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

Greenhouse gas emissions
in the Netherlands 1990-2021

National Inventory Report 2023

RIVM report 2023-0052

Colophon

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Synopsis

Greenhouse gas emissions in the Netherlands 1990–2021

Total greenhouse gas (GHG) emissions in the Netherlands in 2021 increased by 1.8 percent, in comparison with 2020 emissions. This increase was mainly the result of an increase in natural gas combustion of households due to a relatively cold winter. In 2021, the share of renewable energy is 13 percent of total energy consumption. In 2020, this share was 11.5 percent.

In 2021, total GHG emissions (including indirect CO_2 emissions and including emissions from Land use, land use change and forestry (LULUCF)) in the Netherlands amounted to 172 Tg CO_2 eq. This is approximately 24.9 percent below the emissions in the base year 1990 (228.9 Tg CO_2 eq.).

CO_2 emissions in 2021 were 14.8 percent 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 53.7 percent over this period.

This report documents the Netherlands' annual submission for 2023 of its GHG emissions inventory 1990-2021 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 2022), the results of recalculations and planned improvements.

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

Publiekssamenvatting

Emissies van broeikasgassen tussen 1990 en 2021

In 2021 zijn in Nederland in totaal 1,8 procent meer broeikasgassen uitgestoten dan in 2020. Deze stijging komt vooral doordat huishoudens meer aardgas verstookt hebben door de relatief koude winter. In 2021 ligt het aandeel onuitputtelijke bronnen, zoals zon- en windenergie, op 13 procent van het totale energieverbruik. In 2020 was dit 11,5 procent.

De totale hoeveelheid broeikasgassen die naar de lucht is uitgestoten, wordt uitgedrukt in CO_2-equivalenten en bedroeg in 2021 172 miljard kilogram. Het jaar 1990 is het referentiejaar (basisjaar) voor de te halen doelen. In 1990 was de uitstoot 228,9 miljard kilogram CO_2-equivalenten. Ten opzichte van het basisjaar is de uitstoot gedaald met 24,9 procent.

De uitstoot van CO_2 alleen ligt 14,8 procent onder het niveau van het basisjaar. De uitstoot van de andere broeikasgassen (methaan, distikstofoxide en gefluoreerde gassen) is sinds 1990 met 53,7 procent gedaald.

Dit blijkt uit de definitieve inventarisatie van broeikasgasemissies die het RIVM elk jaar op verzoek van het ministerie van Economische Zaken en Klimaat (EZK) opstelt. Met deze inventarisatie voldoet Nederland aan de nationale rapportageverplichtingen voor 2023 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 2021 zijn al in het najaar van 2022 gepubliceerd.

De inventarisatie bevat verder analyses van ontwikkelingen in de uitstoot van broeikasgassen tussen 1990 en 2021. 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 2023, in line with the annual reporting requirements under 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 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).

Part I of the 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, respectively:
  - 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 2022).

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 2020 (PBL, 2020) (biennial edition; in Dutch: *Balans van de Leefomgeving*) prepared by the Netherlands Environmental Assessment Agency (PBL), the 8th National Communication under the UNFCCC (EZK, 2022), the Climate and Energy Outlook 2022 (PBL, TNO, CBS and RIVM, 2022) and the National Energy and Climate Plan 2021-2030 (EZK, 2019).

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 2023 in PDF format, are also available on the website http://english.rvo.nl/nie.

Please note that a detailed description of calculation methods for the different 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 with detailed information, both the CRF and 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 National Institute for Public Health and the Environment (RIVM) has been contracted by the Ministry of Infrastructure and Water Management and the Ministry of Economic Affairs and Climate Policy (EZK) to compile and maintain the PRTR and to coordinate the annual preparation of the NIR and the completion of the CRF tables.

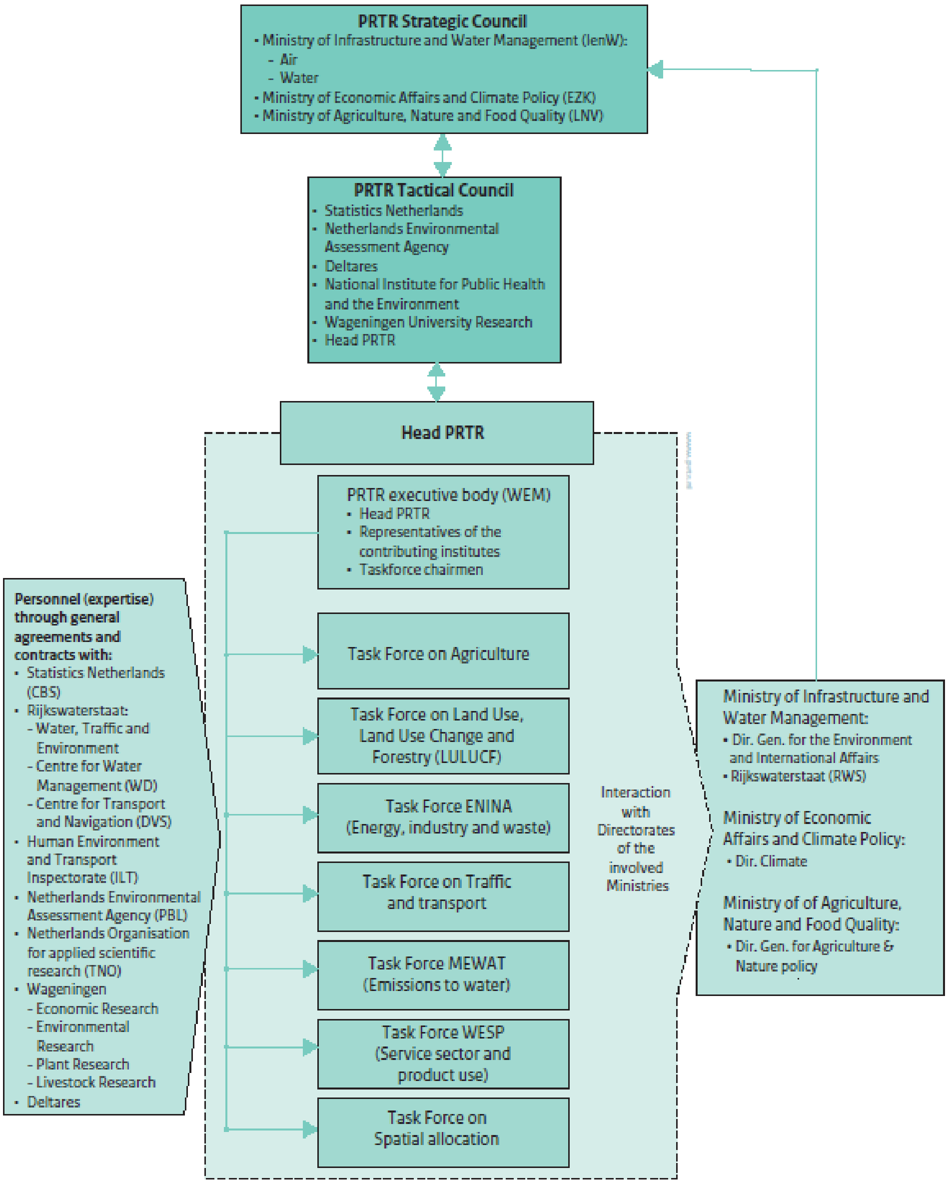

Figure ES.1 Main elements in the GHG emissions inventory compilation process.

Methodology reports

Emissions data are 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 these, are prepared and approved under the lead of the chair of the respective task force of the PRTR. Besides the methodology reports are also 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 national total annual emissions and to the national total trend (for details of the Approach 1 uncertainty 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 2021) and 48 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 summarized in Annex 1. A combination of Approach 1 and 2 and level and trend assessments shows a total of 63 key categories including LULUCF.

ES2 Summary of trends in national emissions and removals

Total GHG emissions (including indirect CO_2 emissions and including emissions from LULUCF) in the Netherlands in 2021 were estimated at 172.0 Tg (Teragram or Megaton) CO_2 equivalents (CO_2 eq.). This is approximately 24.9% below total emissions in the base year (228.9 Tg CO_2 eq.).

CO_2 emissions (including indirect CO_2 emissions and including emissions from LULUCF) in 2021 were about 14.8% lower than in 1990. CH_4 emissions in 2021 were 47.4% lower than 1990 levels, mainly due to decreases in emissions from the Waste sector and the Agricultural sector. N_2O emissions decreased by 55.3% in 2021 compared with 1990, mainly due to decreases in emissions from Agriculture and from Industrial processes and product use (IPPU).
In contrast, CH_4 and N_2O emissions from fossil fuel combustion (for CH_4, mainly from agriculture and for N_2O mainly from energy industries and transport) increased.
Compared with the base year, the emissions of F-gases (HFCs, PFCs and SF_6) decreased by 75.0%, 96.7% and 41.9%, respectively (see Table ES.1). Total emissions of all F-gases were 81.2% 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), 1990–2021 (differences due to rounding).

	CO2 incl. LULUCF	**CH4 incl. LULUCF**	**N2O incl. LULUCF**	**HFCs**	**PFCs**	**SF6**	**Total (incl LULUCF)**
1990	169.4	36.0	16.2	4.7	2.4	0.2	228.9
1995	179.6	33.5	16.3	6.3	2.1	0.3	238.0
2000	177.9	27.4	14.4	4.0	1.7	0.2	225.7
2005	183.7	22.4	13.0	1.3	0.3	0.2	220.9
2010	187.6	21.9	7.9	2.0	0.3	0.1	219.8
2015	169.3	20.5	8.1	1.7	0.1	0.1	199.9
2020	140.9	19.2	7.5	1.1	0.1	0.1	168.9
2021	144.4	19.0	7.2	1.2	0.1	0.1	172.0

Compared with 2020, overall 2021 GHG emissions increased by about 1.8%. The changes for the specific gases were as follows (please note that differences compared with table ES.1 are due to rounding):

- CO_2 emissions (including LULUCF) increased by 2.5% (3.5 Tg), mainly in the category 1A4 Other Sectors (+2.8 Tg CO_2) due to an increase in natural gas combustion for heating purposes as a result of a relatively cold winter in 2021 compared to 2020. The road transport emissions increased by 0.1 Tg CO_2) in 2021. The emissions are still below the level of 2019 as a result of measures taken during the COVID19 pandemic in 2020, which were still partly implemented in 2021. On the other hand, the amount of energy from renewables and waste in the Netherlands increased from 11% in 2020 to 13.0% of energy consumption in the Netherlands in 2021.
- CH_4 emissions decreased by 1.4% (-0.2 Tg CO_2 eq.), mainly in category 5A1 (Managed waste disposal on land), category 3A1 (enteric fermentation cattle) and category 3B Manure management. In category 1A4 (Other sectors) emissions increased (+0.2 TG CO_2 eq.).
- N_2O emissions decreased by 4.0% (-0.3 Tg CO_2 eq.), mainly due to small decreases of emissions in 2B4 (Caprolactam production) and 2G (Other).
- F-gas emissions increased by 10.0% (0.1 Tg CO2 eq.). Emissions of both HFCs and PFCs increased (HFC emissions increased by 11.0% or 0.12 Tg CO2 eq.), SF_6 emissions show a small decrease. Fluctuations in F-gas emissions over the past few years are mainly due to market circumstances. The main increase for both HFCs and PFCs in 2020 stem from category 2B9 (fluorochemical production).

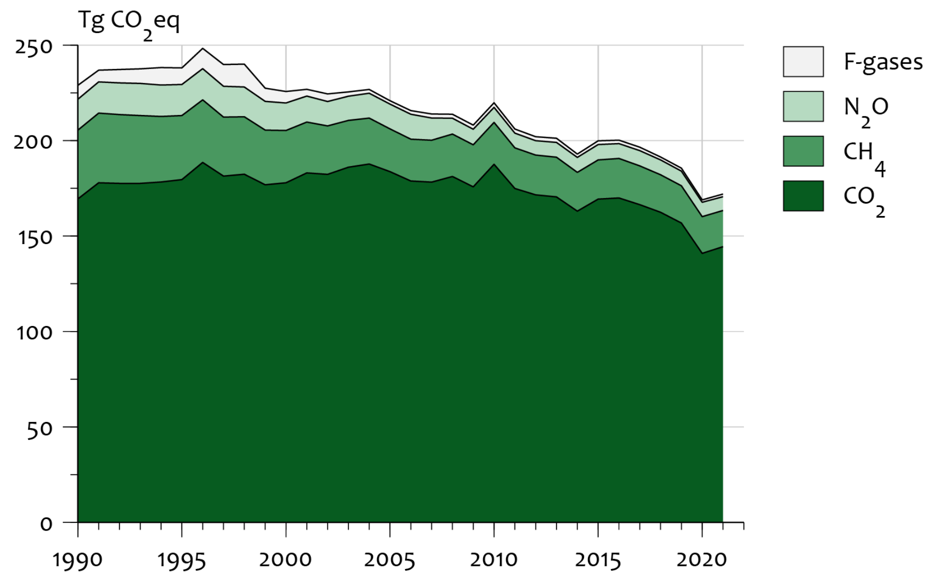

Figure ES.2 Overview of the trends in GHG emissions (including LULUCF), 1990–2021.

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. Emissions from this sector in 2021 were about 14.0% 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.), 2D Non-energy products from fuels and solvent use (+0.2 Tg CO_2 eq.), category 2F Product uses as substitutes for ODS (+0.93 Tg CO_2 eq.), 3H Urea application (+0.1 Tg CO_2 eq.), 4E Settlements (+0.2 Tg CO_2 eq.), 4F Other land (+0.1 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), 1990–2021.

	1. Energy	2. IPPU	3. Agriculture	4. LULUCF	5. Waste	Total (incl.) LULUCF
1990	159.7	21.3	25.2	6.2	16.5	228.9
1995	170.4	22.8	24.2	6.1	14.6	238.0
2000	168.1	19.8	20.6	5.7	11.5	225.7
2005	174.0	15.2	18.3	5.8	7.6	220.9
2010	179.9	10.8	18.2	5.1	5.7	219.8
2015	161.1	10.0	19.0	5.4	4.4	199.9
2020	133.8	9.0	18.4	4.1	3.6	168.9
2021	137.4	8.8	18.0	4.3	3.5	172.0

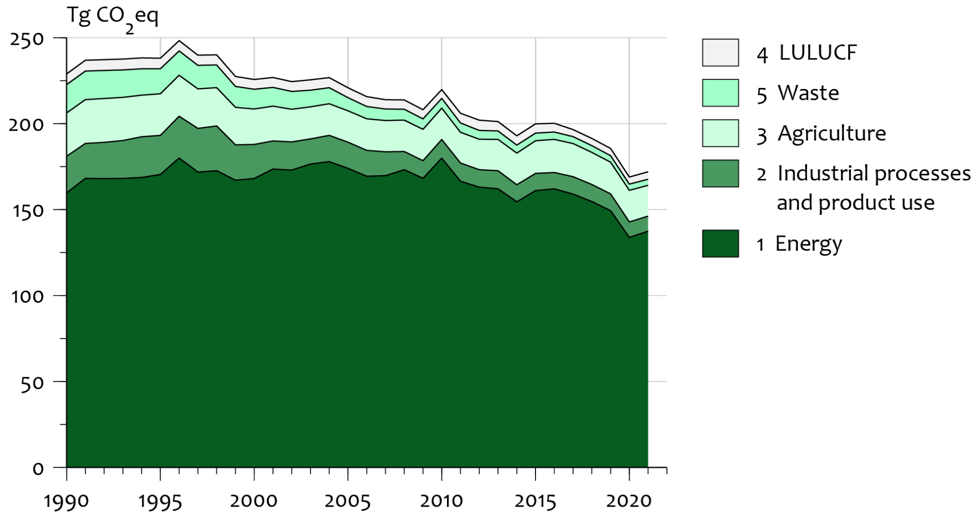

Figure ES.3 Overview of trends in GHG emissions per sector (incl. LULUCF), 1990–2021.

ES4 Other information

General uncertainty evaluation

The results of the uncertainty estimation according to IPCC Approaches 1 and 2 are summarised in Annex 2 of this report (main focus is on Approach 2).

The ***level*** uncertainty in total CO_2-equivalent emissions (including LULUCF) in 2021 is ±3%. This means that, with a confidence level of 95%, total emissions of greenhouse gases in the Netherlands are between 166.8 and 177.1 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%, ±31% and ±24%, respectively.
The ***trend*** uncertainty in total CO_2-eq. emissions (including LULUCF) for 1990–2021 is ±1,6%. This means that the trend in total CO_2-eq. emissions between 1990 and 2021 (including LULUCF), which is calculated to be a 24.7% decrease, will range between a 23.1% decrease and a 26.3% decrease.
The uncertainties in the trend for the individual gases are ±1,5%, ±5%, ±6% and ±5%, respectively. Annex 2 provides details of the uncertainties not only in 2021, 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 from Enteric fermentation of poultry (3A4), due to missing emission factors;
- N_2O from Septic tanks (5D3), due to negligible amounts;
- 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 the National total emissions.

Methodological changes, recalculations and improvements
Since the NIR 2022 (Ruyssenaars et al., 2022), some improvements to the inventory (including recalculations) have been implemented, and these are documented in this NIR 2023. 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 shows the results of these recalculations in the NIR 2023 in comparison with the figures reported in the NIR 2022.

Table ES.3 Differences between the NIR 2022 and NIR 2023 for the period 1990–2020 due to recalculations (Units: ***Tg CO_2 eq.;*** *for F-gases:* ***Gg CO_2 eq****.)*

Gas	Source	1990	2000	2010	2015	2019	2020
CO_2 [Tg]	NIR 2023	168.5	177.3	187.1	168.9	156.4	140.5
	NIR 2022	167.5	176.2	186.3	168.6	156.5	141.3
	Difference	*0.6%*	*0.7%*	*0.4%*	*0.2%*	*-0.1%*	*-0.6%*
CH_4 [Tg]	NIR 2023	36.0	27.4	21.9	20.5	19.5	19.2
	NIR 2022	35.7	27.1	21.7	20.3	19.3	19.0
	Difference	*1.1%*	*1.1%*	*1.2%*	*1.1%*	*1.2%*	*1.1%*
N_2O [Tg]	NIR 2023	16.2	14.4	7.9	8.1	7.7	7.5
	NIR 2022	15.6	13.9	7.3	7.5	7.1	7.0
	Difference	*3.4%*	*4.1%*	*7.7%*	*7.5%*	*8.1%*	*8.1%*
PFCs [Gg]	NIR 2023	2397.3	1723.2	299.9	104.0	118.2	65.3
	NIR 2022	2662.9	1902.8	313.8	104.2	117.7	67.2
	Difference	*-10.0%*	*-9.4%*	*-4.4%*	*-0.2%*	*0.4%*	*-2.8%*
HFCs [Gg]	NIR 2023	4697.2	4029.0	1977.9	1730.7	1302.8	1056.6
	NIR 2022	5606.3	4608.5	2128.8	1817.3	1434.9	1151.9
	Difference	*-16.2%*	*-12.6%*	*-7.1%*	*-4.8%*	*-9.2%*	*-8.3%*
SF_6 [Gg]	NIR 2023	213.1	234.6	108.1	115.1	120.7	128.4
	NIR 2022	213.1	234.6	108.1	115.1	120.7	128.4
	Difference	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*
Total [Tg CO_2-eq.]	NIR 2023	228.9	225.7	219.8	199.9	185.5	168.9
	NIR 2022	226.3	223.2	217.0	197.6	183.9	167.9
	Difference	*1.2%*	*1.1%*	*1.3%*	*1.1%*	*0.9%*	*0.6%*

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 with 1990, CO and NMVOC emissions were reduced in 2021 by 63.2% and 54.3%, respectively. For SO_2, the reduction was 89.5%; for NO_x, the 2021 emissions were 69.0% lower than the 1990 level. Table ES.4 provides trend data. Further documentation of these gases can be found in the annual Informative Inventory Report (IIR, Wever et al., 2022).

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

	1990	1995	2000	2005	2010	2015	2019	2020	2021
Total NOx	680	581	496	440	360	285	238	216	211
Total CO	1,189	953	772	747	709	572	517	449	438
Total NMVOC	607	436	338	273	279	253	238	270	277
Total SO2	198	137	79	68	36	31	23	20	21

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 2023, 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. This 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 remain in line with the requirements for National Systems.

With 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) 2023, 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 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) and the latest annotated outline of the National Inventory Report.

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 since 10 October 2010 have been public bodies (*openbare lichamen*) with their own legislation that 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 period 1990–2021. It also summarises the methods and data sources used for the Approach 1 assessments of the uncertainty in annual emissions and in emissions trends; and 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 the 8th Netherlands National Communication under the United Nations Framework Convention on Climate Change (NC8: EZK, 2022),, the Climate and Energy Outlook 2022 (PBL, TNO, CBS,RIVM 2022), amongst others..

The Netherlands also reports emissions under other international agreements. All emissions estimates are taken 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 kept up to date on an annual basis. More information can be found in annex 11 Information on changes in the National System.
Since 2015, emissions data have been calculated according to 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.
The methodologies applied in the NIR 2023 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 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 given 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.

1.1.3 Background information on supplementary information required by Article 7 of the Kyoto Protocol

With the ending of the second commitment period of the Kyoto Protocol in 2020, supplementary information on land use, land use change, and forestry according to the Kyoto Protocol definitions (KP-LULUCF) is no longer included in this NIR.

Information on the accounting of Kyoto units is still provided in the SEF file RREG1_NL_2022_CP2*.xlsx*, as submitted to the UNFCCC secretariat.

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, in line with the Kyoto requirements, was finalised and established at 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. With the replacement of the Kyoto Protocol by the Paris Agreement it is required that national arrangements for the preparation of the inventory are 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.
The National Institute for Public Health and the Environment (RIVM) was assigned by EZK 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 are 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 has been split in 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 47 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). The following organisations are represented: PBL, Statistics Netherlands, RIVM, Rijkswaterstaat and TNO.

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 task force LULUCF 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 expert 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 Part I with input from the relevant PRTR Task Forces and from RVO in its role as NIE.
RVO prepares most of the NIR Part II. RIVM integrates all information into the NIR. RVO is responsible for submission to the UNFCCC in its role as NIE, after approval by EZK.

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

With the ending of the second commitment period of the Kyoto Protocol in 2020, this information is no longer included in this NIR.
An overview of the changes in national registry can still be found in this report, in annex 12.

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 after 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 if necessary, updated. The key elements of the current programme (RVO, 2022 are summarised in this chapter, notably those relating to the current NIR.

1.2.3.2 QA/QC procedures for the CRF/NIR 2023

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, if 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 timeseries – this year 1990–2021 (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. After a first check of the data by RIVM for completeness, the (corrected) data are 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 (8 December 2022). The verification process is described in more detail in section 1.2.3.3. The workshop's conclusions, including 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 2023 also includes the following activities:

- Take any remaining issues from former UNFCCC reviews and ESD reviews into account and make the requested improvements (summarised in Annex 10 and).
- A peer and public review on the basis of the final submission of the previous NIR in Q2, and in the period August – October 2022, respectively. Results of these reviews are summarised in Chapter 10. 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 over 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, 2022), which has been developed and implemented as part of the national arrangements. This programme includes quality objectives the QA/QC plan and a schedule for the implementation of the activities. It is updated annually and available for review. 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, based on the 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).

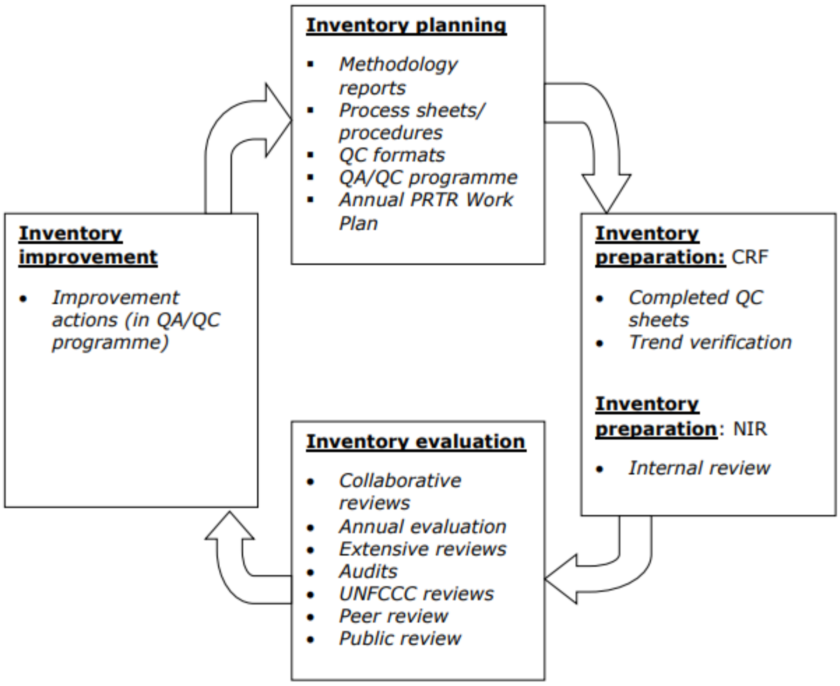

Figure 1.1 QA/QC cycle (RVO, 2022).

