR of its next annual submission and addresses the issue in the LULUCF bookkeeping model.
Updated NLD Response in NIR/CRF 2024	The misallocation of land converted to grassland that changes within the 20 yr transition period from one grassland sub-category to the other is now solved in the CRF 2023. The mentioning of this issue in chapters 6.6 and 6.6.2 has been removed.
Paragraph or table number in: NIR, CRF and or Methodology report (MR)	NIR section 6.6.2; CRF Table 4.C

Sector	LULUCF
ID# concept ARR	L.8
Addressing/Not resolved/ New from 2022 review	Not resolved
Issue and/or problem classificationa[, b]	4.D Wetlands –CO2 (L.17, 2021) Accuracy
Recommendation made in previous review report	Report in the NIR and CRF table 4.D the correct estimation results for mineral soils under wetlands remaining wetlands.
ERT assessment and rationale	Not resolved. The Party reported in its NIR (section 6.7.6, p.237) that the misallocation of land converted to wetlands that change within the 20-year transition period from one wetlands subcategory to another will be corrected in a further update of the LULUCF model. The ERT considers that the recommendation has not yet been addressed because the Party has not corrected the allocation of CSCs in mineral soils in the wetlands remaining wetlands category.
Updated NLD Response in NIR/CRF 2024	The misallocation of land converted to wetlands that changes within the 20 yr transition period from one wetland sub-category to another is now solved in the CRF 2023.

Sector	LULUCF
Paragraph or table number in: NIR, CRF and or Methodology report (MR)	CRF Table 4.D

Sector	LULUCF
ID# concept ARR	L.9
Addressing/Not resolved/ New from 2022 review	Not resolved
Issue and/or problem classificationa[, b]	4.G HWP –CO2 (L.19, 2021) Accuracy
Recommendation made in previous review report	Include carbon inflows for the years before 1990 in its estimation of CSCs for HWP.
ERT assessment and rationale	Not resolved. The Party reported in its NIR (annex 10, p.488) that, for its 2022 submission, it had continued to report CSCs from HWP under the Convention using the same methods as those used for reporting under the Kyoto Protocol, on the basis of the Kyoto Protocol Supplement, to maintain consistency. The Party also confirmed that starting from the 2023 NIR, the methodologies will be updated to include carbon inflows for the years before 1990 in its estimation of CSCs for HWP.
Updated NLD Response in NIR/CRF 2024	Since the NIR 2023 carbon inflows for HWP starting from 1961 are included. As a result the legacy effect of these inputs in later years a resulting from the first order decay of those carbon inflows are considered in the emissions and removals for HWP.
Paragraph or table number in: NIR, CRF and or Methodology report (MR)	CRF Table 4.Gs2, NIR section 6.10.2

Sector	LULUCF
ID# concept ARR	L.10
Addressing/Not resolved/ New from 2022 review	Not resolved
Issue and/or problem classificationa[, b]	4.G.2 Paper and paperboard – CO2 (L.11, 2021) (L.25, 2019) Convention reporting adherence
Recommendation made in previous review report	Apply QC procedures to the source data for HWP to ensure that recycling practices are consistently accounted for in the balance of production, exports and imports of paper and paper products.
ERT assessment and rationale	Not resolved. The Party did not provide in its NIR information on the QC procedures applied to HWP source data. During the review, the Party clarified that Probos data are used for comparing national statistics from CBS and data from Vereniging Nederlandse Papier- en Kartonfabrieken (Association of Dutch Paper and Cardboard Factories). Further QC procedures on the Probos data were not performed because the Party considers those to be the most reliable data for the Netherlands. The ERT considers that the recommendation has not yet been addressed because the Party has not provided in its NIR a summary of a comparison of HWP source data and the justification for using Probos data.
Updated NLD Response in NIR/CRF 2024	Since the NIR 2023 we now have explicitly included the conclusion that since the Netherlands applies the production approach no gains are expected for in paper and paperboard
Paragraph or table number in: NIR, CRF and or Methodology report (MR)	NIR section 6.10.2