- *Adaptation of the PRTR project to RIVM quality system* (ISO 9001:2008 system), completed in 2012.
- *The annual RIVM Work Plan* (RIVM, 2022). 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 Emission 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). Documentation is required for all changes to the historical dataset (recalculations) and for emissions trends that exceed 5% at the sector level and 0.5% at the national total level. The Netherlands' interpretation of the IPCC Good Practice Guidance requirement in section 8.7.1.4 is: '[…] *it is good practice to check emissions estimates for all source categories or sub-source categories that show greater than 10% change in a year compared to the previous year's inventory'.*
  - A peer and public review based on the final submission of the previous NIR. Results of this review are summarised in Chapter 10 and the QA/QC sections of the specific chapters. 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 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, RIVM database has held storage space for the Task Forces to 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 quality systems at the external agencies.
  - Methodology reports: These have been updated and documented and are an integral part of this submission (see Annex 7).
  - RVO (as 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 update 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 further improve the inventory.

A revised uncertainty assessment (Approach 2 using Monte Carlo analysis) of Dutch GHG emissions is performed annually. Results of Approach 1 and Approach 2 show few differences. Since 2022, a more detailed analysis for Approach 1 is implemented. Uncertainties for both activity data and emission factors per CRF category were calculated from uncertainty estimates at emission source level (at the same level of detail as in the Approach 2 uncertainty assessment) using an error propagation calculation. Any correlated sources were first summed before calculating the uncertainty of a CRF category.
In chapters 3-8, the uncertainties per emission source (or group of emission sources) are documented in the respective subsections on uncertainties. Results of approach 2 are more specifically documented in Annex 2.

1.2.3.3 Verification activities for the CRF/NIR 2023

Two weeks prior to the trend analysis meeting, a snapshot of the database was made available by RIVM 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 inconsistency 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 with 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 formed 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 2021 were checked in two ways:
1. The datasets from previous years’ submissions were compared with the current submission; emissions from 1990 to 2020 should be identical to those reported last year for all emissions for which no methodological changes have been announced.
2. The data for 2021 were compared with 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.

Exceptional trend changes and observed outliers were noted and discussed at the trend analysis workshop, resulting in an action list. Actionable items have either to be processed within two weeks or be dealt with in the following year's inventory.

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 verification workshop and supplemented with the actions agreed at this workshop. Table 1.1 shows the key verification actions for the CRF tables/NIR 2023.

The completion of an action was reported on the checklist. Based on 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 2023

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	30-06-2022	RIVM-PRTR	List of remaining issues/actions from last inventory	Actiepunten Voorlopige cijfers 1990-2021 v 30-06-2022.xlsx
Sheets for comparing final data 2019 and 2020	1-12-2022	RIVM	Input for trend analyses	Verschiltabel_LuchtIPCC_01-12-2022.xlsx
Trend analysis	8-12-2022	Task Forces	Updated action list	Actiepunten Definitieve cijfers 1990-2021 05122022.xlsx
Resolving the issues on the action list	18-01-2023	Task Forces RIVM/ TNO National Inventory Compiler (NIC)	Final dataset	Actiepunten Definitieve cijfers 1990-2021 18012023.xlsx
Comparison of data in CRF tables and E-PRTR database	Until 10-01-2022	NIC/TNO	First draft CRF sent to EU final CRF to EU	13-01-2023 15-03-2023
Writing and checks of NIR	Until 15-3-2022	Task Forces/ NIC/TNO/NIE	Draft texts	R:\.\NI National Inventory Report\NIR 2023\NIR redactie
Generation of tables for NIR from CRF tables	Until 15-3-2022	NIC/TNO	Final text and tables NIR	R:\....\NIR 2023\CRF….\Tables and Figures v20.xlsx

1.2.3.4 Treatment of confidentiality issues

Some of the data used in the compilation of the inventory are 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 review UNFCCC 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 which are described in greater detail in the following sections.

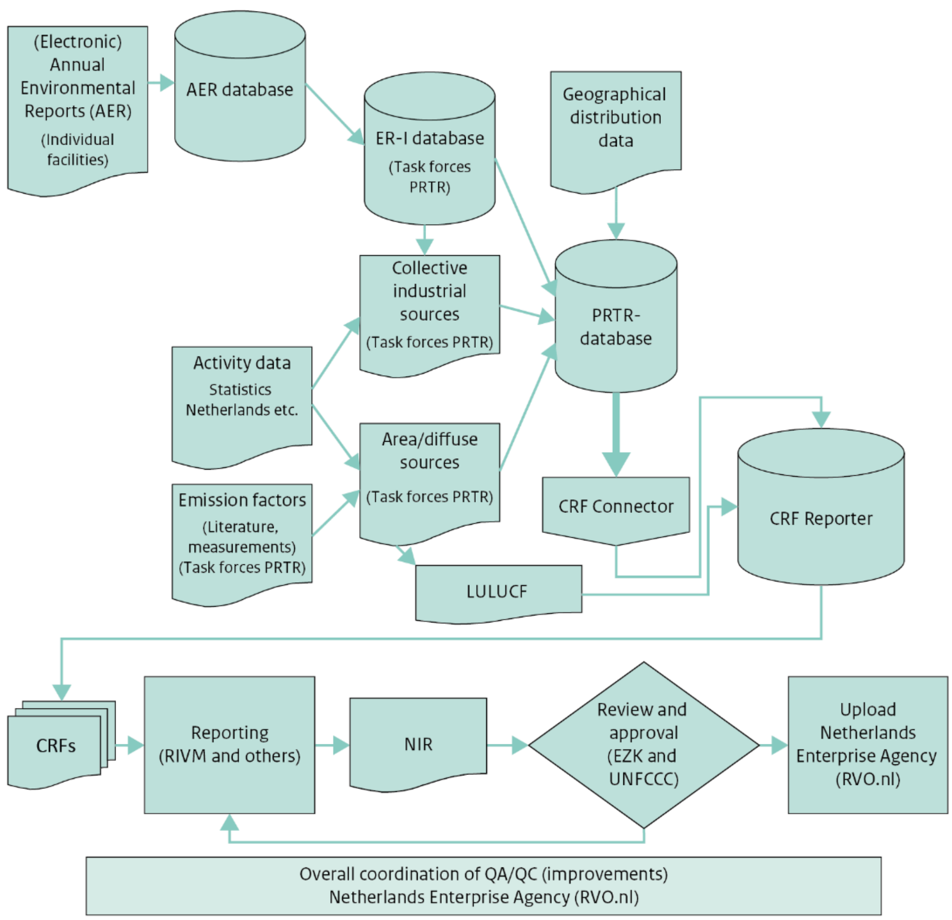

Figure 1.2 Main elements in the GHG emissions inventory process.

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 are provided under various (not specifically GHG-related) obligations and legal arrangements. These include national statistics from Statistics Netherlands and a number of 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), which 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 these 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 these 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 as required by legislation. This results in an open and constructive communication on activity levels and emissions between plant operators and competent authorities. 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). These companies 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 in the calculation of CO_2 emissions estimates for specific sectors.
The AERs from individual companies also provide essential information for 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, on request all confidential data can and will be made available to the EU and UNFCCC review teams.

Additional GHG-related data
Additional GHG-related data are 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 most notably of the elaboration of emissions estimates and data preparation in the PRTR database. The emissions data are stored in a central database thereby efficiently and effectively satisfying national and international criteria for emissions reporting. Using a custom-made programme (CRF Connector), all relevant emissions and activity data are extracted from the PRTR database and included in the CRF Reporter, thus ensuring the highest level of consistency. Data from the CRF Reporter are 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.
The Task Forces are responsible for assessing emissions estimates based on the input data and EFs provided. RIVM commissioned TNO to assist in the compilation of the CRF tables (see Figure 1.3).

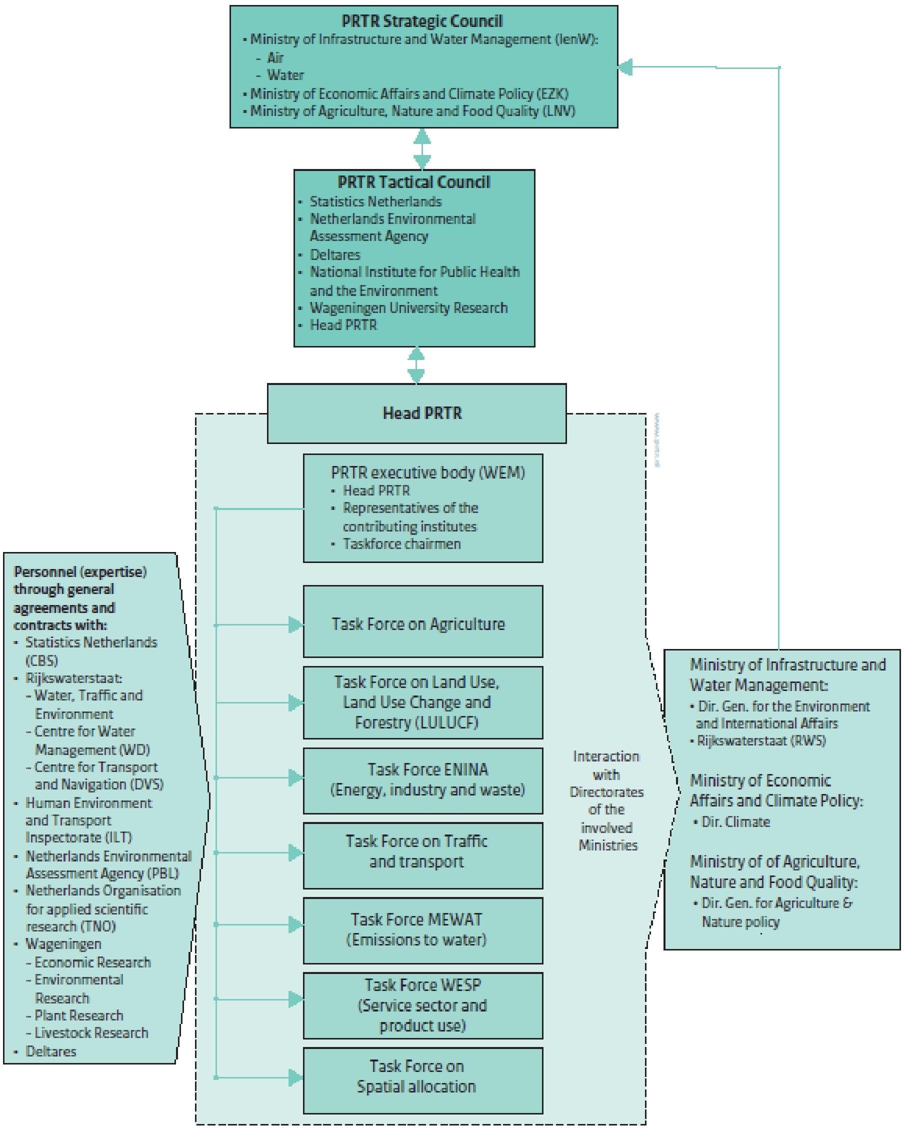

Figure 1.3 Organisational arrangements for PRTR project.

1.4 General description of methodologies (including tiers used) 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
C. Rice cultivation						
D. Agricultural soils(3)					T1,T1b,T2	CS,D
E. Prescribed burning of savannas						
F. Field burning of agricultural residues						
G. Liming	T1	D				

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO_2		CH_4		N_2O	
	Method applied	**Emission factor**	**Method applied**	**Emission factor**	**Method applied**	**Emission factor**
H. Urea application						
I. Other carbon-containing fertilizers						
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			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	CS	CS	CS,T1,T2	CS,D	CS,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	CS	CS	CS	CS	CS	CS
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	CS	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					CS	CS		
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 data source and for QA/QC reasons.
- Confidential data obtained directly from firms: production data and N_2O emission data from the Chemelot site; as it had a site permit for the AERs no N_2O emission 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 based on 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), fifth National Forest Inventory (NFI-5, 2001–2005), sixth National Forest Inventory (NFI-6 2012–2013) and seventh National Forest Inventory (NFI-7 2017-2021);
  - EFISCEN-space forest model, Wageningen Environmental Research
  - 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) and 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 sources, the contribution of source categories to emissions per gas is classified 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 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 of sources. The key category analysis is used for the prioritisation of possible inventory improvement actions.

The IPCC Approach 1 method has 39 categories for annual level assessment (emissions in 2021) and 48 categories for the trend assessment out of a total of 124 source categories. A combination of Approach 1 and 2 and level and trend assessment give a total of 61 key categories including LULUCF.

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

The IPCC Approach 1 methodology for estimating uncertainty in annual emissions and trends has been applied to the list of potential key categories (see Annex 1).
The IPCC Approach 2 methodology for estimating uncertainty in annual emissions has also been applied to all of the emission categories to compare the results with the Approach 1 methodology.

1.6.1 *GHG emissions inventory*

Approach 1 uncertainty – propagation of error

The following information sources were used for estimating the Approach 1 uncertainty in activity data and EFs:

- Estimates used for reporting uncertainty in GHG emissions in the Netherlands discussed at a national workshop in 1999 (van Amstel et al., 2000);
- Default uncertainty estimates provided in the 2006 IPCC Guidelines;
- Sections on uncertainties included in the methodology reports. See Annex 7 for references;
- The uncertainty of waste incineration, landfilling and composting, and digestion is described in a separate report (RWS, 2014).

These data sources were supplemented by expert judgements by RIVM, PBL, WUR and Statistics Netherlands emissions experts. They independently prepared uncertainty estimates. Their views were discussed to reach consensus.
This was followed by an estimation of the uncertainty in the emissions in 1990 and 2021 according to the IPCC Approach 1 methodology for both annual emissions and the emissions trend for the Netherlands. All uncertainty figures should be interpreted corresponding to a confidence interval of two standard deviations (2σ), or 95%. In cases where asymmetric uncertainty ranges were assumed, the larger percentage was used in the calculation.

The results of the uncertainty calculation according to the IPCC Approach 1 and 2 are summarised in Annex 2 of this report. The Approach 1 uncertainties are also indicated in the relevant sections of Chapters 3–9.
The Approach 1 calculation of annual uncertainty in CO_2-equivalent emissions gives an overall uncertainty of approximately 3% in 2021, based on calculated uncertainties of 3%, 8%, 31% and 24% 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 a correction for non-reported sources. The correlation between source categories can be included in an Approach 2 uncertainty assessment.

Approach 2 uncertainty – Monte Carlo analysis

An Approach 2 uncertainty assessment (using Monte Carlo analysis) has been implemented in the Dutch emissions inventory and results are used for comparison with the Approach 1 results.

Most of the uncertainty estimates now incorporated in the Dutch Inventory database are based on the results of expert elicitations (within the Task Forces ENINA (Energy/Industry/Waste), Traffic and transport, Agriculture, and WESP (product use).
The expert elicitations were set up following the expert elicitation guidance in the 2006 IPCC Guidelines. These were performed to assess the uncertainties of the individual source-specific activity data and EFs

separately; this approach is more detailed than the uncertainty assessment at the level of the CRF categories).
Where possible, correlations between activity data and the EFs of different emissions sources have been included in the Monte Carlo analysis. These correlations are included for the following types of data:

- Activity data:
  - The energy statistics are more accurate on an aggregated level (e.g. for Industry) than on a detailed level (e.g., for the individual industry sectors separately). This type of correlation is also used in several Transport sub-sectors such as road transport, shipping, and aviation.
  - The number of animals in one emissions source is correlated to the same number of animals in another emissions source. This type of correlation is used where the identifier of the activity (animal number or inhabitants) has to be equal in different source/ pollutant combinations.
- Emission factors:
  - The uncertainty of an EF of a fuel from stationary combustion is assumed to be equal for all the sources using the specific 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 different types of cows (cows for meat production or dairy cows) are assumed to be correlated. The same is true for the EFs for ducks and chickens, and for horses and asses.

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

Table 1.3 Uncertainties (95% confidence ranges) based on the Approach 2 level uncertainty assessment (Monte Carlo analysis) for 2021, including LULUCF.

CRF category	CO_2	CH_4	N_2O	F-gases	Total (CO_2 eq.)
1	3%	37%	29%		3%
2	15%	64%	29%	24%	13%
3	19%	9%	45%		14%
4	38%	78%	100%		35%
5	27%	21%	145%		36%
Total	3%	9%	34%	24%	3%

Table 1.4 Uncertainties (95% confidence ranges) based on the Approach 1 level uncertainty assessment (KSA, standard error propagation) for 2021, including LULUCF.

CRF category	CO_2	CH_4	N_2O	F-gases	Total (CO_2 eq.)
1	3%	28%	29%		3%
2	16%	62%	28%	24%	12%
3	19%	9%	40%		13%
4	58%	65%	229%		54%
5		21%	145%		37%
Total	3%	8%	31%	24%	3%

The differences between the Approach 1 and Approach 2 assessment can be explained as follows:

- For CO_2 and N_2O in LULUCF there is a triangular distribution in the Monte Carlo analysis (eg -80% and +400%). In the Monte Carlo analysis both values are used, while in the KSA calculation only the + value (or 400%) is used. As a result, the uncertainty according to the KSA is higher than the uncertainty according to the Monte Carlo analysis.
- For CH_4 in LULUCF, the uncertainty in the KSA calculation is lower than in the Monte Carlo analysis, because the error propagation calculation does not take correlations into account, while the Monte Carlo analysis does.
- Also with CH_4 in CRF 1 the uncertainty in the KSA is lower than in the Monte Carlo analysis, also because the correlations are not taken into account in the error propagation calculation.

Table 1.5 presents the uncertainties in the trend between 1990 and 2021 for the specific CRF categories and the emission totals, based on the Approach 1 level assessment and including LULUCF.

Table 1.5 Uncertainties (95% confidence ranges) of CRF categories based on the Approach 1 trend uncertainty assessment (KSA, standard error propagation) including LULUCF.

CRF category	Trend compared to base year (%)	Uncertainty in trend (%)
1	-14	1.5
2	-59.5	5.1
3	-28.6	5.3
4	-24.5	4.2
5	-78.7	5.8
Total	**-24.7**	**1.6**

Table 1.6 Uncertainties (95% confidence ranges) of individual gases based on the Approach 1 trend uncertainty assessment (KSA, standard error propagation) including LULUCF.

CRF category	Trend compared to base year (%)	Uncertainty in trend (%)
CO_2	-14.9	1.4
CH_4	-47.4	4.7
N_2O	-55.3	6.3
F gases	-81.2	5.5
Total	**-24.7**	**1.6**

More details on the level and trend uncertainty assessment 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 systematic errors which can occur in practice.

Base year (1990) uncertainties
Because the Netherlands uses the uncertainties in the current year as an instrument to set priorities for further inventory improvement, little attention has been paid in the past to reporting the uncertainties in the base year.
Table 1.7 shows the uncertainties in the base year (Approach 1) based on expert judgement in 2000 (van Amstel et al., 2000) as well as on the 2020 methodology (Ruyssenaars et al., 2020), which accounts for the specific uncertainties for all source categories. Please note that these uncertainties were calculated excluding LULUCF.

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

Greenhouse gas	Approach 1 2000 methodology	Approach 1 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 from Enteric fermentation of poultry (3A4), due to missing emission factors;
- N_2O from Septic tanks (5D3), due to negligible amounts;
- 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 the National total emissions.

A number of recommendations by DNV GL related to the 2019 refinement of the IPCC Guidelines will be further explored. During the COP26, it was decided that the implementation of these guidelines will be voluntary as of the NIR2023.

Annex 6 presents the assessment of completeness and sources, potential sources and sinks for this submission of the NIR 2023 and the CRF tables.

2 Trends in GHG emissions

2.1 Emissions trends for aggregated GHG emissions

This chapter summarises the trends in GHG emissions for the period 1990–2021 by GHG and by sector. More sectoral details are provided in chapters 3–8.

Figure 2.1 shows the index of economic development (GDP) since 1990, compared with the development in GHG emissions for the period 1990–2021.

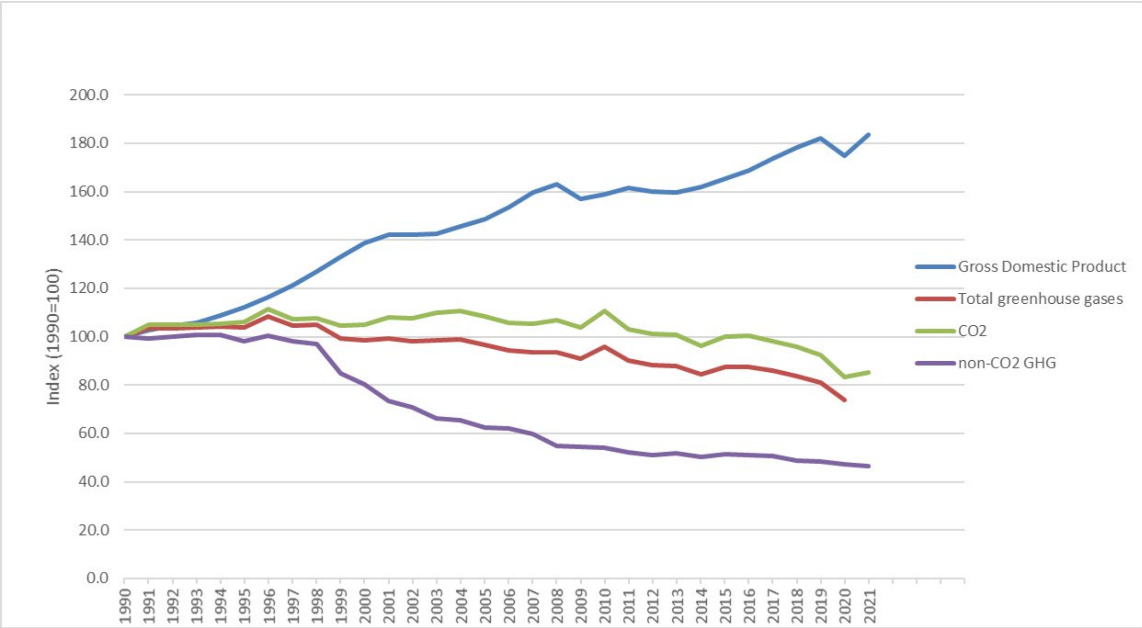

Figure 2.1 Development of greenhouse gas emissions compared with GDP (Gross Domestic Product), for the period 1990–2021.

In 2021, total GHG emissions (including indirect CO_2 emissions and including emissions from LULUCF) in the Netherlands were estimated at 172.0 Tg CO_2 eq. This is 24.9% lower than the 228.9 Tg CO_2 eq. reported for the base year (1990), while the economy increased by more than 80% in the same period. The trend in total GHG emissions was largely determined by the emission reductions achieved in non-CO_2 gases (53.7% reduction in 2021 compared with 1990; CO_2 emissions declined over the same period by 14.8%).

Figure 2.2 shows the trends and contributions of the different gases to the aggregated national GHG emissions. In the period 1990–2021, emissions of carbon dioxide (CO_2) decreased by 14.8% (including LULUCF). Emissions of non-CO_2 GHGs methane (CH_4), nitrous oxide (N_2O) and F-gases decreased by 47.4%, 55.3% and 81.2%, respectively.