Sector	LULUCF
ID# concept ARR	L.11
Addressing/Not resolved/ New from 2022 review	Not resolved
Issue and/or problem classificationa[, b]	4.G.2 Paper and paperboard – CO2 (L.11, 2021) (L.25, 2019) Transparency
Recommendation made in previous review report	Include in the NIR a table of statistical information showing the balance of produced, imported and exported wood pulp, and explain the industrial and trade practices that justify accumulation of carbon stocks in the paper pool being reduced to zero for 1994 onward.
ERT assessment and rationale	Not resolved. The Party reported in its NIR (table 6.16, p.243) information on the balance of produced, imported and exported wood pulp, but the NIR does not contain information on the justification for the paper pool being reduced to zero for 1994 onward. During the review, the Party clarified that section 3.1.5 of Oldenburger et al. (2022) indicates that paper and cardboard produced in the Netherlands are produced from imported cellulose (wood pulp) and recycled paper, and that, as the Party applies a production approach for HWP, no gains in paper and paperboard are expected. The ERT considers that the recommendation has not yet been addressed because the Party has not provided in its NIR information on industrial and trade practices that justify accumulation of carbon stocks in the paper pool being reduced to zero for 1994 onward.
Updated NLD Response in NIR/CRF 2024	see L.10
Paragraph or table number in: NIR, CRF and or Methodology report (MR)	-

Sector	LULUCF
ID# concept ARR	L.12
Addressing/Not resolved/ New from 2022 review	Not resolved
Issue and/or problem classificationa[, b]	4(II) Emissions/removals from drainage and rewetting and other management of organic/mineral soils – CO2 and CH4

Sector	LULUCF
	(L.14, 2021) (L.27, 2019) Transparency
Recommendation made in previous review report	Update the NIR to include a correct description of rewetting activities in the country.
ERT assessment and rationale	Not resolved. The Party reported in its NIR (section 6.7.6, p.237) that improved and higher-tier approaches for assessing emissions and removals from draining and rewetting activities will be included in future years. During the review, the Party clarified that a methodological change will be implemented in the 2023 NIR. The ERT considers that the recommendation has not yet been addressed because an updated description of rewetting activities was not included in the NIR.
Updated NLD Response in NIR/CRF 2024	CH4 emissions resulting from drainage ditches are now considered for drained organic soils in forest land, cropland and grassland.
Paragraph or table number in: NIR, CRF and or Methodology report (MR)	NIR sections 6.1.2 and 6.1.3

Additional provisional findings made during the 2022 review

Sector	General
ID# concept ARR	G.3
Addressing/Not resolved previous review as reported in NIR2022 or New from 2022 review	New from 2022 review
Finding classification	Other
Is finding an issue/problem	Yes. Transparency
Description of the finding with recommendation or encouragement	The Party reported in its NIR (annex 6, pp.396–397) on categories for which emissions are reported as “NE”. According to paragraph 37(b) of the UNFCCC Annex I inventory reporting guidelines, Parties may decide to report “NE” when the emissions of a category are

Sector	General
	insignificant, but shall provide a justification in the NIR or CRF tables. The Party provided qualitative justifications but not emission estimates for the following categories that are reported as “NE”, for which methodologies exist in the 2006 IPCC Guidelines: (a) 4.A.2 Land converted to forest land – accumulation of deadwood and litter in newly established forest plots – CO2; (b) 4.A Forest land – drainage and rewetting of organic soils – CO2; (c) 5.D.2 Industrial sludge treatment – CH4. During the review, the Party provided estimates for emissions from those categories reported as “NE” for which methodologies exist in the 2006 IPCC Guidelines. On the basis of these estimates, the ERT noted that these categories can indeed be considered as insignificant in line with paragraph 37(b) of the UNFCCC Annex I inventory reporting guidelines. The ERT recommends that the Party either include estimates for those categories considered as insignificant and reported as “NE” for which methodologies exist in the 2006 IPCC Guidelines or further justify their exclusion (e.g. providing the likely level of emissions), in line with paragraph 37(b) of the UNFCCC Annex I inventory reporting guidelines.
Updated NLD Response in NIR/CRF 2024	From a recent survey among IWWTPs conducted by CBS in 2016, it can be concluded that anaerobic sludge digestion within industries is applied at only 2 industrial WWTP. These data are not published on www.cbs.statline.nl for reasons of confidentiality. Via a rough estimate, it was calculated that the methane emissions from this source amounts approximately 6.2 kg CH4 per year, equalling 0.0009% of national methane emissions in 2016. Forthcoming CH4 emissions are therefore reported as NE for 1990-2021.
Paragraph or table number in: NIR, CRF and/or Methodology report (MR)	7.5.2 Last paragraph