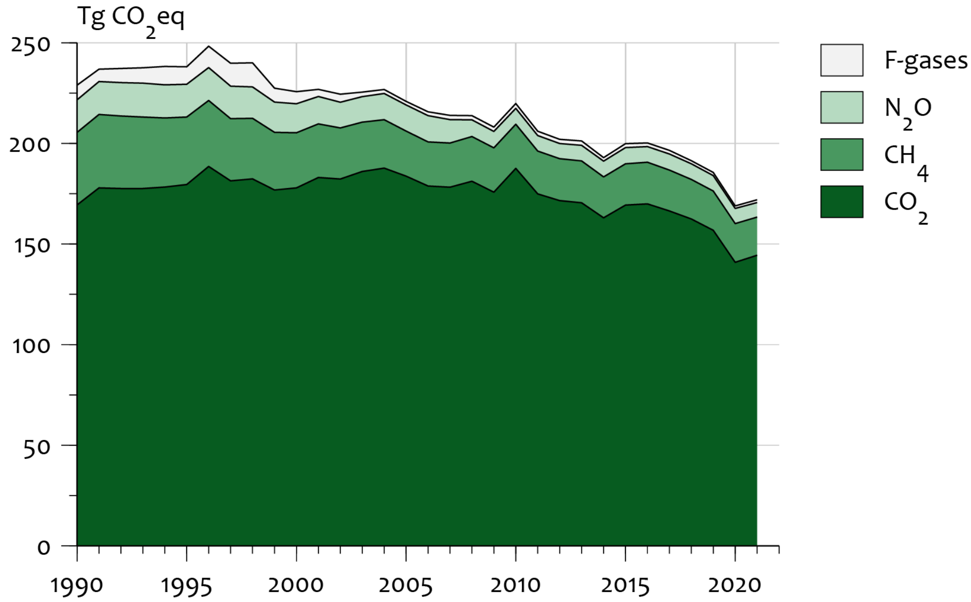

Figure 2.2 Greenhouse gases: emission levels and trend (incl. LULUCF), 1990-2021.

Emissions from LULUCF-related sources decreased for the period 1990–2021 by 30.9% to 4.3 Tg CO_2. Total GHG emissions in the Netherlands for the year 2021 (including LULUCF) were 172.0 Tg CO_2 eq.

The following sections provide more details of trend developments in the individual GHGs for the period 1990–2021.

Energy consumption – most important source of greenhouse gas emissions
About 79.9% of total GHG emissions in the Netherlands are related to sector 1, Energy. Figure 2.3 shows both the division of energy demand between specific sectors and the energy supply divided between energy sources, in PJ Net Calorific Value (NCV) per year. Figure 2.3 shows that total fossil fuel combustion decreased by 4.2% between 1990 and 2021, due to a 36% decrease in solid fuel consumption, a 2% increase in gaseous fuel consumption, and a 4% increase in liquid fuel consumption.

Total fossil fuel consumption for combustion increased by about 1.2% between 2020 and 2021, due to an increase of 36% for solid fuel combustion, an increase of 2% for liquid fuel combustion, and a reduction of 4% for gaseous fuel combustion.

Year-on-year dips and jumps in energy demand can largely be explained by weather conditions. Natural gas is the main source of energy used in the Netherlands for space heating. Figure 2.3 shows that the winters of 1996 and 2010 were relatively cold, whereas the winter of 2014 was relatively warm. The year 2021 was colder than 2020, which resulted in higher CO2 emissions from space heating in 2021 (mainly visible in CRF table 1A4).

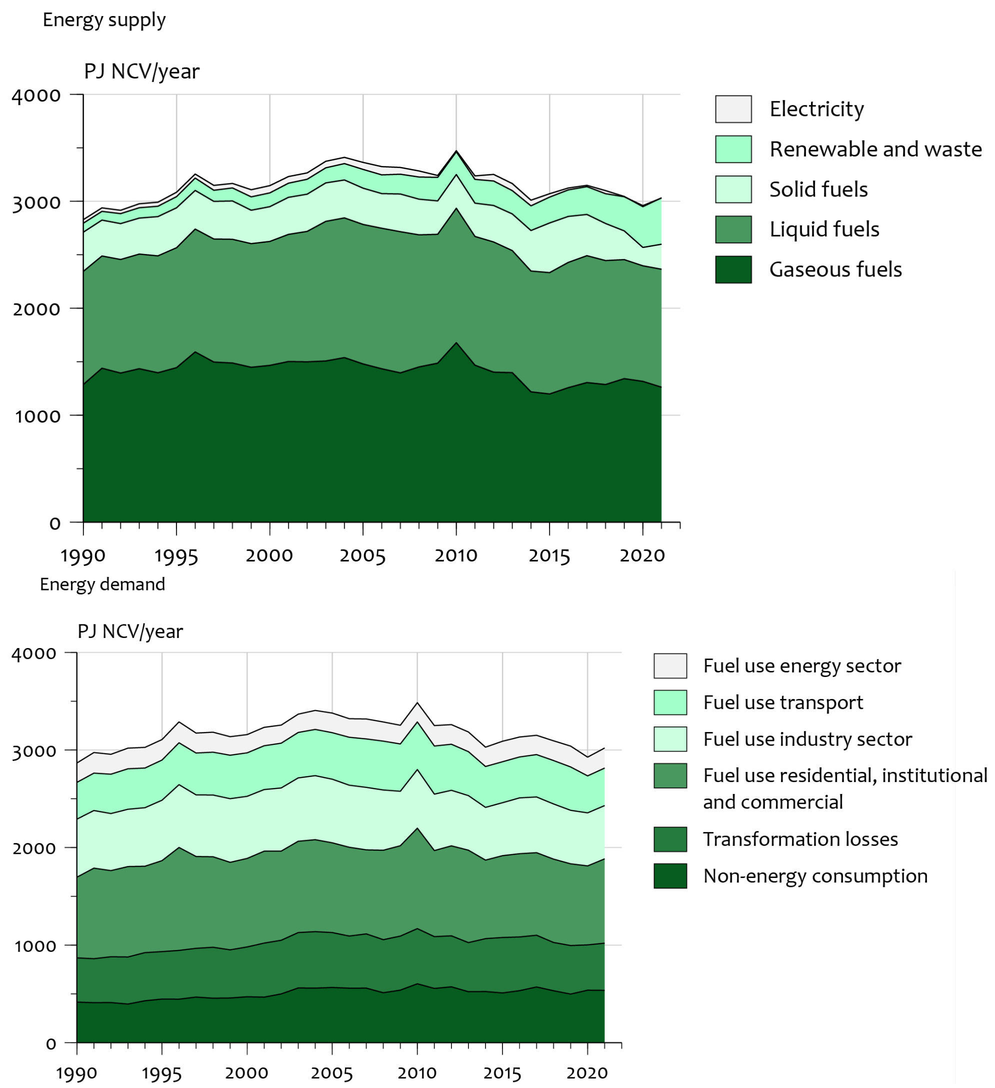

Figure 2.3 Overview of energy supply and energy demand in the Netherlands, 1990–2021 ('Electricity' refers to imported electricity only).

Energy mix

The lower part of Figure 2.3 shows the energy mix. In the Netherlands natural gas is most-used, followed by liquid fuels and solid fuels.
The most noticeable points regarding this figure are:

- In 2020, there was a dip in the graph, mainly due to a decrease in liquid fuel combustion for vehicle use during the COVID pandemic.
- Between 1990 and 2021, the total amount of fossil fuel combustion decreased by 4.2%, due to a 36% decrease in solid fuel consumption, 2% decrease in gaseous fuel consumption and 4% increase in liquid fuel consumption compared to the base year 1990.
- Between 2020 and 2021, there was an increase of total fossil fuel consumption for combustion of 1.2%, due to an increase of 36% for solid fuel combustion, an increase of 2% for liquid fuel combustion and a decrease of 4% for gaseous fuel combustion.
- The increase in solid fuel combustion in 2015 and 2016 was caused by three new coal-fired power plant. After that, in the

years 2016-2019 there was a shift from coal to natural gas and three old coal-fired power plants were closed.

- After a decrease between 2015 and 2020, the combustion of solid fuels increased again in 2021 due to high natural gas prices.
- The amount of energy from renewables and waste in the Netherlands has increased to 14% of the total primary energy supply in 2021.

Figure 2.4 shows the mix of renewable energy sources in the Netherlands and the trend. Renewables accounted for 261 PJ in 2021 (13.0% of total energy use in the Netherlands), a decrease of 7% compared to 2020.

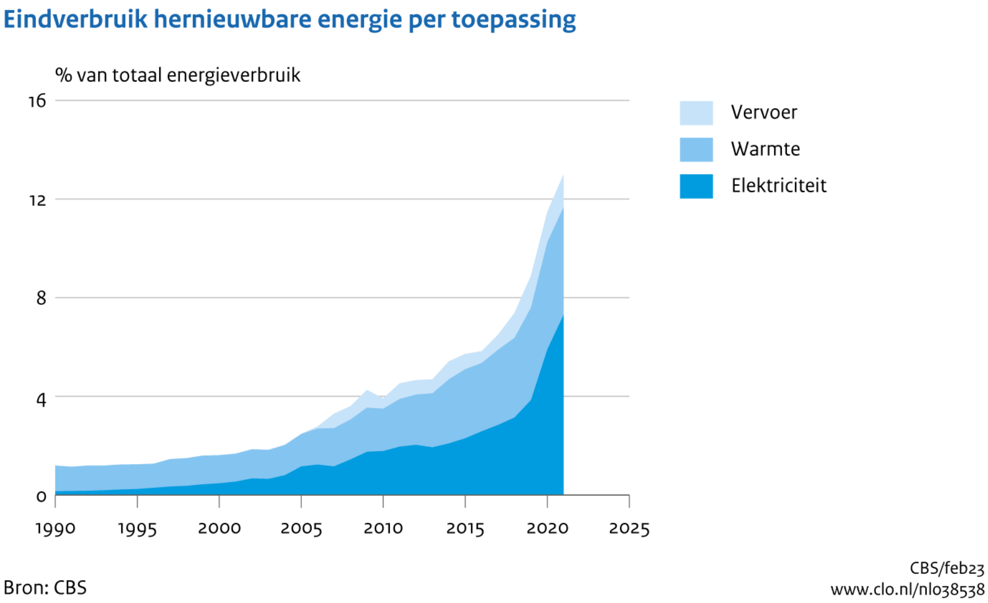

Figure 2.4 Development of renewable energy as a percentage of total energy demand in the Netherlands, 1990–2021 (CLO, 2023)[1], in Dutch

Energy efficiency
The efficiency of total final energy consumption as expressed by the so-called technical ODEX has improved by around 1.6% per year on average over the period 2000-2020[2]. On year-to-year basis, there is a gradual slowdown of the energy efficiency gains after 2006. Smaller than average gains have been registered in transport (0.4% per year excluding international aviation) and services (1.2% per year). Larger gains have occurred in the residential sector and in industry, where efficiency improved on average by 2.5% and 2.2% per year respectively.

2.2 Emissions trends by gas

2.2.1 Carbon dioxide

Figure 2.5 shows the contribution of the most important sectors to the trend in total national CO_2 emissions. In the period 1990–2021, national

[1] Verbruik van hernieuwbare energie 1990-2021 | Compendium voor de Leefomgeving (clo.nl) (consulted 23 February 2023).
[2] According to preliminary data, to be published on Netherlands energy efficiency & Trends policies | Netherlands profile | ODYSSEE-MURE (consulted 08 March 2023)

CO_2 emissions decreased by 14.8% (from 169.4 Tg CO_2 eq. to 144.4 Tg CO_2 eq.).

In 2021, total CO_2 emissions increased by about 2.5% compared with 2020 (3.5 Tg CO_2 eq.). The main reasons for the increase were:

- An increase in category 1A4 Other Sectors of 2.8 Tg CO_2, due to an increase in natural gas combustion for heating purposes as a result of a relatively cold winter in 2021 compared to 2020;
- Road transport emissions increased by 0.1 Tg CO2 in 2021. The measures taken during the COVID19 pandemic in 2020, were still partly implemented in 2021;
- On the other hand, the amount of energy from renewables and waste in the Netherlands increased from 11% in 2020 to 13.0% of total energy consumption in the Netherlands in 2021.

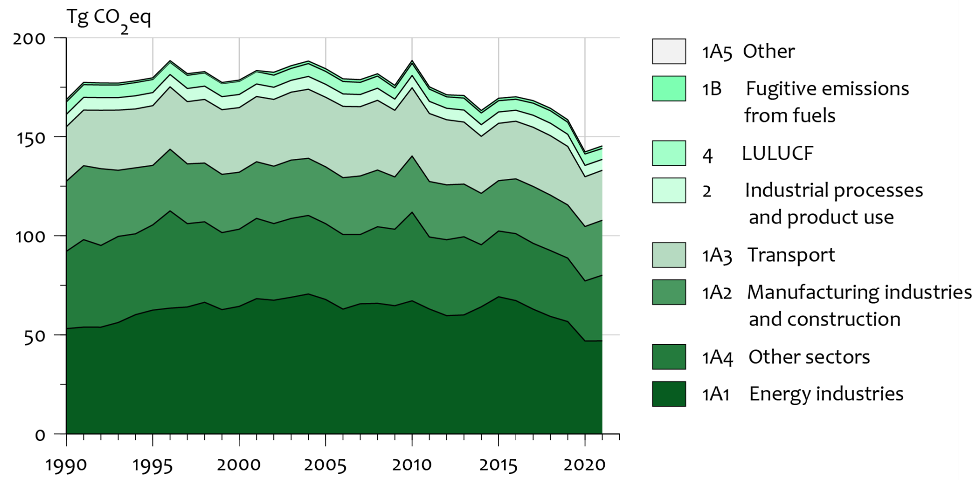

Figure 2.5 CO_2 trend and emissions levels of sectors (incl. LULUCF), 1990–2021.

Energy industries (1A1)
The Energy sector (Energy industries, Category 1A1) is the largest contributor to total CO_2 emissions in the Netherlands (32.5%). Figure 2.6 shows the emissions trend in category 1A1 between 1990 and 2021.

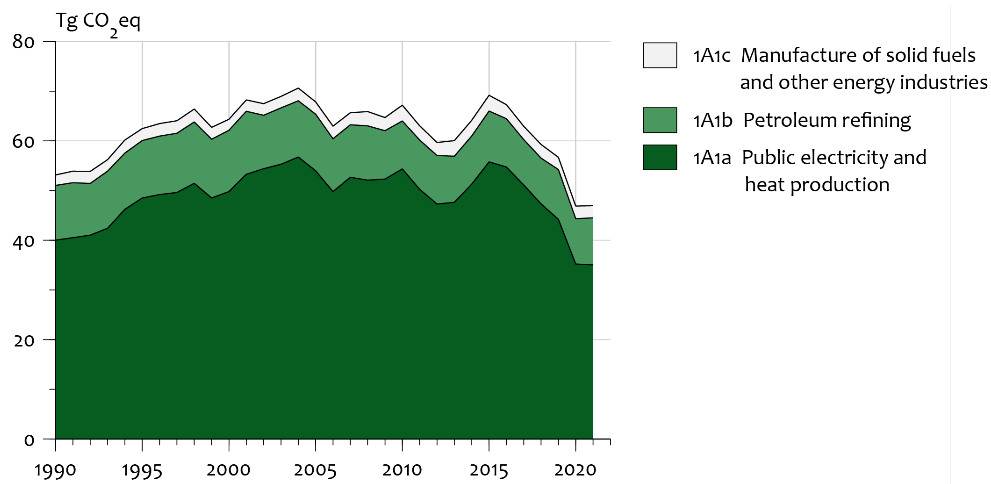

Figure 2.6 1A1 Energy industries – trend in total GHG emission by sub-category, 1990–2021.

The Dutch electricity sector has a few notable features: it has a relatively large share of coal-fired power stations and a large proportion of gas-fired cogeneration plants (combined heat and power, CHP), many of the latter being operated as joint ventures with industry. The increasing trend in electric power production until 2015 corresponds to a substantial increase in CO_2 emissions from fossil fuel combustion by power plants (see Figure 2.6). The declining trend of CO_2 between 2016 and 2020 is caused by a decrease in coal combustion as a result of the closure of coal fired power plants and an increase in renewable energy.

Over time, a fluctuation in CO_2 emissions in 1A1 can be seen; this is 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, 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. 1999–2008, 2012–2014) than in other years.

There are five large refineries in the Netherlands which export a large part of their products to the European market. As a consequence, the Dutch petrochemical industry (category 1A1b) is relatively large. Between 1990 and 2021, total CO_2 emissions from the refineries (as reported in 1A1b and 1B2a-iv) fluctuated between 10 and 13 Tg CO_2.

CO_2 emissions from combustion of natural gas by the oil and gas production industry for heating purposes (category 1A1cii) increased from 2008 till 2013, 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 shown by this category with respect to gas consumption. 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.

Manufacturing Industries (1A2)

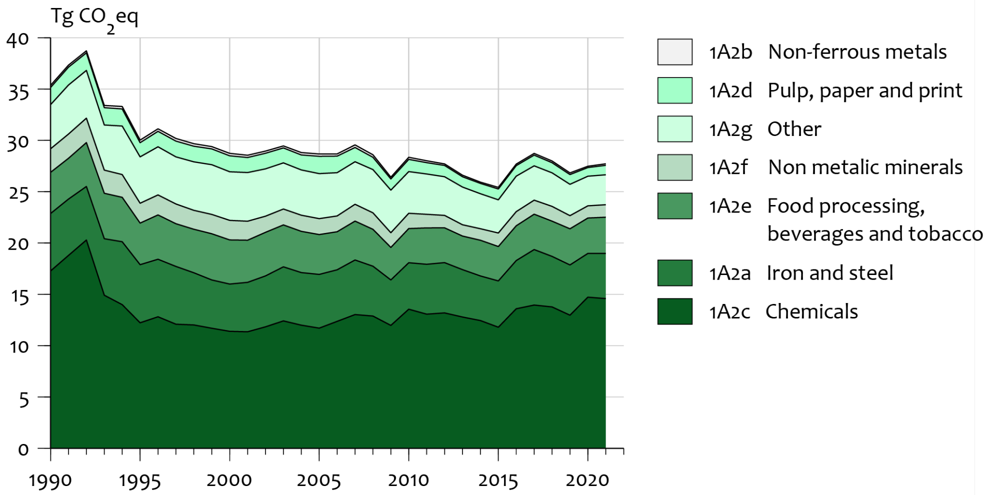

Figure 2.7 1A2 Manufacturing industries and construction – trend and emissions levels of source categories, 1990–2021.

The sector Manufacturing industries consists of 7 sub-categories. Figure 2.7 shows that category 1A2c Chemicals is the largest fuel user, with decreasing emissions between 1990 and 2000, mainly due to a decrease of cogeneration facilities in the industrial sector. In general, emissions in the category 1A2 generally follow production in the manufacturing industries: the effect of the economic crisis in 2008 is clearly visible. Over 2016 and 2017, emissions tended to increase because of positive economic developments. The decrease in 2018 and 2019, especially in category 1A2c (chemicals), was a result of less natural and residual gas combustion. 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.

Road transport (1A3)

GHG emissions from road transport increased by 30% between 1990 and 2006; see Figure 2.8. The increase was mainly due to an increase in diesel fuel consumption.

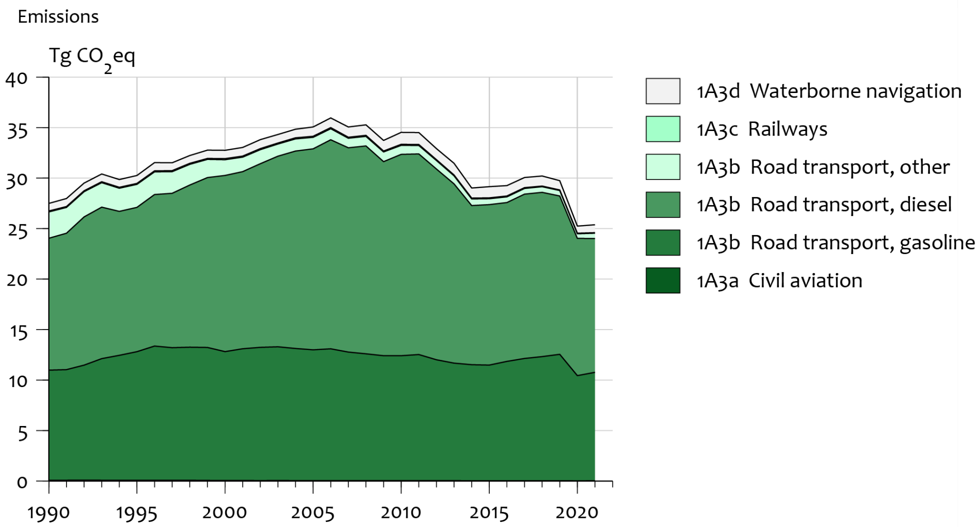

Figure 2.8 1A3 Transport – emissions levels of source categories, 1990–2021.

Since 2006, GHG emissions from transport have decreased and from 2014 till 2020 slightly increased again. In 2020, GHG emissions from transport were 15% lower than in 2019. This decrease in emissions is a result of measures taken during the COVID19 pandemic. In 2021, GHG emissions from transport increased with 0.5% compared to 2020.

Other sectors (1A4)

The principal developments in Other sectors (1A4) in Figure 2.9 are:

- Substantial interannual fluctuations in emissions, as a result of fluctuations in temperature, as clearly shown in Figure 2.9. 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 have 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 2021, CO_2 emissions have slightly increased again.

More information is provided in section 3.2.7.

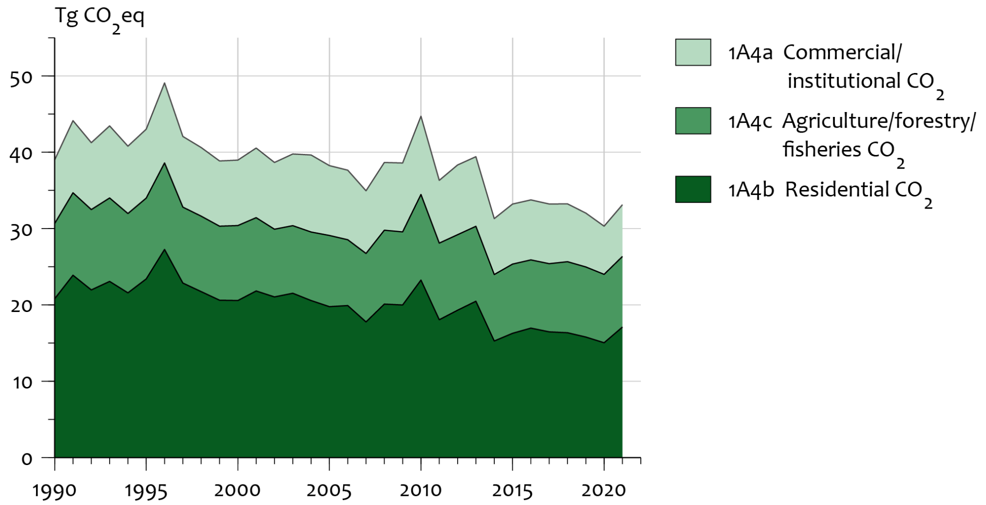

Figure 2.9 1A4 (Other sectors) – trend and emissions levels of source sub-categories, 1990–2021.

2.2.2 *Methane*

Figure 2.10 shows the contribution of the most relevant sectors to the trend in total CH_4 emissions. The Agriculture sector (68.8%) was the largest contributors in 2021.

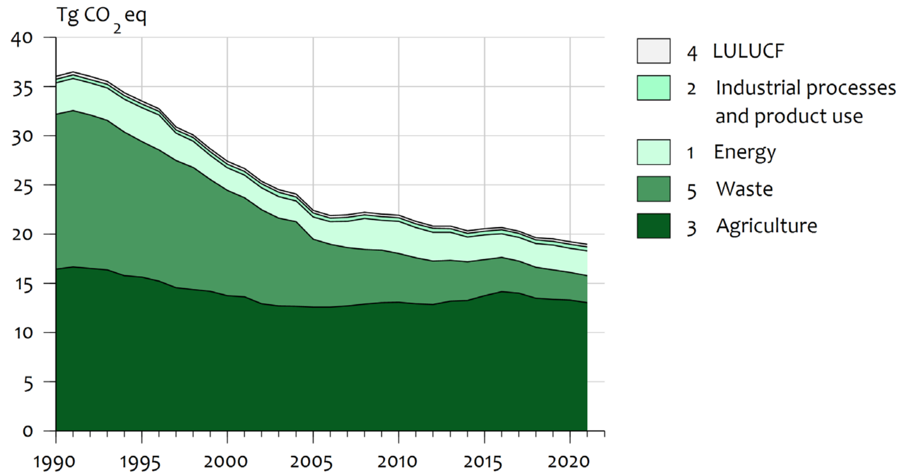

Figure 2.10 CH_4 – trend and emissions levels of sectors, 1990–2021.