Sector	Energy
ID# concept ARR	E.9
Addressing/Not resolved previous review as reported in NIR2022 or New from 2022 review	New from 2022 review
Finding classification	1.A.2.c Chemicals – solid fuels, gaseous fuels – CO_2, CH_4 and N_2O
Is finding an issue/problem	Yes. Comparability
Description of the finding with recommendation or encouragement	The Party reported in its NIR (section 3.2.5.1, p.96) the variation of the CO_2 IEF from combustion of the phosphorus gas that is a by-product of solid fuels, which contributed to the modification of the CO_2 IEF for natural gas combustion used for estimating emissions under category 1.A.2.c (chemicals). The plant that provided the specific data for this activity operated in 1998–2012 and it reported a CO_2 EF of 149.5 kg/GJ. The ERT noted a possible inconsistency in this information in the NIR; namely, the indication that the phosphorus gas is a by-product of solid fuels but that it contributes to the CO_2 IEF from combustion of gaseous fuels. According to the 2006 IPCC Guidelines (vol. 2, chap. 1.4.1.1, p.1.14, table 1.1 (Definitions of fuel types)), the derived gases (by-products of solid fuels) should be reported under the relevant fuel type. Consequently, phosphorus gas, being a by-product of solid fuels, should be allocated under solid fuels for category 1.A.2.c (chemicals). During the review, the Party clarified that this by-product is currently included in gaseous fuels, but it will be reallocated to solid fuels in the next annual submission. The ERT recommends that the Party allocate phosphorus gas consumption and the corresponding GHG emissions to solid fuels, in accordance with the 2006 IPCC Guidelines.
Updated NLD Response in NIR/CRF 2024	This change in allocation is implemented.
Paragraph or table number in: NIR, CRF and/or Methodology report (MR)	-

Sector	Energy
ID# concept ARR	E.10
Addressing/Not resolved previous review as reported in NIR2022 or New from 2022 review	New from 2022 review
Finding classification	1.A.3.b Road transportation – LPG – CO2, CH4, N2O
Is finding an issue/problem	Yes. Transparency
Description of the finding with recommendation or encouragement	The ERT noted significant recalculations in CRF table 1.A(a)s3 for LPG consumption in several subcategories under road transport, for the entire time series. For example, for 2019 the consumption of LPG in subcategory 1.A.3.b.iii (heavy-duty trucks and buses) increased by 9,195.83 per cent, in subcategory 1.A.3.b.ii (light-duty trucks) it increased by 66.6 per cent and in subcategory 1.A.3.b.i (cars) it decreased by 30.78 per cent compared with the values presented in the previous submission. The ERT noted similar variations among subcategories for all years after 2011. However, the NIR does not mention this significant level of variation for LPG consumption among the above subcategories, nor the reallocation of it between subcategories performed for the entire time series, nor the impact of the recalculation on the corresponding emissions. During the review, the Party explained that the AD used for estimating road transport emissions are collected from the energy balance for fuels sold within the country's territory (e.g. motor gasoline, gas diesel oil, LPG, natural gas and biofuels) and a new methodology has been used to allocate the fuels among the different types of transport in the 2022 submission. Within this process the allocation of LPG was the most affected, being reallocated among the subcategories for cars, light-duty trucks and heavy-duty trucks and buses. The ERT recommends that the Party explain in its NIR the recalculations performed for each type of fuel and the corresponding categories affected, and indicate the impact of the recalculations on consumption and the corresponding GHG emissions.
NLD Response in NIR /CRF 2023	The activity data for calculating GHG emissions from road transport are derived from the Energy Balance. These include fuel sales of gasoline, diesel, liquefied petroleum gas (LPG), natural gas (CNG) and biofuels. The distribution of fuel sold amongst transport modes is based on fuel used on Dutch national territory. In the NIR2022 submission a new

Sector	Energy
	methodology has been used for the calculation of fuel used on Dutch national territory, as is described in 3.2.6.5 of the NIR2022. The LPG CO2-emissions for road transport as a total have not changed significantly in the entire time series, only the allocation of LPG to cars, light and heavy-duty trucks. The allocation of LPG to cars is 31% lower in 2019, the allocation of LPG to light-duty vehicles is 67% higher in 2019 and the allocation of LPG to heavy-duty vehicles is 9196% higher in 2019. The total LPG consumption of road transport is 0.46% higher in 2019 compared to the NIR2021 and the overall LPG consumption has not changed significantly in the time series.
Updated NLD Response in NIR/CRF 2024	The activity data for calculating GHG emissions from road transport are derived from the Energy Balance. These include fuel sales of gasoline, diesel, liquefied petroleum gas (LPG), natural gas (CNG) and biofuels. The distribution of fuel sold amongst transport modes is based on fuel used on Dutch national territory. The LPG CO2-emissions for road transport as a total have not changed significantly in the entire time series, only the allocation of LPG to cars, light- and heavy-duty trucks. The allocation of LPG to road traffic has been improved. The allocation of LPG previously involved an allocation based on the use of the group of other fuels (LPG, CNG, LNG, hydrogen, alcohol, etc.) and now concerns an allocation based on the group excluding LNG and CNG. As a result, from 2010 onwards, less LPG has been allocated to heavy commercial vehicles and buses and more LPG has been allocated to passenger cars and light commercial vehicles. For 2022, this means a major shift of 1.2 PJ (-98%) in LPG from heavy commercial vehicles and buses to passenger cars (+41%, 0.9 PJ) and light commercial vehicles (+37%, 0.3 PJ).
Paragraph or table number in: NIR, CRF and/or Methodology report (MR)	Chapter 3.2.6.5 in NIR.

Sector	Agriculture
ID# concept ARR	A.17
Addressing/Not resolved previous review as reported in NIR2022 or New from 2022 review	New from 2022 review
Finding classification	3.B Manure management – N2O
Is finding an issue/problem	Yes. Transparency
Description of the finding with recommendation or encouragement	The Party reported in the methodology report (Van der Zee et al., 2022, section 10.3.2, p.108) that manure exported from the Netherlands is accounted for in the emissions calculation methodology. However, the ERT noted that the NIR and the methodology report do not include sufficient information on the methodology used for accounting for manure exported from the Netherlands. During the review, the Party explained that the amount of N in animal manure exported is approximately 6 per cent of the total N in MMS, and that the amount of manure exported is included in a report by CBS. The ERT recommends that the Party include in the NIR a summary of the methodology used for calculating the amount of N in animal manure exported from the Netherlands.
Updated NLD Response in NIR/CRF 2024	The method to calculate manure export is given in section 2.2.5 of Van der Zee et al. (2024).
Paragraph or table number in: NIR, CRF and/or Methodology report (MR)	2.2.5 of Van der Zee et al. and section 5.4.1 of the NIR