National CH_4 emissions decreased by 47.4%, from 36.0 Tg to 19.0 Tg CO_2 eq., between 1990 and 2021. The trend shows a relatively strong reduction in CH_4 emissions between 1990 and 2005 (especially in category 5, Waste). After 2005, emissions further declined, but at a slower pace. In the period 1990-2021, the emissions from the Waste sector decreased by 78.7% (from 16.5 Tg CO_2 eq. in 1990 to 3.5 Tg CO_2 eq.), mainly due to an 84.6% reduction in CH_4 from Managed waste disposal on land (5A1).

Compared with 2020, national CH_4 emissions decreased by 1.4% in 2021 (-0.26 Tg CO_2 eq.). CH_4 emissions from Agriculture (categories 3A and 3B) declined by 20.6% between 1990 and 2021. After an initial decrease of 23.3% between 1990 and 2005 emissions increased again with a peak in 2016. In the last five years, the CH_4 emissions decreased again.

This trends in methane emissions are mainly explained by changes in the number of mature dairy cattle and pigs. The number of dairy cattle has decreased since the 1990s. 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 of cattle (all categories) that can be kept in the Netherlands and resulted in a decrease of cattle numbers from 2017 to 2021.

Between 2020 and 2021, CH_4 emissions from managed waste disposal on land decreased by 4.7%. The decreased CH_4 emissions since 1990 are due to:

- 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 13% in 2021).

2.2.3 *Nitrous oxide*

Figure 2.11 shows the contribution of the most relevant sectors to the trend in national total N_2O emissions. The total national inventory of N_2O emissions decreased by about 55.3%, from 16.2 Tg CO_2 eq. in 1990 to 7.2 Tg CO_2 eq. in 2021.
The IPPU sector contributed the most to this decrease; N_2O emissions decreased by 85.0% compared with the base year. Figure 2.11 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 a change in the process of nitric acid production (2B2) under EU-ETS regulation, leading to a substantive emission reduction in this source category (from 4.8 Tg CO_2 eq. in 2005 to 0.3 Tg CO_2 eq. in 2010).

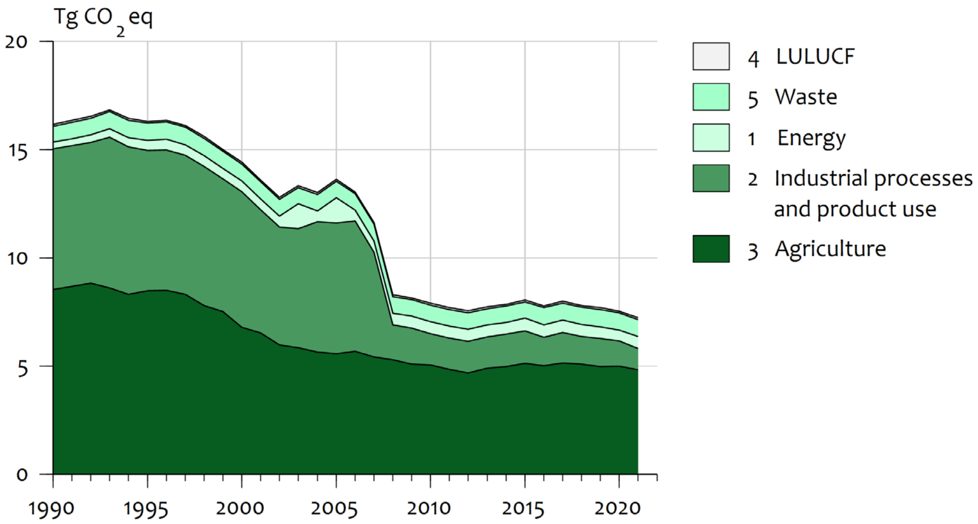

Figure 2.11 N_2O – trend and emissions levels of sectors, 1990–2021.

Compared with 2020, total N_2O emissions decreased by 4.0% in 2021 (-0.3 Tg CO_2 eq.). This was mainly due to a decrease in emissions in category 2B (Chemical Industry) -0.3 Tg CO_2 eq.).

In 2021, agricultural soils were responsible for 23.2% of total GHG emissions in the Agriculture sector. As Figure 2.11 shows, total N_2O emissions from agricultural soils decreased by 45.9% between 1990 and 2021 (Table 5.8). Compared to 2020, in 2021:

- Emissions from both organic and inorganic N fertilizers decreased by 5.6% and 1.5% respectively due to a decrease in application;
- N_2O emissions from grazing decreased by about 5.4%;
- Emissions from crop residues were slightly reduced (0.5%).

The decline in total N_2O emissions from 1990 onwards was caused by a relatively large decrease in N inputs into soil from inorganic fertilizer and organic N fertilizer applications and production of animal manure on pasture during grazing (Figure 5.5). This was partly counteracted by a shift from applying manure on the soil surface (surface spreading) towards incorporating manure 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.

2.2.4 *Fluorinated gases*

Figure 2.12 shows the trend in F-gas emissions. Total emissions of F-gases have decreased by 81.2%, from 7.3 Tg CO_2 eq. in 1990 to 1.4 Tg CO_2 eq. in 2021. Emissions of hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs) decreased by 75.0% and 96.7% respectively during this period, while sulphur hexafluoride (SF_6) emissions decreased by 41.9%.
It should be noted that, due to the fact that there is no separate registration of NF_3 in the Netherlands, emissions of NF_3 are included in PFC emissions.

Emissions of HFC-23 increased by approximately 35% between 1995–1998 due to increased production of HCFC-22. However, in the period 1998–2000emissions 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 production level is the secondary factor influencing the variation in emission levels between 2000–2008.

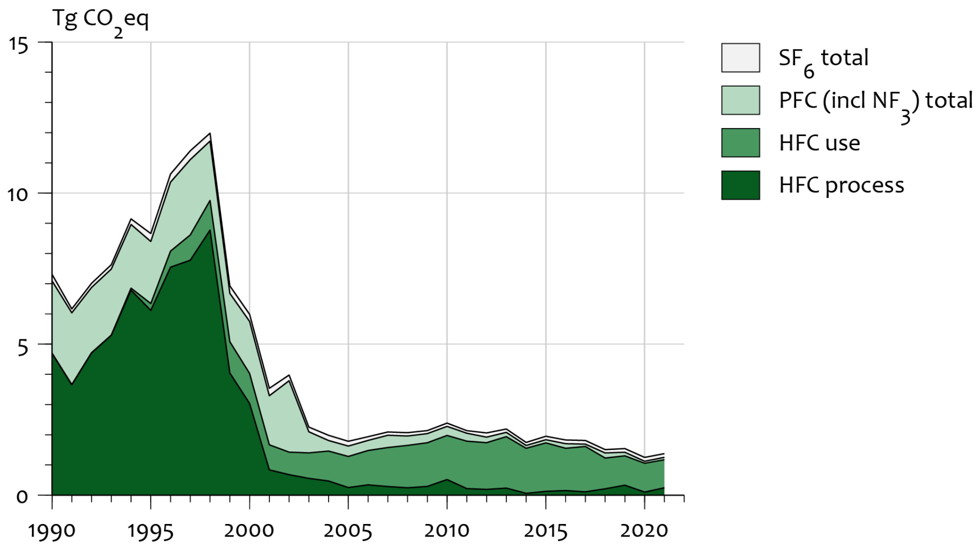

Figure 2.12 Fluorinated gases – trend and emissions levels of individual F-gases, 1990–2021.

Primarily as a result of the economic recovery, the production level of HCFC-22 was much higher in 2010, resulting in higher HFC-23 emissions in 2010 compared with 2009. After 2010, the emission fluctuations are mainly caused by changes in the removal efficiency of the TC and to a lesser extent by the production level.

From 2003 onwards, the level of the PFC emissions from aluminium production (2C3) decreased sharply because reduction measures (side feed to point feed) were taken (see Figure 2.12). From then on, emission levels depended mainly on the number of anode effects rather than on production level. PFC emissions decreased further after 2011 as a result of the closures of two companies. A restart resulted in increased PFC emissions from 2015 onwards.

Since 1990, there has been a substantial increase in HFC consumption as a substitute for (H)CFC use (2F). In 2021, this category accounted for 0.9% of national total emission of GHG emissions (0.9 Tg CO_2 eq.).

Between 2020 and 2021, aggregated emissions of F-gases increased overall by 10.0%. HFC emissions increased by 11.0%; PFC emissions increased by 21.6%, and SF_6 emissions decreased by 3.5%. Please note that, though the relative changes are substantial, the absolute changes are small.

2.2.5 *Uncertainty in emissions specified by greenhouse gas*

The uncertainty in the ***trend*** of CO_2-equivalent emissions of the six GHGs together is approximately 2%, based on IPCC Approach 1 Trend Uncertainty Assessment (see section 1.6 and Annex 2).
For each individual gas, the trend uncertainty is calculated for the total emissions of CO_2 at ±1%, for CH_4 at ±5%, for N_2O at ±6%, and for the sum of the F-gases at ±5%.

The uncertainty estimates in ***annual emissions*** for CO_2, CH_4 and N_2O are ±3%, ±8% and ±31% respectively, and for HFCs, PFCs and SF_6 ±24% (see section 1.7 and Annex 2). For all GHG emissions together, the estimated uncertainty is 3%.

2.3 Emissions trends by source category

Figure 2.13 provides an overview of emissions trends for each IPCC sector in Tg CO_2 equivalents.

The Energy sector is, as expected, by far the largest contributor to total GHG emissions in the national inventory (contributing 69.8% in the base year and 79.9% in 2021). The emissions of the Energy sector decreased by 14.0% in the period 1990–2021.
Total GHG emissions of all other sectors (IPPU, Agriculture, LULUCF and Waste) decreased in 2021 by 58.9%, 28.6%, 30.9% and 78.7% respectively compared with the base year. Trends in emissions by sector category are described in more detail in Chapters 3–8. The trends per gas were given in section 2.2.

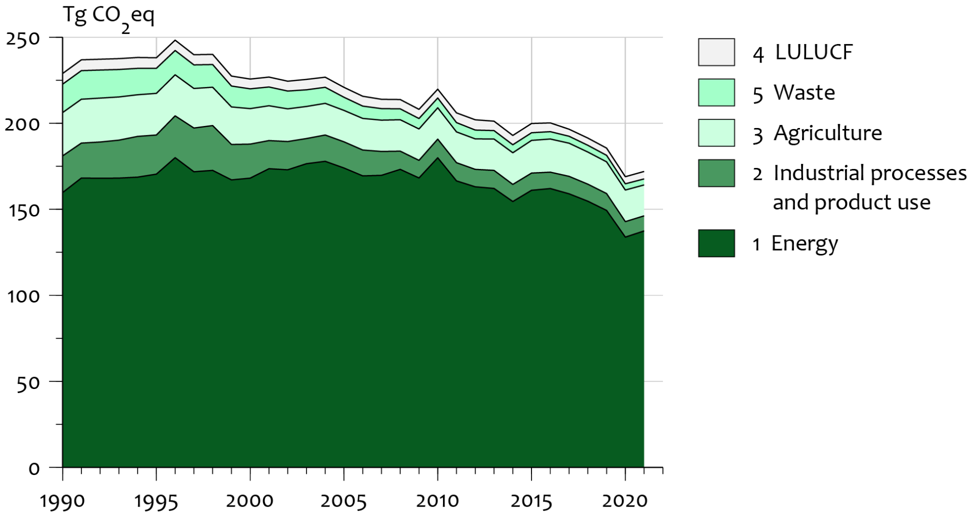

Figure 2.13 Aggregated GHGs – trend and emissions levels of sectors (excl. LULUCF), 1990–2021.

2.3.1 *Uncertainty in emissions by sector*

The uncertainty estimates in annual CO_2-equivalent emissions of IPCC sectors Energy (1), IPPU (2), Agriculture (3),LULUCF (4) and Waste (5) are about ±3%, ±12%, ±13%, ±27% and ±37% respectively.
The uncertainty in the trend of CO_2-equivalent emissions per sector is calculated for sector 1 (Energy) at ±1% in the 14% decrease, for sector 2 (IPPU) at ±5% in the 60% decrease, for sector 3 (Agriculture) at ±5% in the 29% decrease, and for sector 5 (Waste) at ±6% in the 80%

decrease.For sector 4 (LULUCF), the uncertainty is ±4% in the 24% decrease.

2.4 Emissions trends for indirect greenhouse gases and SO_2

Figure 2.14 shows the trends in total emissions of carbon monoxide (CO), nitrogen oxides (NO_x), non-methane volatile organic compounds (NMVOC), and sulphur dioxide (SO_2), which were reduced by 63.2%, 69.0%, 54.3% and 89.5% respectively in 2021 compared with 1990. With the exception of NMVOC, most of the emissions stem from fuel combustion.

The emissions data for the years 1991–1994 and 1996–1998 are of lower quality. Because of problems (incomplete reporting) identified with annual environmental reports, emissions of indirect GHGs and SO_2 from industrial sources were not verified for those years.

The uncertainty in the overall total of sources included in the inventory as far as reported in the IIR (Wever et al., 2023) is estimated to be in the order of 18% for NO_x, 20% for SO_2, and 44% for NMVOC. These uncertainties are based on an Approach 2 (Monte Carlo) analysis.

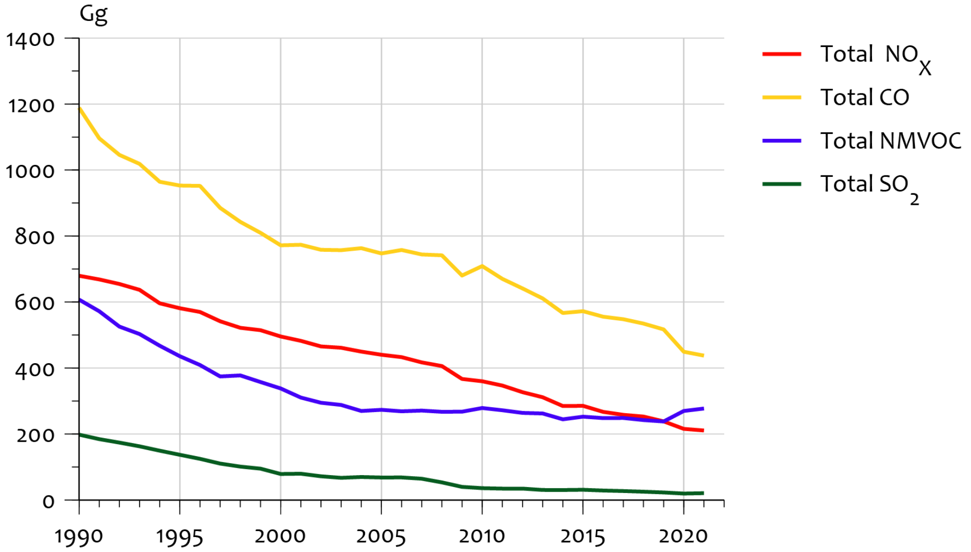

Figure 2.14 Emissions levels and trends of NO_x, CO, NMVOC and SO_2, 1990–2021 (Gg)

3 Energy (CRF sector 1)

Major changes in the Energy sector compared to the National Inventory Report 2022	
Emissions:	In 2021, GHG emissions related to the Energy sector increased by 2.7% compared to 2020, mainly in the other sectors due to an increase in natural gas combustion for heating purposes, as the winter of 2021 was colder than the winter of 2020.
GHG emissions from	transport were 0.5% higher than in 2020, these emissions are still lower than the 2019 level due to COVID19 measures which were still partly implemented in 2021.
New Key categories:	1A1 Energy Industries: all fuels N_2O 1A3b Road transportation gaseous CO_2 1A3e Other CO_2
No longer a key category:	1A3b Road transportation gaseous CO_2
Activity data:	Energy statistics have been updated/improved for the years 2015-2020 (1A1, 1A2) and for 1990-2020 (1A3, 1A4, 1A5). Also the Energy statistics for diesel in road transport and non-road mobile machineries for 1990-2020 have been improved/updated (1A3, 1A4).
other changes:	-

3.1 Overview of 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 most-used, followed by liquid fuels and solid fuels. The contribution of non-fossil fuels, including renewables and waste streams, was small, but increased to 14% of the total primary energy supply in 2021.

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=76914).

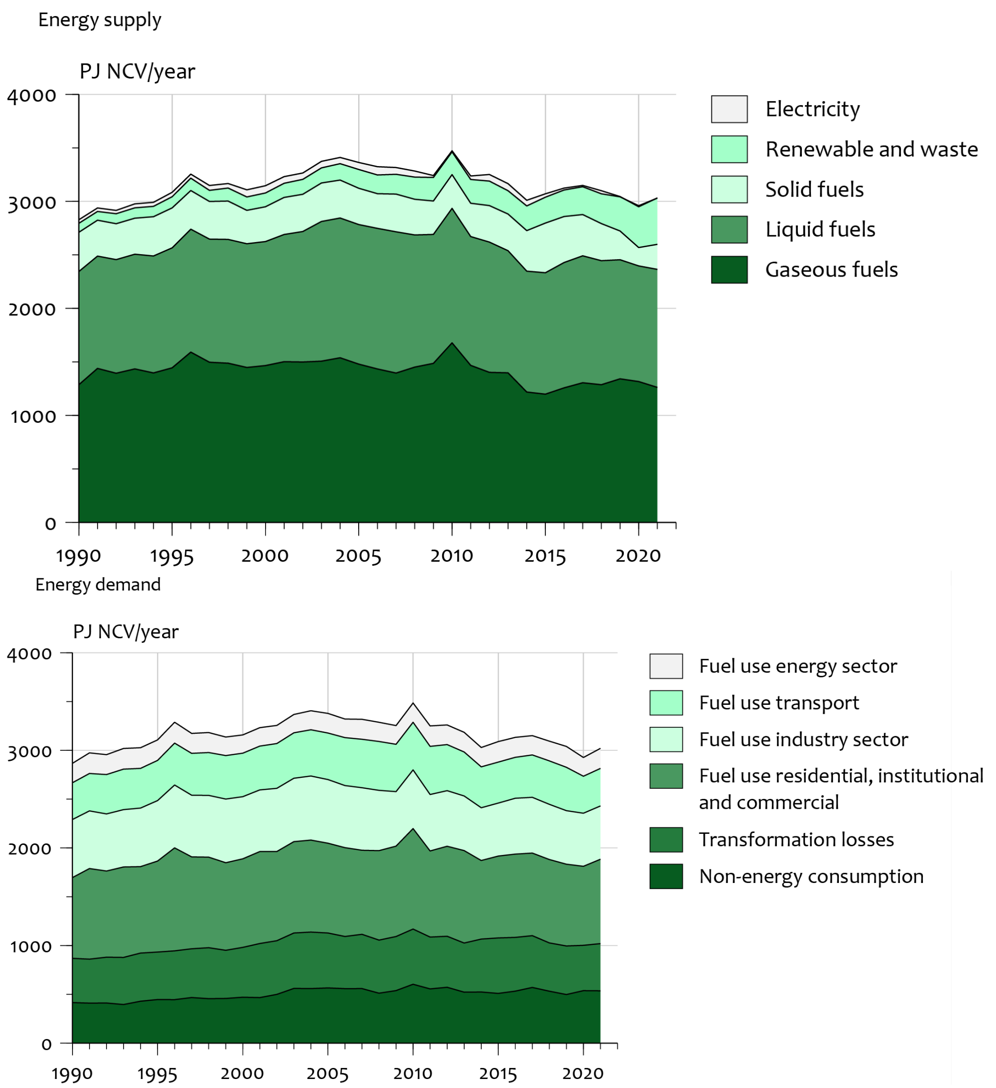

Figure 3.1 Overview of energy supply and energy demand in the Netherlands, 1990–2021, as published by Statistics Netherlands ('Electricity' refers to imported electricity only).

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 1990–2021, total fossil fuel combustion decreased by 4.2%, due to a 36% decrease in solid fuel consumption, a 2% decrease in gaseous fuel consumption, and a 4% increase in liquid fuel consumption. Total fossil fuel consumption for combustion increased by about 1.2% between 2020 and 2021, due to an increase of 36% for solid fuel combustion, an increase of 2% for liquid fuel combustion, and a reduction of 4% for gaseous fuel combustion.
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 with an accompanying decline in the use of gaseous fuel for space heating. The year 2021 was colder than 2020, which resulted in higher CO_2 emissions from space heating in 2021 (mainly visible in CRF table 1A4).

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 more 93% 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 (in Tg CO_2 eq.).

Sector/category	**Gas**	**1990**	**2020**	**2021**	**2021 vs 1990**	**Contribution to total in 2021 (%) by**		
		Emissions in Tg CO_2 eq			**%**	**sector**	**total gas**	**total CO_2 eq**
1 Energy	CO_2	156.2	130.9	134.3	-14.0%	97.8%	93.0%	78.1%
	CH_4	3.2	2.4	2.5	-20.4%	1.8%	13.4%	1.5%
	N_2O	0.3	0.5	0.5	75.8%	0.4%	7.6%	0.3%
	all	159.7	133.8	137.4	-14.0%	100.0%		79.9%
1A Fuel combustion	CO_2	155.3	129.9	133.2	-14.3%	96.9%	92.2%	77.5%
	CH_4	1.0	2.0	2.1	109.6%	1.5%	11.2%	1.2%
	N_2O	0.3	0.5	0.5	75.8%	0.4%	7.6%	0.3%
	all	156.7	132.4	135.9	-13.3%	98.9%		79.0%
1B Fugitive emissions	CO_2	0.9	0.9	1.1	26.9%	0.8%	0.8%	0.7%
	CH_4	2.2	0.5	0.4	-80.8%	0.3%	2.2%	0.2%
	all	3.1	1.4	1.5	-49.7%	1.1%		0.9%
Total national emissions (incl. LULUCF)	CO_2	169.4	140.9	144.4	-14.8%			
	CH_4	36.0	19.2	19.0	-47.4%			
	N_2O	16.2	7.5	7.2	-55.3%			
	Total*	228.9	168.9	172.0	-24.9%			

***** *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)

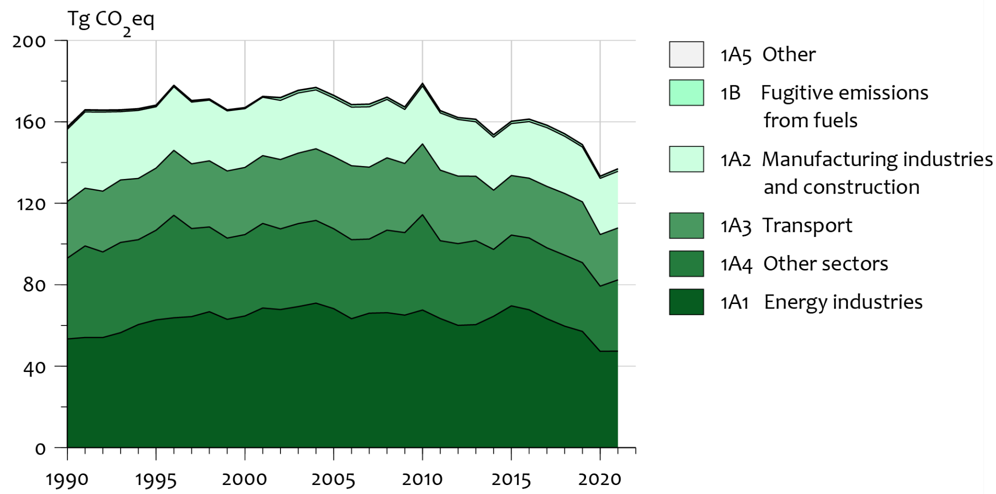

Figure 3.2 Sector 1 Energy – trend and emissions levels of total greenhouse gas emissions per source category, 1990–2021

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 (in Tg CO_2 eq.).

Sector/category	Gas	1990	2020	2021	2021 vs 1990	Contribution to total in 2021 (%) by		
		Emissions in Tg CO_2 eq			%	sector	total gas	total CO_2 eq
1A Fuel combustion	CO_2	155.3	129.9	133.2	-14.3%	96.9%	92.2%	77.5%
	CH_4	1.0	2.0	2.1	109.6%	1.5%	11.2%	1.2%
	N_2O	0.3	0.5	0.5	75.8%	0.4%	7.6%	0.3%
	All	156.7	132.4	135.9	-13.3%	98.9%		79.0%
1A1 Energy Industries	CO_2	53.1	46.9	47.0	-11.6%	34.2%	32.5%	27.3%
	CH_4	0.1	0.2	0.2	113.6%	0.1%	0.9%	0.1%
	N_2O	0.1	0.2	0.3	101.0%	0.2%	3.7%	0.2%
	All	53.4	47.3	47.4	-11.2%	34.5%		27.6%
1A2 Manufacturing industries and construction	CO_2	35.4	27.5	27.7	-21.6%	20.2%	19.2%	16.1%
	CH_4	0.1	0.1	0.1	-2.8%	0.1%	0.4%	0.0%
	N_2O	0.0	0.0	0.0	14.7%	0.0%	0.5%	0.0%
	All	35.5	27.6	27.8	-21.5%	20.3%		16.2%
1A3. Transport	CO_2	27.5	25.1	25.2	-8.3%	18.4%	17.5%	14.7%
	CH_4	0.2	0.1	0.1	-68.8%	0.0%	0.4%	0.0%
	N_2O	0.1	0.2	0.2	100.8%	0.1%	2.7%	0.1%
	All	27.8	25.4	25.5	-8.4%	18.6%		14.8%
1A4. Other sectors	CO_2	39.0	30.3	33.1	-15.1%	24.1%	22.9%	19.3%
	CH_4	0.6	1.7	1.8	183.6%	1.3%	9.5%	1.1%
	N_2O	0.0	0.0	0.0	9.2%	0.0%	0.7%	0.0%
	All	39.7	32.0	35.0	-11.8%	25.5%		20.3%
1A5 Other	CO_2	0.3	0.2	0.2	-47.6%	0.1%	0.1%	0.1%
	CH_4	0.0	0.0	0.0	-52.0%	0.0%	0.0%	0.0%
	N_2O	0.0	0.0	0.0	-51.6%	0.0%	0.0%	0.0%
	All	0.3	0.2	0.2	-47.7%	0.1%		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 and the RA.

Energy supply balance

The energy supply balance of fossil fuels for the Netherlands in 1990 and 2021 is shown in Table 3.3 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. From 2014 onwards, the production of natural gas has been reduced, and 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 by Statistics Netherlands.

Year	Role	Indicator name	Solid fuels	Liquid fuels	Gaseous fuels
1990	Supply	Primary production	0	170	2283
		Total imports	390	5344	85
		Stock change	2	2	0
		Total exports	-25	-3973	-1081
		Bunkers	0	-520	0
	Consumption	Gross inland consumption	-367	-1023	-1287
		whereof: Final non-energy consumption	-11	-317	-88
2021	Supply	Primary production	0	36	650
		Total imports	235	7759	1725
		Stock change	1	275	191
		Total exports	-1	-6449	-1299
		Bunkers	0	-576	0
	Consumption	Gross inland consumption	-234	-1046	-1267
		whereof: Final non-energy consumption	-2	-423	-111

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). In the RA, national energy statistics (production, imports, exports, stock changes and bunkers) are used 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.
National energy statistics are provided by the Statistics Netherlands (available via: https://opendata.cbs.nl/statline/#/CBS/en/dataset/83140ENG/table?dl=76914). National default, partly country-specific, CO_2 EFs are taken from Zijlema (2023) (see Annex 5).

The fuels from the energy statistics are allocated to the fuels in the RA, as shown in Table 3.4.

The energy statistics for motor gasoline and gas/diesel oil also contain the amount of biogasoline and biodiesel. Since the comparison between the RA and the SA is performed for fossil fuels only, biogasoline and biodiesel consumption is subtracted from the total apparent consumption of gasoline and gas/diesel oil in the RA.
The production/import/export data of biogasoline and biodiesel is confidential, and therefore no fuel supply data could be used. Instead, biogasoline and biodiesel consumption data (as available from Statistics Netherlands:
https://opendata.cbs.nl/statline/#/CBS/en/dataset/84714ENG/table?dl=76921) was used and subtracted from 'imports' of the fossil gasoline and diesel in the RA.

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

Fuel types in the Reference Approach			**Fuel types in the Netherlands' energy statistics**	
Fuel type			**In Dutch**	**In English**
Liquid fossil	Primary fuels	Crude oil	Ruwe aardolie	Crude oil
		Orimulsion	NO 1)	NO 1)
		Natural gas liquids	Aardgascondensaat	Natural gas liquids
	Secondary fuels	Gasoline	Additieven	Additives
			Jetfuel op benzinebasis	Gasoline type jet fuel
			Motorbenzine 5)	Motor gasoline 5)
			Vliegtuigbenzine	Aviation gasoline
		Jet kerosene	Vliegtuigkerosine	Kerosine type jet fuel
		Other kerosene	Overige kerosine (petroleum)	Other kerosene
		Shale oil	NO 1)	NO 1)
		Gas/diesel oil	Gas-, dieselolie en lichte stookolie 5)	Heating and other gasoil 5)
		Residual fuel oil	Zware stookolie	Fuel oil
		Liquefied petroleum gases (LPG)	LPG	LPG
		Ethane	IE 3)	IE 3)
		Naphtha	Nafta	Naphtha
		Bitumen	Bitumen	Bitumen
		Lubricants	Smeermiddelen	Lubricants
		Petroleum coke	Petroleumcokes	Petroleum coke
		Refinery feedstocks	Overige aardoliegrondstoffen	Other hydrocarbons
		Other oil	Minerale wassen	Paraffin waxes
			Overige aardolieproducten	Other petroleum products
			Restgassen uit olie	Residual gas
			Terpentine en speciale benzine	White spirit and industrial spirit (SBP)
Solid fossil	Primary fuels	Anthracite	Antraciet	Anthracite
		Coking coal	Cokeskool	Coking coal
		Other bituminous coal	Totaal steenkool	Total coal

Fuel types in the Reference Approach			Fuel types in the Netherlands' energy statistics	
Fuel type			**In Dutch**	**In English**
		Sub-bituminous coal	IE 2)	IE 2)
		Lignite	Bruinkool	Lignite
		Oil shale and tar sand	NO 1)	NO 1)
	Secondary fuels	BKB and patent fuel	Bruinkoolbriketten	BKB (Brown coal briquettes)
		Coke oven/gas coke	Cokesovencokes	Coke-oven cokes
		Coal tar	Steenkoolteer	Coal tar
Gaseous fossil		Natural gas (dry)	Aardgas	Natural gas liquids
Waste (non-biomass fraction)		Other	Niet biogeen huish. afval en reststoom	Non-renewable municipal waste + residual heat
			Energie uit overige bronnen	Energy from other sources
Peat			NO 1)	NO 1)
Biomass total		Solid biomass	Vaste en vloeibare biomassa 4)	Solid and liquid biomass 4)
		Liquid biomass	Biobenzine	Biogasoline
			Biodiesel	Biodiesel
		Gas biomass	Biogas	Biogas
		Other non-fossil fuels (biogenic waste)	Hernieuwbaar huishoudelijk afval	Municipal waste; renewable fraction

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.
4. In Dutch energy statistics, solid- and liquid biomass are reported together. This excludes biogasoline and biodiesel. Therefore, this is allocated to the CRF fuel 'solid biomass'.
5. In the Dutch energy statistics, motor gasoline and heating and other gas oil include biogasoline and biodiesel. In the reference approach, the biogenic part is excluded.

Table 3.5 presents the results of the RA calculations for the period 1990-2021, compared to the official national total emissions reported as fuel combustion (SA, source category 1A).
The annual difference calculated from the direct comparison varies between -1.5% and +1.9%.

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

	1990	1995	2000	2005	2010	2015	2020	2021
Reference Approach								
Liquid fuels	50.5	52.6	53.7	56.1	52.9	48.3	41.1	44.2
Solid fuels	33.4	34.1	30.2	31.4	29.5	43.8	16.1	22.1
Gaseous fuels	68.1	76.3	77.5	78.7	87.5	62.1	68.6	65.3
Other fuels	0.9	1.5	1.9	2.8	3.1	3.7	4.0	4.1
Total RA	153.0	164.5	163.3	169.0	173.0	157.9	129.9	135.7
	1990	**1995**	**2000**	**2005**	**2010**	**2015**	**2020**	**2021**
Sectoral Approach								
Liquid fuels	51.3	53.6	55.9	57.1	54.4	47.8	43.5	44.0
Solid fuels	33.6	34.2	30.2	31.7	29.9	42.9	16.2	21.8
Gaseous fuels	69.9	77.4	77.3	79.2	88.2	63.3	67.5	64.6
Other fuels	0.6	0.8	1.6	2.1	2.5	2.9	2.8	2.7
Total SA	155.3	165.9	164.9	170.1	174.9	156.9	129.9	133.2
	1990	**1995**	**2000**	**2005**	**2010**	**2015**	**2020**	**2021**
Difference (%)								
Liquid fuels	-1.4%	-1.8%	-3.9%	-1.8%	-2.7%	0.9%	-5.4%	0.4%
Solid fuels	-0.4%	-0.2%	0.1%	-0.8%	-1.4%	2.3%	-0.2%	1.2%
Gaseous fuels	-2.6%	-1.4%	0.2%	-0.7%	-0.7%	-2.0%	1.7%	1.0%
Other fuels	55.6%	83.1%	22.4%	37.0%	23.0%	27.5%	44.3%	50.2%
Total	-1.5%	-0.9%	-1.0%	-0.6%	-1.1%	0.6%	0.0%	1.9%

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

- There is a 'statistical difference' in the energy statistics, responsible for max 1% of the SA total.
- In the SA, company-specific EFs are used, while country-specific EFs are used in the RA. This results in small differences in the emissions estimation.
- CO_2 emissions from other fuels show a large difference. This is due to the fact that in the energy statistics (from Statistics Netherlands, see also Annex 4), fossil waste is aggregated together with waste heat. Therefore, the amount of fossil waste is overestimated in the RA.
- The energy statistics contain production data for chemical waste gas and additives. These cannot be included in the RA tables and are therefore excluded from the RA (while combustion of these fuels is included in the SA). The CO_2 emissions from liquid fuels in the RA are therefore 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 period 2008-

2012 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 COVID19 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 33% to 474 PJ in 2021. 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 e.g., 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 2021.

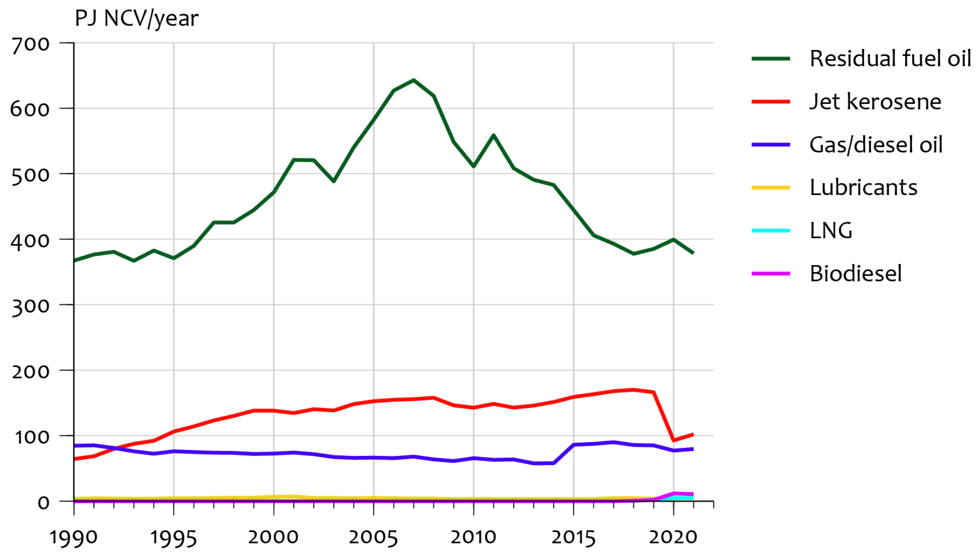

Figure 3.3 Marine and aviation bunker fuel exports, 1990–2021, as reported in CRF table 1.D (from Statistics Netherlands).

3.2.2.2 Methodological issues

As described in Geilenkirchen et al. (2023), 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, 2023). CH_4 and N_2O emissions resulting from the use of bunker fuels are calculated using 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:

- Lubricants: The fuel consumption has been updated for the years 1990-2010 (maximum 1.5% deviation).
- LNG (international navigation): The fuel consumption of LNG has been updated for 2017 and 2018, resulting in an increase in LNG consumption of 18% (28 TJ) in 2017 and 10% (51 TJ) in 2018.
- Gas/diesel oil and biodiesel (international navigation): In 2020, 3% of the gas/diesel oil (2.3 PJ) has been reallocated from gas/diesel oil to biodiesel.

The 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, etc.). 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 shows the development of total GHG emissions by sub-category of the energy industries, in the years 1990-2021.

Table 3.6 Overview of emissions in the energy industries sector (1A1) in the base year and the last two years of the inventory (in Tg CO_2 eq.).

Sector/category	**Gas**	**1990**	**2020**	**2021**	**2021 vs 1990**	**Contribution to total in 2021 (%) by**		
		Emissions in Tg CO_2 eq			**%**	**sector**	**total gas**	**total CO_2 eq**
1A1 Energy Industries	CO_2	53.1	46.9	47.0	-11.6%	34.2%	32.5%	27.3%
	CH_4	0.1	0.2	0.2	113.6%	0.1%	0.9%	0.1%
	N_2O	0.1	0.2	0.3	101.0%	0.2%	3.7%	0.2%
	All	53.4	47.3	47.4	-11.2%	34.5%		27.6%
1A1a Public Electricity and Heat Production, total	CO_2	40.0	35.2	35.0	-12.4%	25.5%	24.3%	20.4%
1A1a liquids	CO_2	0.2	0.3	0.3	37.7%	0.2%	0.2%	0.2%
1A1a solids	CO_2	25.9	11.2	16.7	-35.4%	12.2%	11.6%	9.7%
1A1a gas	CO_2	13.3	21.1	15.3	15.0%	11.2%	10.6%	8.9%
1A1a other fuels	CO2	0.6	2.7	2.7	344.1%	1.9%	1.8%	1.6%
1A1b. Petroleum refining, total	CO_2	11.0	9.1	9.5	-14.0%	6.9%	6.6%	5.5%
1A1b liquids	CO_2	10.0	6.3	6.9	-30.3%	5.1%	4.8%	4.0%
1a1b gases	CO_2	1.0	2.9	2.5	142.2%	1.8%	1.7%	1.5%
1A1c Manufacture of Solid Fuels and Other Energy Industries, total	CO_2	2.1	2.6	2.4	15.7%	1.8%	1.7%	1.4%
1A1c solids & liquid	CO_2	0.9	1.1	1.2	24.3%	0.8%	0.8%	0.7%
liquids	CO_2	0.0	0.0	0.0	-100.0%	0.0%	0.0%	0.0%
solids	CO_2	0.9	1.1	1.2	25.6%	0.8%	0.8%	0.7%
1A1c gases	CO_2	1.2	1.4	1.3	9.0%	0.9%	0.9%	0.8%

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:

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

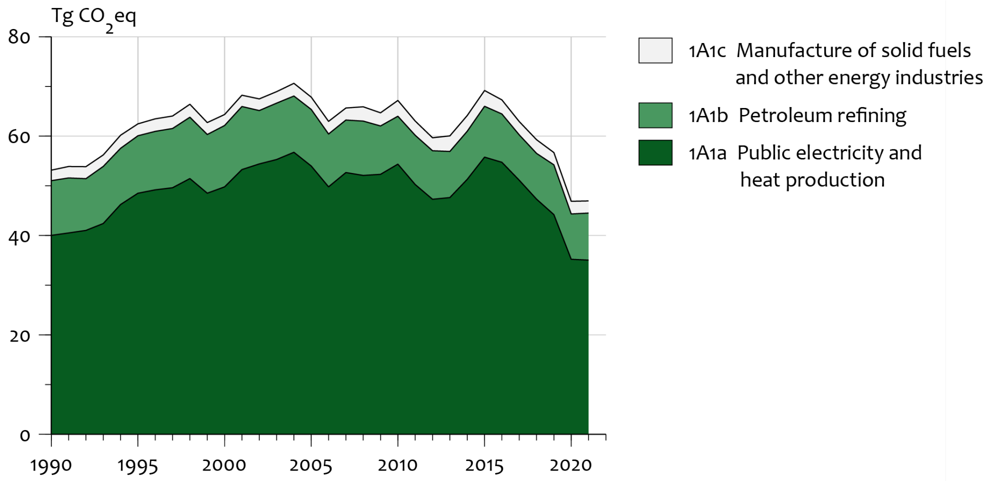

Figure 3.4 1A1 Energy industries – trend in total GHG emission by sub-category, 1990–2021.

Public electricity and heat production (1A1a)
The Dutch electricity sector mainly consist of 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 33% respectively of the total electricity production in 2021 (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 are 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).

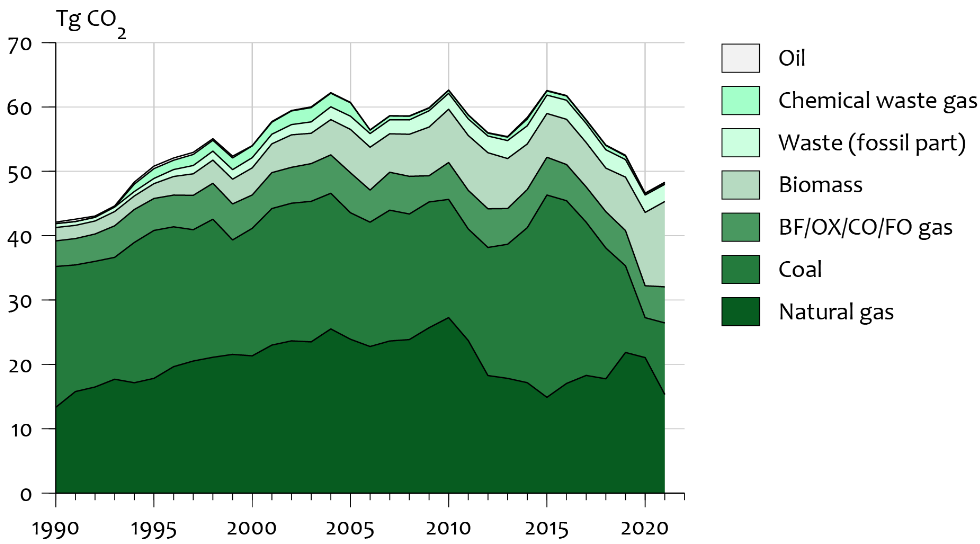

Figure 3.5 Trend in CO_2 emissions from fossil and biogenic fuel use in power plants, 1990–2021.

Waste oils (waste oil, waste lubricant, waste solvent, etc.) 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 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 not 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, an increasing amount of waste was combusted instead of being deposited in landfills, the result of environmental policy aimed at reducing waste disposal in landfills as well as the import of waste (see Chapter 7). The increase in the CO_2 EF for other fuels between 2004 and 2010 is 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 period 1990-2000 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) to 1A1a (Public electricity and heat production). The increase in natural gas combustion in 1A1a between 1990 and 1998 can largely be explained by this shift. 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 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 of chemical waste gas is lower than the EF of 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 resulted in a decrease in coal consumption from 2017 onwards;
- 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; these 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. Between 1990 and 2021, 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 are available and have been used since 2002, 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 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 2002 onward.

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 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 2021, the production of natural gas declined by 75% 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 this sector; only a small amount of liquid fuels was used until 2013. From 2014 on, no liquid fuel use was registered in the energy statistics for this sub-sector.

3.2.4.2 Methodological issues

The methodology for fuel combustion emissions is described in this section, with the exception of emissions from waste incineration. For waste incineration the activity data and EFs are explained in section 7.4 of this report and in section 2.3.2.1 of the ENINA methodology report (Honig et al., 2023).

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., 2023). 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 emission 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).

Emission calculation step 1
The first step of the emission calculation consists of a multiplication of fuel consumption by country-specific EFs.
Activity data are 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 are based on confidential data from individual companies. When necessary, emission data from individual companies are also used; for example, when companies report a different EF for derived gases (see the following section, Emission 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 taken 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., 2023) for more details on the CH_4 EF of 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., 2023).

Emission calculation step 2
In the second step, the reported emissions of selected companies are used to refine the emission calculation. Emissions data from individual companies (as reported in the AER and/or ETS reports) are used if companies report a different CO_2 EF for derived gases or other bituminous coal. The reported emission data are validated by the competent authority. If these data are not accepted by the competent authority, the CO_2 emissions data are 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 become available.
For each relevant company, data from the AERs and the ETS are compared (QC check) and the data that provide greater detail for the relevant fuels and installations are 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. For the years prior to 2003, EFs from the Netherlands' list of fuels (Zijlema, 2023) 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, 2023) 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 were missing, then a company-specific EF for the missing company was used (derived in 1995). For the period 1990–1994, a country-specific EF based on an average EF for four (large) companies has been used.

- Blast furnace gas: Since 2007, company-specific EFs have been derived for most companies. As blast furnace gas is produced only at the single iron and steel company in the Netherlands, it is assumed that all blast furnace gas has the same content and the derived EF is used for all companies using blast furnace gas. For years prior to 2007, EFs from the Netherlands' list of fuels (Zijlema, 2023) are 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, 2023) 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, 2023) are used. This fuel is 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 companies 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, 2023) are used.
- Coke oven/gas coke: 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.

Comparison of emission factors

For 2021, 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.

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) is provided in Table 3.7. Since some emissions data in this sector originate from individual companies, some of the values (in Table 3.7) deviate from the standard emission factors. For reasons of confidentiality, detailed data on fuel consumption and EFs per CRF category and fuel are not presented in the NIR, but these are available to reviewers upon request.

Table 3.7 Overview of IEFs used for the most important fuels (up to 95% of fuel use) for the year 2021 in the category Energy industries (1A1).

Fuel	Amount of fuel used in 2021 (TJ NCV)	IEFs (g/GJ)		
		CO_2 (x1000)	N_2O	CH_4
Natural gas	338,877	56.5	0.25	9.39
Other Bituminous Coal	194,227	93.9	0.96	0.44
Waste gas	97,106	62.3	0.10	3.60
Solid biomass	74,653	109.6	4.00	30.00
Waste, biomass	37,916	129.0	6.38	0.00
Waste, fossil	32,689	81.7	5.35	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 (56.4 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 'wet' 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 based on default IPCC emission factors (for 1A1a) and a company specific emission factor for the combined iron/steel plant (for 1A1c). The IEF of N_2O in table 3.7 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., (2023); 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 of CO_2 is dependent on the carbon content of the waste, which is determined annually (section 7.4 and Honig et al., 2023).

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 varies between 103.1 and 132.7 kg/GJ. The main fuels used are other bituminous coal (with an EF of 94.7 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 (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 varies 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 of wet natural gas is variable and most often slightly higher than the EF of regular natural gas. The variation in the EF of 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 varies 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 because the data recorded in national energy statistics are 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% based on 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 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 EF 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.

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. Company-specific data from the most relevant companies for a number of years have 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 are consistent for the complete time series.

Time series consistency in other sectors
For 1A1cii, the emissions data for 1990–2001 are taken from the annual reports by the oil and gas extraction companies as drawn up by Fugro-Ecodata; data from 2002 on are 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 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., 2023).