Sector	LULUCF
ID# concept ARR	L.13
Addressing/Not resolved previous review as reported in NIR2022 or New from 2022 review	New from 2022 review
Finding classification	4.D Wetlands – CO2, CH4 and N2O
Is finding an issue/problem	Not an issue/problem
Description of the finding with recommendation or encouragement	The ERT noted that the Party did not fully implement the methodologies set out in the Wetlands Supplement. During the review, the Party explained that it is assessing the methods and data available for improving the reporting of emissions from wetlands, including CH4 emissions, that are covered by the Wetlands Supplement and that possible methodological improvements will be considered on the basis of this assessment. The ERT acknowledges the Party's ongoing efforts and encourages it to use the Wetlands Supplement in preparing its annual inventory for future annual submissions.
NLD Response in NIR /CRF 2023	Improved and higher tier approaches for assessing emissions and removals from wetlands are being assessed. This will result in improved methodologies to be included in future NIRs. This is expected to be a stepwise process with successive improvements in successive years
Updated NLD Response in NIR/CRF 2024	In the NIR 2024 a first step has been made towards a Tier 1 method for the reporting of emissions from Wetlands. See NIR section 6.7.2. Steps to higher Tier levels are being activily assessed for incorporation in future submissions.
Paragraph or table number in: NIR, CRF and/or Methodology report (MR)	See NIR section 6.7.6
Updated paragraph or table number in: NIR, CRF and or Methodology Report (MR) for NIR/CRF 2024	NIR section 6.7.2. and NIR section 6.7.6 for future developments.; CRF Table 4.D and 4(II)

Sector	LULUCF
ID# concept ARR	L.14
Addressing/Not resolved previous review as reported in NIR2022 or New from 2022 review	New from 2022 review
Finding classification	4.C.2.1 Forest land converted to grassland – CO_2
Is finding an issue/problem	Yes. Transparency
Description of the finding with recommendation or encouragement	The Party reported in its NIR (section 6.4.2.3, p.223) that for conversions between forest land and grassland trees outside forest, it is assumed that no loss of biomass occurs. The ERT noted that this is not in line with the Party's CRF tables 4.A and 4.C, in which losses and an overall net gain is assumed for both forest land converted to trees outside forest and trees outside forest converted to forest land. During the review, the Party clarified that the Dutch LULUCF bookkeeping model accounts for an equal loss and gain in living biomass for conversions between forest land and trees outside forest and that the additional annual carbon stock gains resulting from growth of biomass are included. The ERT noted that the justification for applying the same assumptions regarding biomass growth to trees outside forest and to forest land is not included in the NIR (p.228) or the referenced report (Schelhaas et al., 2022a). The ERT recommends that the Party include information in its NIR on the assumed gains and losses for conversions between forest land and trees outside forest, and include information to justify the assumption that biomass growth rates are the same for trees outside forest as in forest land.
Updated NLD Response in NIR/CRF 2024	In the new cycle of the National Forest Inventory also plots of Trees outside forest (TOF) will be monitored. This will provide the required data to assess the assumption and if needed to develop TOF specific emission factors. Nevertheless, this is a longer-term improvement as the NFI measurement campaign will run over the next 5 years.
Paragraph or table number in: NIR, CRF and/or Methodology report (MR)	-

Sector	LULUCF
ID# concept ARR	L.15
Addressing/Not resolved previous review as reported in NIR2022 or New from 2022 review	New from 2022 review
Finding classification	4(II) Emissions/removals from drainage and rewetting and other management of organic/mineral soils – CO2 and CH4
Is finding an issue/problem	Yes, completeness
Description of the finding with recommendation or encouragement	The Party did not correct the description of rewetting activities in its NIR in line with the previous recommendation (see ID# L.12 in table 3). During the review, the Party clarified that it will update the methodology in its 2023 NIR to include CH4 emissions in CRF table 4(II). In the new approach, it will apply a tier 1 ditch fraction from the 2013 Wetlands Supplement in combination with a country-specific CH4 EF. Emissions from organic soils under forest land, cropland and grassland under agricultural use (CRF tables 4.A, 4.B and 4.C) are expected to decrease, and CH4 emissions will be reported in CRF table 4(II). The Party estimates that the net effect will be a decrease in emissions (81 kt CO_2-eq for 1990 and 31 kt CO_2-eq for 2020). classification Description of finding with recommendation or encouragement Is finding an issue/problem? The ERT recommends that the Party include estimates of CH4 emissions in CRF table 4(II) in future annual submissions.
Updated NLD Response in NIR/CRF 2024	This methodological change has been implemented in the NIR 2023
Paragraph or table number in: NIR, CRF and/or Methodology report (MR)	NIR sections 6.1.2 and 6.1.3.

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