3.2.4.5 Category-specific recalculations

The energy statistics have improved for 2015-2020, the main improvements being seen in solid biomass, natural gas and diesel consumption from electricity production (1A1a), in natural gas and refinery 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):

1A1a	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
CO_2	-66.86	-77.20	-63.67	-44.07	-5.05	-8.52
CH_4	-0.015	-0.014	-0.011	-0.009	+0.005	+0.255
N_2O	-0.002	-0.001	-0.001	-0.001	+0.001	+0.002

1A1b	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
CO_2	+116.08	+67.55	+115.33	+122.32	+0.00	33.09
CH_4	+0.008	+0.005	+0.009	+0.010	+0.000	+0.000
N_2O	+0.000	+0.000	+0.000	+0.000	+0.000	+0.000

1A1c	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
CO_2	+0.00	-0.36	-0.27	-0.32	+0.03	-99.12
CH_4	-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

Other changes:

- 1A1a: For 2020, the CO_2 EF of blast furnace gas in 1A1a has been improved, resulting in a reduction of the CO_2 emissions of 132.52 Gg.
- 1A1b: The CO_2 emission of 1 refinery in 2020 has been corrected. By accident, this CO_2 emission included emissions from a chemical company as well. The emissions of this chemical company have been removed from the emissions of the refinery and reallocated to the chemical plant (see also 3.2.5.5 for the recalculation in 1A2c). This resulted in a reduction in CO_2 emissions of 283.29 Gg in 1A1b. This does not affect the CH_4 and N_2O emissions, as only the CO_2 emission is based on company reporting.

- 1A1ci: For the CO_2 emissions from coke production (1A1c) for 2015-2017, an error in the CO_2 emission factor of solid fuels has been corrected. This resulted in a change in CO_2 emissions of -93.56 Gg (in 2015), +38.22 Gg (in 2016) and +24.91 Gg (in 2017).

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

This sector comprises following key categories:

1A2	Manufacturing Industries and Construction: liquids	CO_2	Key(L,T)
1A2	Manufacturing Industries and Construction: solids	CO_2	Key(L,T)
1A2	Manufacturing Industries and Construction: gaseous	CO_2	Key(L,T1)

Table 3.8 Overview of emissions in the Manufacturing industries and construction sector (1A2) in the base year and the last two years of the inventory (in Tg CO_2 eq.).

Sector/category	**Gas**	**1990**	**2020**	**2021**	**2021 vs 1990**	**Contribution to total in 2021 (%) by**		
		Emissions in Tg CO_2 eq			**%**	**sector**	**total gas**	**total CO_2 eq**
1A2 Manufacturing industries and construction	CO_2	35.4	27.5	27.7	-21.6%	20.2%	19.2%	16.1%
	CH_4	0.1	0.1	0.1	-2.8%	0.1%	0.4%	0.0%
	N_2O	0.0	0.0	0.0	14.7%	0.0%	0.5%	0.0%
	All	35.5	27.6	27.8	-21.5%	20.3%		16.2%
1A2 liquids	*CO_2*	9.7	9.4	9.2	-5.0%	6.7%	6.4%	5.4%
1A2 solids	*CO_2*	6.6	3.8	4.0	-40.2%	2.9%	2.7%	2.3%
1A2 gases	*CO_2*	19.0	14.2	14.5	-23.6%	10.6%	10.1%	8.5%
1A2a. Iron and steel	CO_2	5.6	4.3	4.4	-21.4%	3.2%	3.0%	2.6%
1A2b. Non-Ferrous Metals	CO_2	0.2	0.1	0.2	-29.6%	0.1%	0.1%	0.1%
1A2c. Chemicals	CO_2	17.3	14.7	14.6	-15.6%	10.6%	10.1%	8.5%
1A2d. Pulp, Paper and Print	CO_2	1.7	0.8	0.9	-44.9%	0.7%	0.6%	0.5%
1A2e. Food Processing, Beverages and Tobacco	CO_2	4.0	3.5	3.5	-12.0%	2.6%	2.4%	2.1%
1A2f. Non metalic minerals	CO_2	2.3	1.2	1.2	-47.1%	0.9%	0.8%	0.7%
1A2g. Other	CO_2	4.3	2.9	2.9	-32.1%	2.1%	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 3.9).
Within the category 1A2 (Manufacturing industries and construction), the sub-category 1A2c (Chemicals) is the largest fuel user (see Table 3.9). Other large fuel-using industries are included in 1A2a (Iron and steel), 1A2e (Food processing, beverages and tobacco), and 1A2g (Other).
Please note that emissions from the combustion of waste gases resulting from the non-energy use of fuels is accounted for in the energy statistics and allocated to the 1A sector. In volume 3, chapter 1, box 1.1 of the IPCC 2006 Guidelines it is stated that reporting can be simplified by allocating combustion emissions of waste gases in the source category where the process occurs (CRF2). However, as information on the combustion of waste gases is available in the Dutch energy statistics, it was decided that these emissions are to be reported in CRF 1A.

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

In the period 1990–2021, CO_2 emissions from combustion in 1A2 decreased by 21.5% (see Table 3.8 and Figure 3.6); the chemical industry mainly contributed to this decrease.

Table 3.9 Fuel use in 1A2 Manufacturing industries and construction in selected years (PJ NCV/year).

Fuel type/	Amount of fuel used (PJ NCV/year)							
Sub-category	**1990**	**1995**	**2000**	**2005**	**2010**	**2015**	**2020**	**2021**
Gaseous fuels								
Iron and steel	11.7	13.0	13.7	12.5	12.0	11.1	11.0	11.9
Non-ferrous metals	3.8	4.3	4.2	4.0	3.6	2.7	2.3	2.7
Chemicals	170.7	138.9	115.8	103.6	96.4	93.8	124.9	124.3
Pulp, paper and print	29.2	24.4	27.4	29.7	21.0	18.7	15.0	16.3
Food processing, beverages and tobacco	63.7	68.4	73.7	67.1	57.0	57.8	59.9	61.2
Non-metallic minerals	26.1	23.8	26.5	23.5	22.6	20.4	19.1	19.3
Other	30.1	34.8	36.2	32.6	31.4	24.0	19.6	22.3
Liquid fuels								
Iron and steel	0.3	0.3	0.1	0.1	0.1	NO	0.1	0.1
Non-ferrous metals	NO	NO	NO	NO	NO	NO	NO	NO
Chemicals	96.2	77.6	82.6	93.2	112.7	110.0	123.7	118.3
Pulp, paper and print	0.0	0.0	NO	NO	NO	NO	NO	NO
Food processing, beverages and tobacco	2.2	0.6	0.2	0.2	NO	NO	0.0	0.0
Non-metallic minerals	5.6	4.2	1.9	0.8	0.7	0.2	0.0	0.0
Other	34.6	34.3	36.1	33.8	29.2	25.2	24.1	22.5
Solid fuels								
Iron and steel	73.4	80.6	68.5	81.0	70.5	80.7	71.1	76.6
Non-ferrous metals	0.0	NO	NO	NO	NO	NO	NO	NO
Chemicals	12.8	0.2	2.1	1.7	1.2	NO	NO	NO

Fuel type/ Sub-category	Amount of fuel used (PJ NCV/year)							
	1990	1995	2000	2005	2010	2015	2020	2021
Pulp, paper and print	0.1	NO	NO	NO	NO	NO	NO	NO
Food processing, beverages and tobacco	2.4	1.2	1.1	0.6	1.0	0.9	0.7	0.8
Non-metallic minerals	3.3	2.1	2.3	1.5	1.5	1.4	1.0	1.1
Other	0.4	0.2	0.3	0.5	1.6	0.5	0.3	0.3

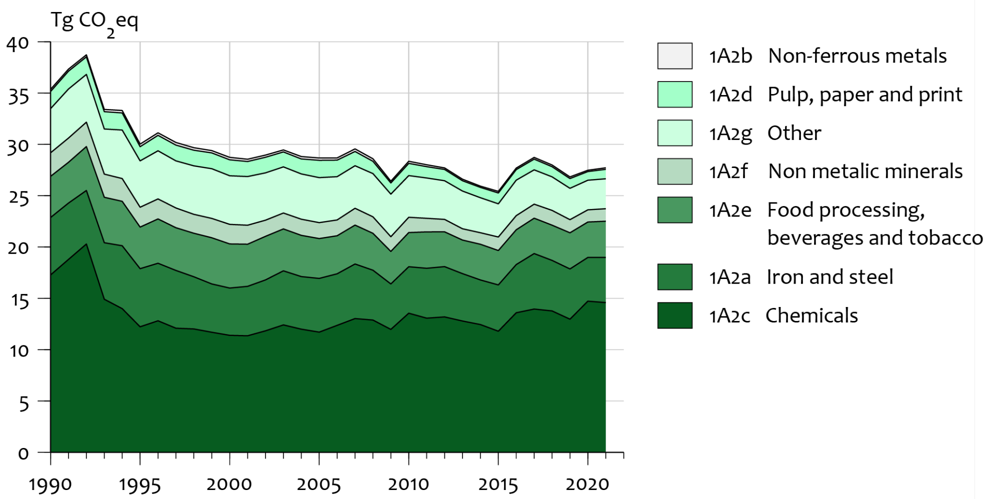

Figure 3.6 1A2 Manufacturing industries and construction – trend and emissions levels of source categories, 1990–2021.

Iron and steel (1A2a)
This sub-category refers mainly to the integrated steel plant (Tata Steel, previously 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 3.10). As a result, CO_2 emissions can be determined at plant level only; the allocation of emissions to the different 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 3.10 does not include the quantities of the inputs and outputs. The figures can, however, be made available for review purposes.

Table 3.10 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 3.10 (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).

Inter-annual 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 inter-annual 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 has not increased. This indicates a substantial energy efficiency improvement in the sector.

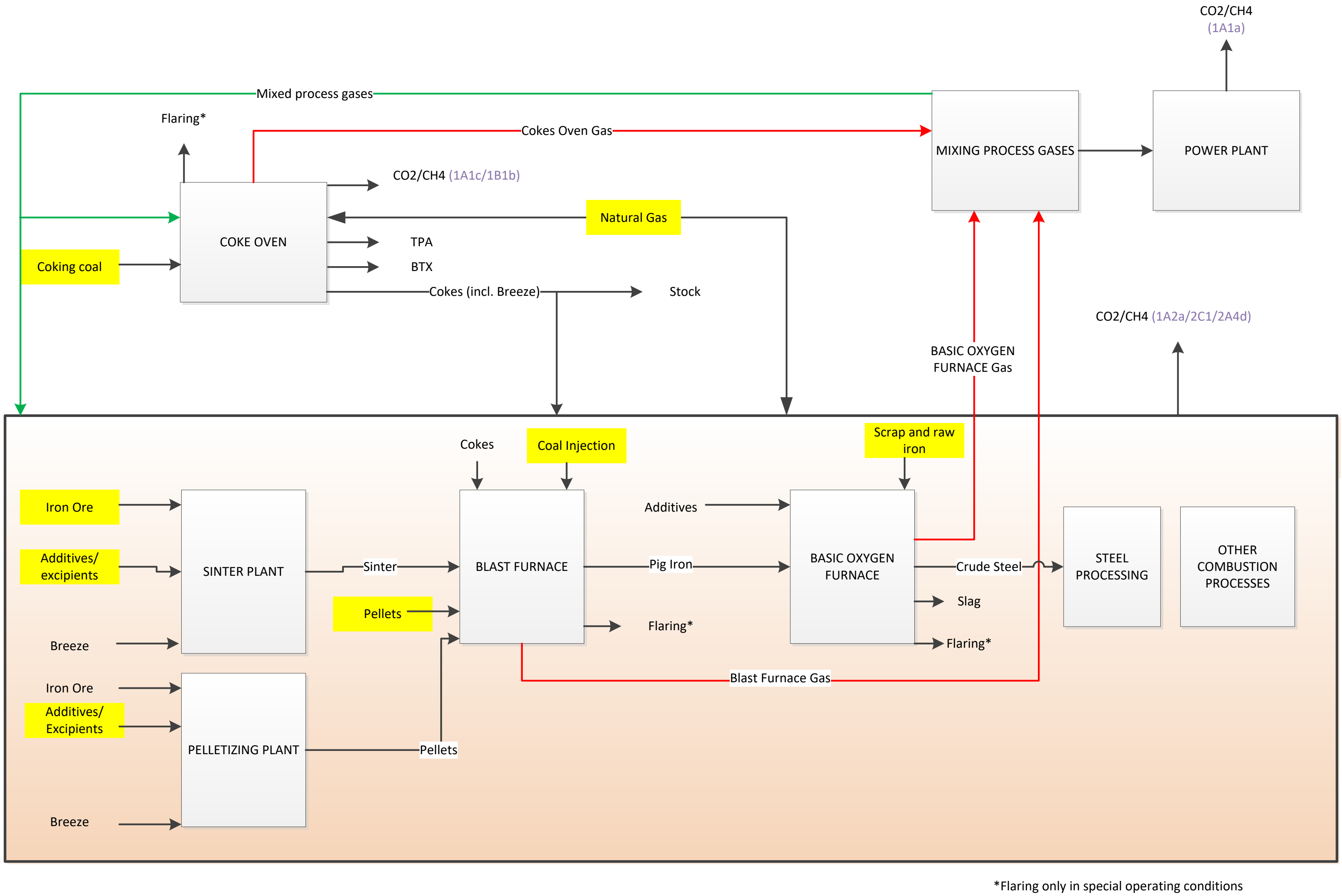

Figure 3.7 Production process of the Tata Steel integrated steel plant.

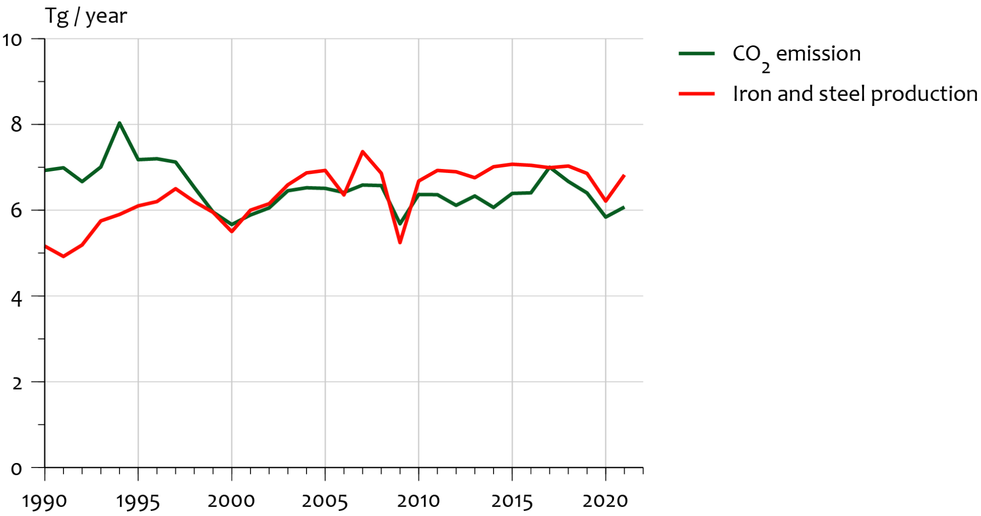

Figure 3.8 CO_2 emissions (Gg) and crude steel production (in kton) category 1A2a, 1990–2021.

Non-ferrous metals (1A2b)
This sub-category consists mainly of two aluminium smelters. 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 total National 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 of cogeneration facilities in this industrial sector. The increase in gaseous and liquid fuel consumption between 2019 and 2020 is the result of one power plant (using natural gas and chemical waste gas) now being 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.
CO_2 emissions from liquid fuel combustion stem predominantly from the combustion of chemical waste gas. The decrease in liquid fuel consumption in the 1990s was mainly due to a shift in the ownership of cogeneration plants to joint ventures, thus reallocating liquid fuel consumption to energy industries.
The increase in 2003 of the IEF for CO_2 emissions from liquid fuels is explained by the increase in the use of chemical waste gas and a change in its composition. For CO_2 from chemical waste gas (reported under Liquid fuels), source-specific EFs were used from 1995 onwards based on data from selected years. For 16 individual plants, the residual

chemical gas from the combustion of liquids consisted of hydrogen for which the CO_2 EF is 0. For another 9 companies, plant-specific CO_2 EFs based on annual reporting by the companies were used (most in the 50–55 kg CO_2/GJ range, with exceptional values of 23 and 95 kg CO_2/GJ). For 1990, an average sector-specific value for the chemical industry was calculated using the plant-specific EFs for 1995 from the four largest companies and the amounts used per company in 1990.
The variation in the amount of chemical waste gas (included in Liquid fuels) explain the variations in the IEF for liquid fuels between 55 and 70 kg CO_2/GJ. For 1990, an average sector-specific value for the chemical industry was calculated using the plant-specific EFs for 1995 from the four largest companies and the amounts used per company in 1990.

For CO_2 from phosphorus gas (included in solid fuels), plant-specific values were used, with values of around 149.5 kg/GJ. The operation of the phosphorous plant started in 1998 and closed in 2012.

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 period 1990-1998, decreased in the period 1998-2010, and was rather stable from 2010 onwards. The decrease between 1998 and 2010 is 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 period 1990-2021 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., 2023) and chapter 9 of the transport methodology report (Geilenkirchen et al., 2023). The emission 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) 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 2021, approximately 99% of the fossil CO_2 emissions were calculated using country-specific or company-specific EFs. The remaining 1% of CO_2 emissions were calculated with 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 3.11. As some emissions data in this sector originate 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 are not presented in the NIR, but are available to reviewers upon request.

Table 3.11 Overview of IEFs used for the most important fuels (up to 95% of fuel use) for the year 2021 in the category Manufacturing industries and construction (1A2).

Fuel	Amount of fuel used in 2021 (TJ NCV)	Implied emission factors (g/GJ)		
		CO_2 (x1000)	N_2O	CH_4
Natural gas	257,889	56.4	0.10	6.03
Waste gas	116,549	63.9	0.10	3.60
Coke oven / Gas coke	53,346	107.0	0.29	1.33
Other bituminous coal	40,801	93.5	0.29	0.44
Gas / Diesel oil	21,881	72.5	0.60	1.16
Solid biomass	17,441	109.6	4.00	32.82

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 EF for this sector.

Waste gas

Reported CO_2 emissions from waste gas are based on emissions data from the ETS. Therefore, the IEF is different from the standard country-specific EF.

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) is 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 different EFs for CH_4 and N_2O are used.

Solid biomass

The CH_4 emission factor differs per sector, varying 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 calculation of the iron and steel industry are based on a mass balance.

For the chemical industry, CO_2 emissions from the production of silicon carbide, carbon black, methanol, and ethylene from the combustion of residual gas (a by-product of the non-energy use of fuels) are included in 1A2c (Chemicals). Although these CO_2 emissions are the result of industrial processes, they are in fact combusted for energy purposes and therefore included in 1A2 to be consistent with energy statistics that account for the combustion of residual gases.

The fuel consumption data in 1A2g (Other) are not based on large surveys and therefore are 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 includes 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% based on the fuel quality analysis reported by Heslinga and Van Harmelen (2006) and further discussed in Olivier et al. (2009). The 24% uncertainty estimate in the CO_2 EF for liquids is based on an uncertainty of 25% in the EF for chemical waste gas in order to account for the variable composition of the gas and its more than 50% share in the total liquid fuel use in the sector. 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. Company-specific data for a number of years from the most relevant companies have 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 are consistent for the complete time series.

Following a 2017 review recommendation, the CO_2 EF of chemical waste gas for the earlier years was studied. It was concluded that the EFs for combustion of chemical waste gas were based on emissions and activity data of individual companies. The company-specific data were also used to derive a 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.

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. (2023), 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 2015-2020 have improved, the main improvements being seen in natural gas consumption in all sectors. For natural gas in 1.A.2.f, the emissions have increased because fuel consumption of asphalt production facilities have been added to the energy statistics. These resulted in the following changes in emissions (in Gg):

1A2a	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
CO_2	-0.82	+0.21	+0.27	-0.53	+6.84	-33.89
CH_4	-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

1A2b	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
CO_2	-0.13	-5.12	0.81	0.65	0.25	-0.77
CH_4	-0.000	-0.001	0.000	0.000	0.000	-0.000
N_2O	-0.000	-0.000	0.000	0.000	0.000	-0.000

1A2c	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
CO_2	-8.82	42.52	13.21	32.07	38.73	-4.93
CH_4	-0.001	0.004	0.001	0.007	0.004	-0.005
N_2O	-0.000	0.000	0.000	0.000	0.000	-0.000

1A2d	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
CO_2	12.91	-0.74	-33.37	67.77	23.70	2.71

1A2d	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
CH_4	0.001	-0.000	-0.003	0.007	0.002	0.000
N_2O	0.000	-0.000	-0.000	0.000	0.000	0.000

1A2e	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
CO_2	79.84	65.35	34.42	42.02	41.00	15.87
CH_4	0.008	0.006	0.003	0.004	0.004	0.002
N_2O	0.000	0.000	0.000	0.000	0.000	0.000

1A2f	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
CO_2	143.10	141.69	138.38	121.72	201.16	185.23
CH_4	0.013	0.012	0.012	0.012	0.020	0.016
N_2O	0.000	0.000	0.000	0.000	0.000	0.000

1A2gi	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
CO_2	-10.15	1.64	6.24	0.80	0.46	1.16
CH_4	-0.001	0.000	0.001	0.000	0.000	0.000
N_2O	-0.000	0.000	0.000	0.000	0.000	0.000

1A2gii	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
CO_2	8.08	-2.05	0.00	0.00	0.06	0.45
CH_4	0.001	-0.000	0.000	0.000	0.000	0.000
N_2O	0.000	-0.000	0.000	0.000	0.000	0.000

1A2giii	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
CO_2	-8.55	0.23	0.21	12.33	0.04	-7.04
CH_4	-0.001	0.000	0.000	0.001	0.000	-0.001
N_2O	-0.000	0.000	0.000	0.000	0.000	-0.000

1A2giv	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
CO_2	4.08	-0.81	0.00	-0.42	0.76	0.88
CH_4	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

1A2gv	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
CO_2	0.00	0.00	-0.07	-0.00	0.00	-33.89
CH_4	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

1A2gvi	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
CO_2	3.00	-4.81	-0.29	-0.60	0.10	0.98
CH_4	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

1A2gviii	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
CO_2	47.98	38.73	-50.93	-53.20	-34.28	-69.60

1A2gviii	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
CH_4	0.012	0.010	-0.002	-0.001	-0.011	-0.018
N_2O	0.001	0.001	0.000	0.001	-0.001	-0.002

Other changes for stationary combustion:

- 1A2a: For the CO_2 emissions in the iron and steel sector (1A2a) for 2015-2017, an error in the CO_2 emission factor of solid fuels has been corrected. This resulted in a change in CO_2 emissions of -80.31 Gg (in 2015), -11.43 Gg (in 2016) and -18.16 Gg (in 2017). Also the CH_4 and N_2O emission factor in the iron and steel sector have been updated. In the previous submission, an EF from the Tata steel plant has been used for the entire sector. In the current submission, the EF from Tata Steel is only used for Tata Steel, while the default EF is used for the other plants. This resulted in a small change in CH_4 and N_2O emissions in 2015-2020.
- 1A2a: For 2020, the CO_2 EF of blast furnace gas in 1A2a has been improved, resulting in a reduction of the CO_2 emissions of 143.36 Gg.
- 1A2c: The CO_2 emission of 1 chemical facility in 2020 has been corrected. By accident, the CO_2 emission of this facility was included in the emissions of a refinery. Since the reported emissions in the 2022 submission were too low for this company in 2020, a default emission factor was used to calculate the emissions. The emissions from this chemical company in 2020 are corrected and now based on the reported emissions from the company. This resulted in an increase in CO_2 emissions of 13.06 Gg. This does not affect the CH_4 and N_2O emissions, as only the CO_2 emission is based on company reporting.

Mobile combustion

Recalculations related 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 are planned. Planned improvement 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 3.12 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 3.12 Overview of emissions in the sector Transport (1A3) in the base year and the last two years of the inventory (in Tg CO_2 eq.).

Sector/category	Gas	1990	2020	2021	2021 vs 1990	Contribution to total in 2021 (%) by		
		Emissions in Tg CO_2 eq			%	sector	total gas	total CO_2 eq
1A3. Transport	CO_2	27.5	25.1	25.2	-8.3%	18.4%	17.5%	14.7%
	CH_4	0.2	0.1	0.1	-68.8%	0.0%	0.4%	0.0%
	N_2O	0.1	0.2	0.2	100.8%	0.1%	2.7%	0.1%
	All	27.8	25.4	25.5	-8.4%	18.6%		14.8%
1A3a. Civil aviation	CO_2	0.1	0.0	0.0	-68.2%	0.0%	0.0%	0.0%
1A3b. Road vehicles	CO_2	26.3	24.2	24.3	-7.5%	17.7%	16.8%	14.1%
	CH_4	0.2	0.1	0.1	-69.9%	0.0%	0.3%	0.0%
	N_2O	0.1	0.2	0.2	108.0%	0.1%	2.6%	0.1%
1a3b gasoline	CO_2	10.7	10.3	10.7	-0.1%	7.8%	7.4%	6.2%
1a3b diesel oil	CO_2	13.0	13.4	13.1	0.8%	9.5%	9.1%	7.6%
1a3b LPG	CO_2	2.6	0.3	0.3	-89.7%	0.2%	0.2%	0.2%
1a3b Natural gas	CO_2	0.0	0.1	0.2	>100 %	0.1%	0.1%	0.1%
1A3c. Railways	CO_2	0.1	0.1	0.1	-38.6%	0.0%	0.0%	0.0%
1A3d. Domestic Navigation	CO_2	0.7	0.7	0.8	4.0%	0.6%	0.5%	0.4%
1A3e Other Transportation	CO_2	0.3	0.1	0.1	-72.8%	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
Transport was responsible for 14.8% of GHG emissions in the Netherlands in 2021. 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 25.5 Tg CO_2 eq. in 2021.
Total energy use and resulting GHG emissions from transport are summarised in Figure 3.9 and Figure 3.10. As Figure 3.9 shows, road transport accounts for 95–97% of energy use and GHG emissions in this category over the time series.

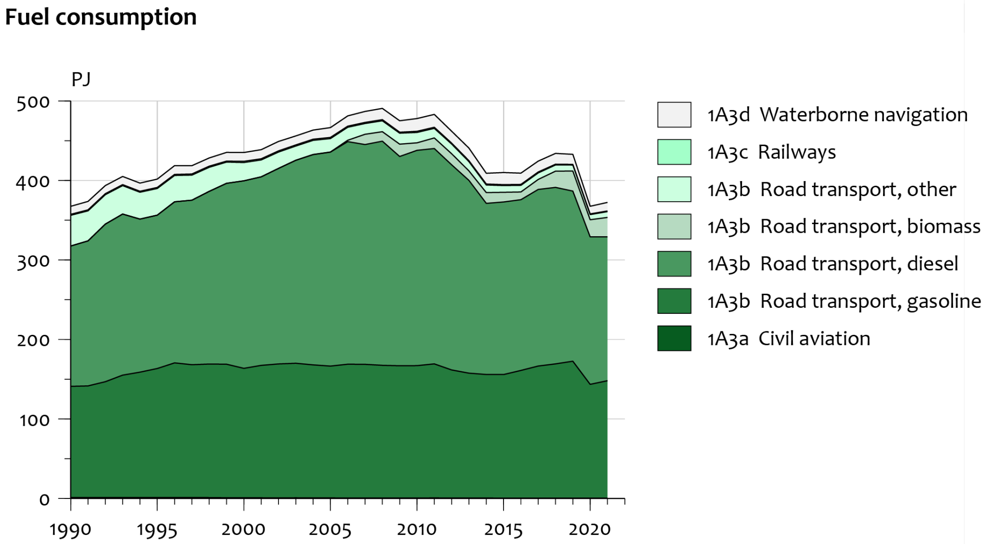

Figure 3.9 1A3 Transport – energy use of source categories in PJ, 1990–2021.

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. In 2021, GHG emissions from transport were 0.5% higher than in 2020. The emissions are still below the level of 2019 as a result of measures taken during the COVID19 pandemic in 2020, which were still partly implemented in 2021.

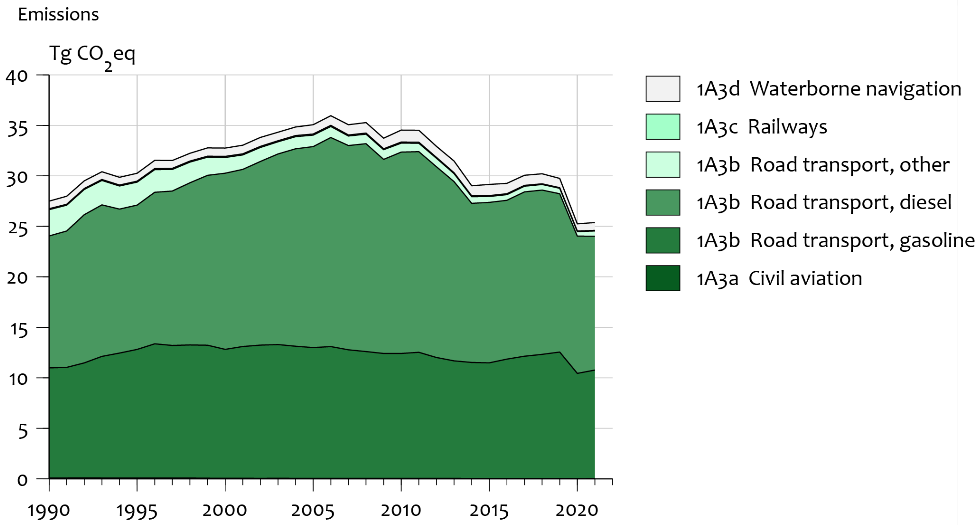

Figure 3.10 1A3 Transport – emissions levels of source categories, 1990–2021.

Civil aviation (1A3a)
Given the small size of the country, 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 PJ in 1990 to 0.3 PJ in 2021, and the use of aviation gasoline decreased from 0.2 PJ in 1990 to 0.05 PJ in 2021. GHG emissions from civil aviation decreased accordingly. In 2021 the use of jet kerosene for domestic aviation increased by 8% after the decrease due to the corona pandemic.

Road transport (1A3b)
The share of road transport (1A3b) in national GHG emissions increased from 11.6% in 1990 to 14.3% in 2021. Between 1990 and 2019, total GHG emissions from road transport increased from 26.6 to 28.8 Tg CO_2 eq., for the most part due to an increase in diesel fuel consumption. In 2021, total GHG emissions decreased to 24.5 Tg CO_2 eq due to the corona pandemic, restrictive policies for social distancing in the Netherlands and a daytime speed reduction to 100 km/h due to nitrogen policies in the Netherlands.

Between 1990 and 2008, diesel fuel consumption increased by 60% (+105 PJ). This increase was, in turn, caused by a large growth in freight transport volumes and the 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, only 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 led to an increase in transport volumes. Finally, an increase in excise duties for diesel fuel in the Netherlands in 2014 led to 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. Thereafter, gasoline sales for road transport decreased to 155 PJ in 2014 but increased again to 172 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 for the most part be attributed to economic growth resulting in increased traffic volumes. Restrictions for social interaction during the corona pandemic (such as the work-from-home policy) caused gasoline and diesel sales to decrease by 17% and 13% respectively. 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.

LPG consumption for road transport decreased steadily throughout the time series: from 39 PJ in 1990 to 4 PJ in 2021, 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 2021. The use of natural gas in road transport has increased in recent years and amounted to 3 PJ in 2021. 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. Biofuel use for road transport increased to 24 PJ in 2021, accounting for 6.6% of total energy use for road transport. This is a result of a legal obligation to use renewable energy for transport. This obligation for the most part is met by the increasing use of biofuels, and also through electrification of road vehicles.

The share of CH_4 in GHG emissions from road transport (in CO_2 eq.) is small (0.03% in 2021). CH_4 emissions from road transport decreased by about 70% between 1990 and 2021. This was due to a reduction in VOC emissions, resulting from the implementation and subsequent tightening of EU emissions legislation for new vehicles.

Total VOC emissions from road transport decreased by almost 90% between 1990 and 2021, primarily due to the penetration of catalyst-equipped and canister-equipped vehicles into the passenger car fleet. As almost the entire gasoline car fleet is currently equipped with catalysts and carbon canisters, the decrease in VOC emissions has stagnated in recent years. Since CH_4 emissions are estimated as a fraction of total VOC emissions, the decrease in VOC emissions throughout the time series has also resulted in a decrease in CH_4 emissions and stabilisation between 2014 and 2021. However, the share of CH_4 in total VOC increased with the introduction of three-way catalysts (TWCs) in gasoline passenger cars. Therefore, the decrease in CH_4 emissions throughout the time series is smaller than the decrease in total VOC emissions.

The share of N_2O in total GHG emissions from road transport (in CO_2 eq.) is also small (0.8% in 2021). N_2O emissions from road transport increased from 0.3 Gg in 1990 to 0.9 Gg in 1997, but have since decreased to 0.7 Gg in 2021. The increase in N_2O emissions up to 1997 resulted from the increasing number of gasoline cars equipped with 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 led to 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.

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 2021. 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 2021, 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 and varies between 0% and 4% throughout the time series (3% in 2021).

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 15 PJ in 2011, but then decreased to 10 PJ in 2021. 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 0.8 Tg in 2021.

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 0.4% in 2021.

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 under 1A3biv, in accordance with the 2006 IPCC Guidelines.
- Emissions from NRMM (non-road mobile machineries) are reported under different 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 3.13 summarises the methods and types of EFs used for transport. More details on methodological issues can be found in Geilenkirchen et al. (2023).

Table 3.13 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 and CH_4. 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 (NOx, CO, NMVOC and SO_2) reported in the CRF under Domestic aviation, are the uncorrected emissions from the NL-PRTR and refer to aircraft emissions during landing and take-off cycles at all Dutch airports. No attempt has been made to estimate non-GHG emissions specifically related to domestic flights (including cruise emissions of these flights) as these are negligible.

Road transport (1A3b)
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. Table 2.1 in Geilenkirchen et al. (2023) provides an overview of the methodology used to divide the Energy Balance data over the different 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 two measurement programmes, the most recent being performed in 2016 and 2017 and is actualised by Statistics Netherlands. The methodology is described in detail in the 2018 inventory report. A detailed description of the methodology currently used for calculating GHG emissions for road transport is provided in chapter 2 of Geilenkirchen et al. (2023). The EFs used are provided in Geilenkirchen et al. (2023) in Table 2.3 (for CH_4 and N_2O EFs) and Table 2.8 (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.

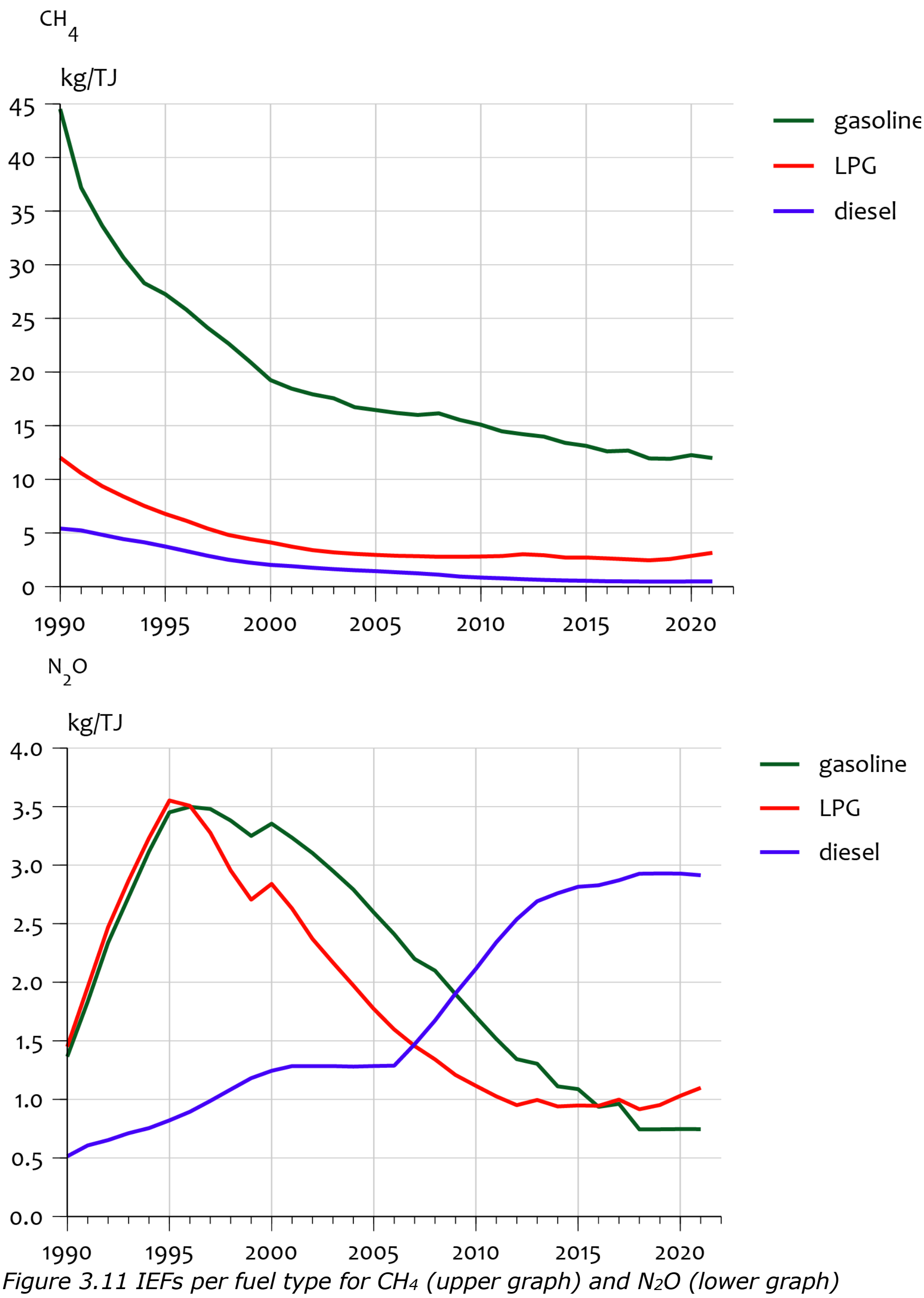

Figure 3.11 IEFs per fuel type for CH_4 (upper graph) and N_2O (lower graph) emissions by road transport, 1990–2021.

Railways (1A3c)
Fuel deliveries to railways are derived from the Energy Balance. Since 2010, Statistics Netherlands has derived these data from Vivens, a cooperation of rail transport companies that purchases diesel fuel for the entire railway sector in the Netherlands. Before 2010, diesel fuel deliveries to the railway sector were obtained from Dutch Railways, responsible for the purchase of diesel fuel for the entire railway sector in the Netherlands until 2009.

CO_2 emissions from railways are calculated with a Tier 2 methodology, using the same country-specific CO_2 EFs as 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, employing EFs 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 a bottom-up approach derived from Deltares & TNO (2016). Gasoline sales data for road transport derived from the Energy Balance are corrected accordingly (as shown in Table 2.1 of Geilenkirchen et al., 2023).

The fuel consumption from the Energy Balance is allocated between 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, etc.) its fuels are 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 CH_4 and N_2O EFs used and the underlying methodology is provided in Geilenkirchen et al. (2023); 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 different types of biogasoline and biodiesel used in the Dutch market, as reported annually by the Dutch Emission Authority (NEa, 2022).

3. Apply the fossil fraction of the carbon content per type of biofuel as provided by Sempos (2018).

Table 3.14 Share (in %, rounded) of different types of biofuels in total biofuel consumption for transport in the Netherlands (NEa, 2022).

	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
			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
			100	100	100	100	100	100	100	100	100	100	100

Table 3.14 shows the input for steps 2 and 3, i.e., the shares of different types of biofuels in total biogasoline and biodiesel use for transport in the 2011–2021 period, as reported by NEa (2022[3]), 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. (2023) which also shows the sources used to estimate uncertainties. Table 3C 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 yearly in accordance with methodological improvements and recalculations, after consultation with experts.

[3] https://www.emissieautoriteit.nl/documenten/publicatie/2022/07/01/totaalrapportage-energie-voor-vervoer-2021

Table 3.15 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) are also calculated using a bottom-up approach based on vehicle–kilometres travelled and specific fuel consumption per vehicle–kilometre for different 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 both the time series for fuel sold and fuel used for gasoline (including bioethanol) and diesel (including biodiesel) in road transport.

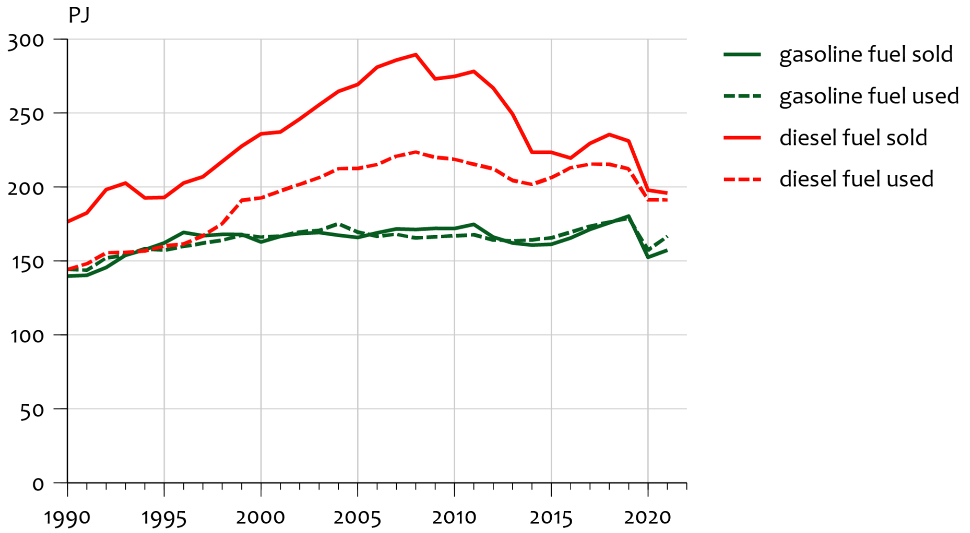

Figure 3.12 Fuel sold and fuel used for road transport in the Netherlands, 1990-2021.

The bottom-up calculation of gasoline consumption in road transport closely corresponds with the (adjusted) sales data from the Energy Balance for the period 1990–2011; differences between the two figures are small throughout the time series. As of 2011, fuel sold decreased compared to fuel used due to an increase in cross-border refuelling, as described in section 3.2.6.1. The difference between fuel used and fuel sold has, however, become smaller in recent years.

The time series fuel sold and fuel consumed show good correspondence for LPG and, to less extent, for gasoline over the entire time series, as can be seen in Figure 3.12. However, the time series for diesel deviate: although the trend is mostly comparable, diesel sales are substantially higher than diesel consumption on Dutch territory throughout the time series. Differences vary between 12% and 37%. In recent years the difference between fuel used and fuel sold has, however, become smaller than in previous years.

The difference between the two time series for diesel 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 to 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. Figures compiled by Rail Cargo (2007, 2013) show 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%. 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

Minor changes were made in the activity data for railways (from 2013), and inland navigation. New data were derived from the Energy Balance and the GHG emissions changed accordingly.

Diesel revision in Energy Balance
The diesel consumption of road transport has been recalculated due to a revision in the Energy Balance. This leads to a decrease of CO_2 emissions from road transport of around 1 Tg in the years 2013-2020.

The total amount of diesel in the Energy Balance is used as activity data to determine the emissions by the combustion of diesel for domestic mobility. In this balance sheet there was a small difference ('statistical difference') between supply and consumption and this difference was also reported in accordance with guidelines for international energy statistics. The amount of diesel in the Energy Balance was recalculated, thus the activity data has changed for the NIR 2023. Energy Statistics Netherlands describes their update of the Energy Balance regarding diesel consumption as stated in the text box below.

Figures for 1990 up to and including 2019 have been revised. The revision mainly concerns the consumption of gas- and diesel oil and energy commodities higher in the classification (total petroleum products, total crude and petroleum produtcs and total energy commodities).
The revision is twofold:

- New data for the consumption of diesel oil in mobile machine have been incorporated. Consequently, the final energy consumption of gas- and diesel oil in construction, services and agriculture increases. The biggest change is in construction (+10 PJ from 1990-2015, decreasing to 1 PJ in 2019. In agriculture the change is about 0.5-1.5 PJ from 2010 onwards and for services the change is between 0 and 3 PJ for the whole period.
- The method for dealing with the statistical difference has been adapted. Earlier from 2013 onwards a difference of about 3 percent was assumed, matching old data (up to and including 2012) on final consumption of diesel for road transport based on the dedicated tax specifically for road that existed until 2012. In the new method the statistical difference is eliminated from 2015 onwards. Final consumption of road transport is calculated as the remainder of total supply to the market of diesel minus deliveries to users other than road transport.

The first and second item affect both final consumption of road transport that decreases consequently about 5 percent from 2015 onwards. Before the adaption of the tax system for gas- and diesel oil in 2013 the statistical difference was positive (more supply than consumption). With the new data for mobile machines total consumption has been increased and the statistical difference has been reduced and is even negative for a few years.

Table 3.16 shows the impact on CO_2-eq emissions from diesel for road transport and non-road mobile machineries.

Table 3.16 Impact of the revision on CO_2-eq emissions from diesel between the NIR 2022 and NIR 2023

	1990	2020
Road transport	0,0 (0%)	-0.8 (-6%)
Non-road mobile machineries	+1.1 (+28%)	+0.3 (+9%)

In 1990, more supply than consumption was observed (+10 PJ) and in 2021 consumption was higher than supply which gave a negative difference (-7 PJ).
This year the method for diesel for the Energy Balance was evaluated, taking into account:

- Recalculation of diesel consumption by non-road mobile machineries (see also section 3.2.7.4) from 1990 onwards.
- Increased uncertainty for specific consumption of diesel by road transport from 2013 onwards, because of the abolishment of specific tax level for diesel for road transport since 2012.

This had led to a two-part revision of the Energy Balance:

1. New data on the consumption of diesel in non-road mobile machineries has been processed. As a result, the final energy consumption of gasoline and diesel in construction, services and agriculture has increased. The largest change is in construction (+10 PJ from 1990 to 2015, decreasing to 1 PJ in 2019. In agriculture, this is about 0.5 to 1.5 PJ from about 2010 and in services from 0 to 3 PJ throughout the period (see also 3.2.7.5).
2. The method for dealing with the statistical difference in the Energy Balance for diesel has been adjusted. Previously, from 2013, a statistical difference (the difference between total diesel supply based on surveys of oil companies and actual diesel sales to road transport, non-road mobile machineries and other sources) of -3 percent on an annual basis was assumed, in line with observed diesel sales to road transport (up to and including 2012) based on the specific excise duty rate for road traffic, which existed until then. In the new method, the statistical difference is set to be 0 percent from 2015. The final energy consumption of road traffic is calculated as a residual item by reducing the total market deliveries of diesel by the deliveries to other applications (mainly non-road mobile machineries).

The first and second point both have an effect on final energy consumption by road traffic, which has therefore decreased by an average of 4 to 7 percent from 2013(-0.7 to -1.2 Tg CO_2 for the years 2013-2020). The revision in the Energy Balance is shown in figure 3.13 and figure 3.14. Table 3.16 shows the impact of the recalculation on CO2-eq emissions in the Netherlands for 1990 and 2020.

Change in period 1990-2012
In the period 1990-2012 the recalculation of CO_2-emissions for non-road mobile machineries (see section 3.2.7.4) leads to an increase in national CO_2-emissions. However, the diesel consumption of road traffic has not been adjusted for this period, because it is based on a separateobservation of the diesel sales, related to the specific excise

duty rate for road transport until 2012. There was a lower rate for diesel ("rode diesel") supplied to non-road mobile machineries. Before the 2013 excise duty rate adjustment, there was a positive statistical difference, ie more supply than consumption. Due to the improved data, whereby consumption has increased, this statistical difference has become smaller and negative in a number of years.

Change in period 2013-2020
From 2013, the recalculation of CO_2-emissions for non-road mobile machineries (NRMM) also leads to an adjustment of diesel sales for road transport. Based on a monthly survey of approximately 100 oil companies, Statistics Netherlands has reliable information available on the supply side of diesel fuel since 1990 (production + import – export + stock change).The observed diesel sales for road transport (described above) up to 2012 are slightly higher than the diesel supply from this survey (reported in the Energy Balance under 'statistical difference'). In previous years, the difference between diesel supply and the observed diesel sales for road transport in 2012 was kept constant for following years.

In the recalculation, as of 2015 the supply side is leading for greenhouse gas emissions. The years 2013 and 2014 are transitional years to ensure that the data match each other properly. As a result of these adjustments, the total diesel consumption decreases (corresponding to the old statistical difference) and there was also a shift of diesel from road traffic to NRMM. Both the recalculation for non-road mobile machineries and the methodological change in energy statistics have led to a decrease in diesel consumption by road traffic from 2015 to 2020, as can be seen in Figure 3.13. Figure 3.13 shows the impact of the recalculation on total diesel consumption in the Netherlands by road and non-road mobile machineries.

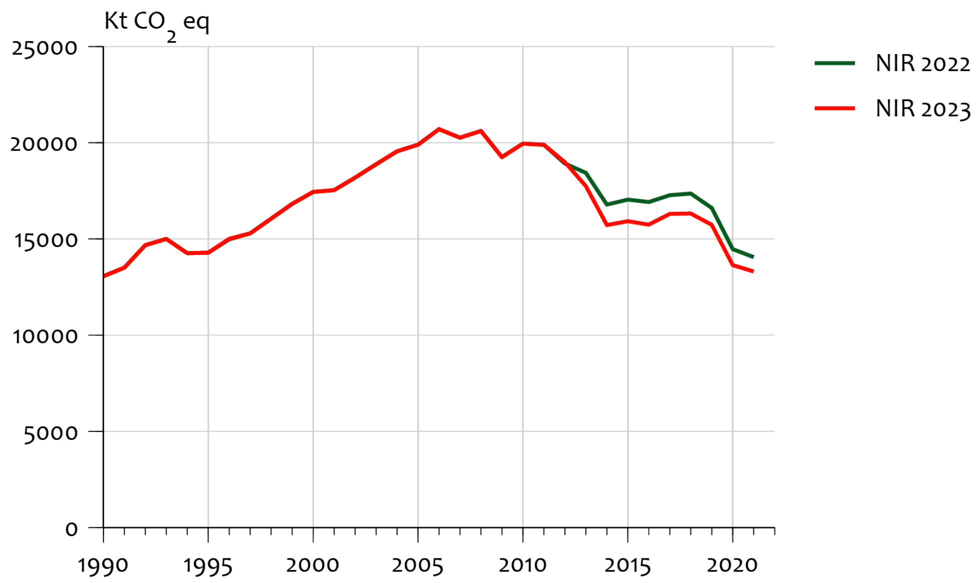

Figure 3.13 1A3b Road Transport – CO2-eq emissions from diesel in the NIR 2022 and 2023, 1990–2021.

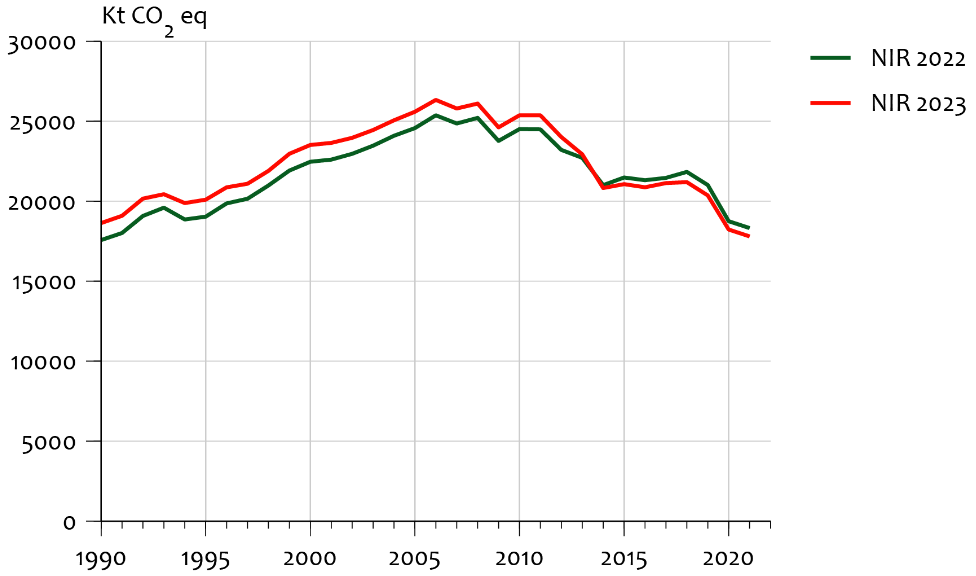

Figure 3.14 CO_2-eq emissions from diesel in the NIR 2022 and 2023, 1990–2021.

Reason for revision
Up to and including 2012, the excise duty rates for road traffic and non-road mobile machineries were different. There was a lower rate for diesel supplied to NRMM. From 2013, the excise duty rate for non-road mobile machineries became equal to the higher rate for road traffic. After the abolition of the separate rate, companies no longer made a distinction between the supply of road traffic and non-road mobile machineries. As a result, companies could no longer provide this distinction to Statistics Netherlands. From that moment on diesel consumption by road traffic was estimated for the years from 2013 onwards, based on developments in market deliveries and traffic volume, which caused an acceptable 3 percent higher consumption than supply for energy statistics. For the first years after 2012 this was a reasonable method. However in the long term, it is not tenable to assume an observation in 2012 with annual changes based on other sources. Therefore the energy balance was revised.

Adjustment of CO_2-emission factors gasoline
For the years 2017-2020 the CO_2-emission factor of gasoline was adjusted by around -1%, following new insights from Energy Statistics. This leads to a small decrease in CO_2-emissions from road transport of 0.1 Tg.

year	NIR2022 kgCO2/TJ	NIR2023 kgCO2/TJ	Change	Effect on CO2-emissions (Tg)
2017	73.023	72.300	-1.0%	-0.12
2018	73.023	72.300	-1.0%	-0.12
2019	73.023	72.200	-1.1%	-0.14
2020	73.023	72.200	-1.1%	-0.12

The activity data for gasoline use in road transport has been adjusted due to a minor revision in the energy balance. The total gasoline consumption in the Netherlands has not changed, but the allocation between NRMM and road transport shifted a little bit. The GHG emissions for road transport changed accordingly (-1.2 percent in 1990 to -0.3 percent in 2020).

Additionally, the allocation of fuel sales amongst transport modes for the period of 2018-2020 was marginally adjusted due to more accurate bottom-up calculations of fuel used.

3.2.6.6 Category-specific planned improvements

No category specific improvements are planned.

3.2.7 Other sectors (1A4)

3.2.7.1 Source category description

Table 3.17 and figure 3.13 show the subcategories and emission trends in sector 1A4.

Table 3.17 Overview of emissions in the Other sectors (1A4) in the base year and the last two years of the inventory (in Tg CO_2 equivalents).

Sector/category	Gas	1990	2020	2021	2021 vs 1990	Contribution to total in 2021 (%) by		
		Emissions in Tg CO_2 eq			%	sector	total gas	total CO_2 eq
1A4. Other sectors	CO_2	39.0	30.3	33.1	-15.1%	24.1%	22.9%	19.3%
	CH_4	0.6	1.7	1.8	183.6%	1.3%	9.5%	1.1%
	N_2O	0.0	0.0	0.0	9.2%	0.0%	0.7%	0.0%
	All	39.7	32.0	35.0	-11.8%	25.5%		20.3%
1A4a. Commercial/Institutional	CO_2	8.3	6.3	6.8	-18.7%	4.9%	4.7%	3.9%
	CH_4	0.1	0.0	0.0	-5.1%	0.0%	0.3%	0.0%
1A4a Natural gas	CO_2	7.8	5.8	6.3	-18.5%	4.6%	4.4%	3.7%
1A4b. Residential	CO_2	20.8	15.0	17.1	-17.8%	12.4%	11.8%	9.9%
	CH4	0.5	0.4	0.4	-17.6%	0.3%	2.2%	0.2%
1A4b Natural gas	CO_2	19.9	14.9	16.9	-15.0%	12.3%	11.7%	9.8%
1A4c. Agriculture/Forestry/ Fisheries	CO_2	9.8	9.0	9.3	-6.1%	6.7%	6.4%	5.4%
	CH_4	0.1	1.2	1.3	1500.5%	1.0%	7.1%	0.8%
1A4c liquids	CO_2	2.5	1.9	1.8	-27.8%	1.3%	1.3%	1.1%
1A4c Natural gas	CO_2	7.3	7.1	7.4	1.3%	5.4%	5.1%	4.3%

Sector 1A4 comprises following key categories:

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

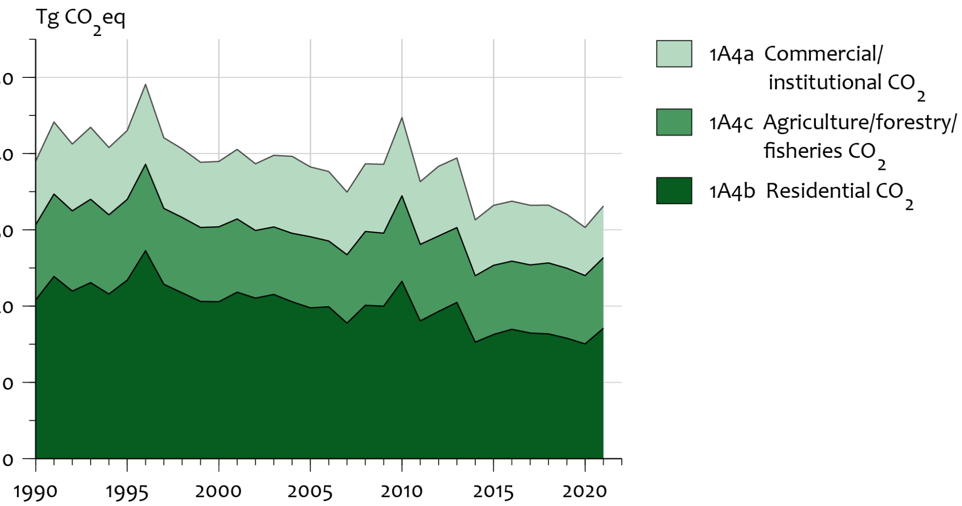

Figure 3.15 1A4 Other sectors – emissions levels of source categories, 1990–2021.

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%. The 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 while 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 1.1 PJ in 2021, 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; almost no 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 fertilization, less natural gas is combusted by the sector for producing CO_2 for crop fertilization.

The CH4 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 CH4 emissions is the result of the higher CH4 emission factor for gas engines.

GHG emissions from agricultural NRMM (1A4cii) have been relatively constant throughout the time series at 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 0.4 Tg in 2021. 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., (2023), section 2.1: Stationary combustion;
- Visschedijk et al. (2023), chapters 21 and 25: Residential wood combustion and charcoal use;
- Geilenkirchen et al., (2023), chapter 9: Non-road mobile machinery.

This section provides a brief description of the methodology applied for 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 are mainly derived from energy statistics from Statistics Netherlands. For the following emission sources, other activity data are used:

- The activity data for charcoal consumption in barbecues are based on energy statistics from Statistics Netherlands and corrected for annual meat consumption.
- The activity data for residential wood combustion are based on surveys by Statistics Netherlands (every 6 years); the results of these surveys are used to prepare a complete time series. See Visschedijk et al. (2023
-) for more details on these wood combustion statistics.
- The activity data for landfill gas are 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, 2023) indicates 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., 2023). 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 6 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 are 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 shown in Geilenkirchen et al. (2023).
- Fuel consumption by NRMM is derived from the Energy Balance, which in turn uses the output of the EMMA model (Hulskotte and Verbeek, 2009). 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. (2023).

Table 3.18 Overview of methods used for 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 2021, 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 with 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 (category 1A4) is provided in Table 3.19.

Table 3.19 Overview of IEFs used used for the most important fuels (up to 95% of fuel use) for the year 2021 in Other sectors (1A4).

Fuel	Amount of fuel used in 2021 (TJ NCV)	IEFs (g/GJ)		
		CO_2 (x 1000)	N_2O	CH_4
Natural gas	543,709	56.4	0.1	109.1
Gas/Diesel oil	29,541	72.5	0.9	2.3
Solid biomass	24,391	113.5	4.1	192.8

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 IEF 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 of gaseous fuels. This is caused by the difference in CH_4 EF used for natural gas combusted in gas engines (varying between 250 and 450 g/GJ) and the CH_4 EF used for natural gas combusted in other plants (5.7 g/GJ). Figure 3.16 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.

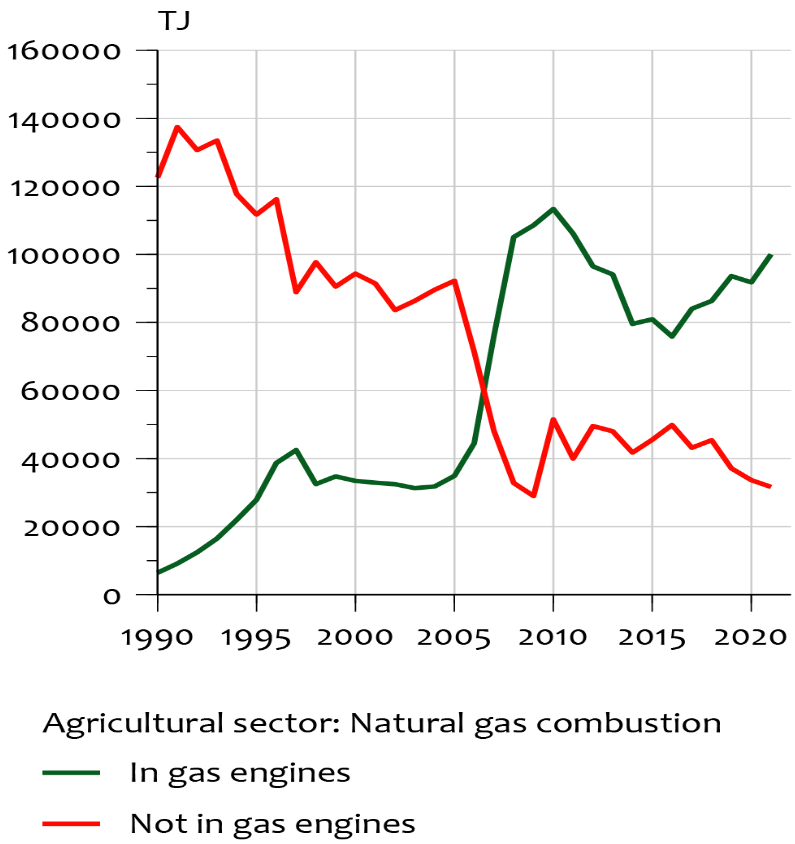

Figure 3.16 Trend in natural gas consumption in gas engines (with a relatively high emission factor) and other engines (with a relatively low emission factor) in the agricultural sector, 1990–2021.

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 for the Services and Residential category. Since the uncertainty in small values in national statistics is generally greater than for 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). For 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. (2023). 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 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 have 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. (2023).

NRMM data and model
Significant effort was invested in the past two years into checking and verification of NRMM modelling and outcomes. In 2021, a survey was held among users of mobile machinery across multiple sectors (e.g. construction, agriculture, services) which focussed on gathering data on the fleet composition (e.g. construction year, power rating, fuel types), usage (e.g. annual operating hours, typical lifespan) and fleet size. The results allowed a comparison between the composition and usage parameters of the modelled machine fleet and the machine fleet of the respondents, and led to improvements in the modelling on several points (see section 3.2.7.5.).

As of January 1st 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 allowed a further comparison with and validation of the modelled machine fleet, again leading to several substantial changes to the model, especially to the estimated machine sales for some machinery types (see section 3.2.7.5.).

An important next verification step was the comparison of the new modelled diesel usage for NRMM with a time series of 'red diesel' sales in the Netherlands between 1990 and 2012, compiled by Statistics Netherlands. Over this period, a separate 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 is now much closer to the available diesel sales statistics, going from -35% to -13% in 1990, compared to the sales statistics, and from -15% to +6% in 2000. Only for the period 2009-2011, following the economic crisis, the model appears to underestimate the effect of the crisis and overestimates the diesel usage compared to the sales statistics by 15-20%, indicating that further model improvements may be needed.

3.2.7.5 Category-specific recalculations

Stationary combustion

The energy statistics have improved, the main improvements being seen in diesel consumption in the commercial/institutional sector (1A4ai) and in the residential sector (1A4bi) for 1990-2020 and in natural gas consumption in the commercial/institutional sector (1A4ai) and the agricultural sector (1A4ci) for 2015-2020. The change in diesel consumption is further explained in the paragraph below on mobile combustion.

The changes in energy statistics (including the other small changes) resulted in the following changes in emissions (in Gg):

1A4ai	**1990**	**2005**	**2010**	**2015**	**2019**	**2020**
CO_2	-231.23	-130.26	-53.22	-89.11	-58.73	-186.96
CH_4	-0.015	-0.015	-0.009	-0.011	-0.011	-0.082
N_2O	-0.002	-0.001	-0.000	-0.000	-0.000	-0.000

1A4bi	**1990**	**2005**	**2010**	**2015**	**2019**	**2020**
CO_2	3.68	0.37	0.21	0.00	0.42	-0.00
CH_4	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

1A4ci	**1990**	**2005**	**2010**	**2015**	**2019**	**2020**
CO_2	-	-	-	-0.00	-0.00	-96.98
CH_4	-	-	-	-0.000	0.936	0.908
N_2O	-	-	-	-0.000	-0.000	-0.000

For the wood combustion in the residential sector, the emission model has been updated. In the previous version of the model, the emission model for wood combustion used the 6-year monitoring data, and interpolated the activity data for years that were not monitored. In the new emission model the interpolation now also accounts for cold/warm winters (only for wood stoves, and not for fireplaces) This resulted in the following changes in emissions in Gg:

1A4bi	**1990**	**2005**	**2010**	**2015**	**2019**	**2020**
CO2	-52.89	13.18	427.55	51.40	8.31	-63.34
CH4	-0.125	0.072	0.688	0.144	0.100	0.027
N2O	-0.002	0.000	0.015	0.002	0.000	-0.002

Non-road Mobile Machineries

Following the QA/QC and verification steps described in section 3.2.7.4., and following the availability of a national registry of NRMM in the Netherlands since 2022, a number of significant updates have been implemented into the model and the input data. The new insights have led to the following improvements in the modelling of NRMM energy use and emissions:

1. Several previously missing machine types have been added to the EMMA (Emission Model Mobile Machineries) model used to calculate fuel use and resulting emissions for NRMM. Important new additions are yard tractors, pile drivers, mobile drilling rigs,

light towers, several types of cranes, and additional types of mobile pumps and generator sets. These additions lead to significant increases in emissions and fuel use over the full time series, mostly in the construction sector (1A2gvii).

2. Based on survey data, the modelling of machine scrappage and annual operating hours has been improved. Older machines remain in the fleet for a longer period, but have their annual operating hours gradually lowered. This leads to a more accurate fleet composition when compared to survey data and information from the RDW NRMM registry.
3. Based on survey data, an update to average annual operating hours and median lifespan for several machinery types.
4. Historical machine sales data have been extrapolated further into the past, from 1986 to 1970, in order to get more realistic machine age distributions for the full 1990 – 2020 time series. This represents a major recalculation of emissions, leading to a significant increase in fuel use and emissions, especially in the beginning of the time-series (1990-2000). While there is considerable uncertainty when extrapolating back in time so many years, the new outcomes do match much better the available data on the current fleet composition (based on survey and machinery registration data), including the substantial number of machines reported with construction years before 1990, being still active in the current fleet. Furthermore, the resulting modelled diesel consumption is much closer to available statistics on diesel sales to NRMM (see section 3.2.7.4).
5. 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.
6. Engine load profiles have been updated based on new available telemetry data. The average engine load has decreased for all load profiles, typically leading to reduced fuel consumption and emission per operating hour.
7. The calculation of fuel use and CO_2 emissions has been updated based on an experimentally derived formula (using a Willans line) that takes into account the construction year, rated power, fuel type, annual operating hours, and average engine load of mobile machines.
8. Electric machinery types have been introduced into the model, replacing some of the sales of traditional machinery in recent years.
9. The previously separate emission calculation for container handling machinery has been implemented into the EMMA model to improve consistency.
10. The fuel consumption and emissions from LPG-powered NRMM (e.g. forklifts) in the industry and construction sector (1A2gvii) has been partly reallocated to the Commercial/institutional sector (1A4aii).
11. The branch organisation for (agricultural) contractors in the Netherlands, CUMELA, has provided an updated time series for the estimated diesel consumption of agricultural contractors in the Netherlands between 2006 and 2021, leading to an increased diesel consumption in category 1A4cii.

The changes that are described above together result in a substantial increase of fuel use and emissions for all NRMM sectors (1A2gvii, 1A4aii, 1A4bii and 1A4cii) over the full time-series, with the largest increase in the beginning of the time-series (related to point 4 above) (+1.2 Tg CO_2) and a smaller increase for recent years (+0.3 Tg CO_2). For the years 1990-2012 this leads to an increase of total CO_2 emissions in the Netherlands, for 2013-2020 the increase for NRMM diesel use leads to less diesel consumption in road transport (see also the explanation in 3.2.6.5).

The model updates and results have been discussed with numerous stakeholders and experts, and were broadly concluded to be more realistic than the previous reporting, and better match independently gathered data on diesel sales to NRMM.

3.2.7.6 Category-specific planned improvements

No category-specific improvements for stationary combustion are 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 will likely lead to further updates and model improvements in the NRMM calculation. Furthermore, as the comparison with historical diesel sales (see section 3.2.7.4.) indicated that the model may underestimate the effect of the economic crisis on NRMM activity in the period after 2008 (2009 – 2011), this will be analysed in more detail to see whether model improvements are possible.

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 3.20. This sector has no key categories.

Table 3.20 Overview of emissions in the sector Other (1A5) in the base year and the last two years of the inventory (in Tg CO_2 eq.).

Sector/category	Gas	1990	2020	2021	2021 vs 1990	Contribution to total in 2021 (%) by		
		Emissions in Tg CO_2 eq			%	sector	total gas	total CO_2 eq
1A5 Other	CO_2	0.3	0.2	0.2	-47.6%	0.1%	0.1%	0.1%
	CH_4	0.0	0.0	0.0	-52.0%	0.0%	0.0%	0.0%
	N_2O	0.0	0.0	0.0	-51.6%	0.0%	0.0%	0.0%
	All	0.3	0.2	0.2	-47.7%	0.1%		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 are derived from the National Energy Statistics and include 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

3.21. 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 3.21 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 2021 (Gg)	164	0.01	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 in 2014-2020 and for military aviation in 2015-2020. This resulted in the following changes in emissions (in Gg):

1A5b	2014	2015	2016	2017	2018	2019	2020
CO_2	7.42	0.00	0.00	0.00	0.00	-0.00	0.01
CH_4	0.001	0.000	0.000	0.000	0.000	-0.000	0.000
N_2O	0.001	0.000	0.000	0.000	0.000	-0.000	0.000

3.2.8.6 Category-specific planned improvements

No category-specific improvements are 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).

Following categories are key categories:

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

Table 3.22 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 2021.

Table 3.22 Overview of emissions in the Fugitive emissions from fuels sector (1B) in the base year and the last two years of the inventory (in Tg CO_2 eq.).

Sector/category	Gas	1990	2020	2021	2021 vs 1990	Contribution to total in 2021 (%) by		
		Emissions in Tg CO_2 eq			%	sector	total gas	total CO_2 eq
1B Fugitive emissions from fuels	CO_2	0.9	0.9	1.1	26.9%	0.8%	0.8%	0.7%
	CH_4	2.2	0.5	0.4	-80.8%	0.3%	2.2%	0.2%
	All	3.1	1.4	1.5	-49.7%	1.1%		0.9%
1B1. Solid fuels transformation	CO_2	0.1	0.1	0.1	-35.5%	0.1%	0.0%	0.0%
	CH_4	0.0	0.0	0.0	-57.4%	0.0%	0.0%	0.0%
1B2. Oil and Natural Gas and Other Emissions from Energy Productions	CO_2	0.8	0.9	1.1	35.7%	0.8%	0.7%	0.6%
	CH_4	2.2	0.5	0.4	-80.9%	0.3%	2.2%	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 over 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 share of the market 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 paragraph 2.2.3.1 of the annex 'Methodology Report on the Calculation of Emissions to Air from the Sectors Energy, Industry and Waste' in Honig et al., (2023).

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. Until this submission, the figures for emissions from transformation losses were 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 with 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 'Methodology Report on the Calculation of Emissions to Air from the Sectors Energy, Industry and Waste' in Honig et al., (2023).

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 CH4 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 made.

3.3.1.6 Category-specific planned improvements
No improvements are 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 pipelines for oil 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 CH4 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 were 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 as ‘not applicable’ (NA) and activity data as ‘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 stabilized 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., 2023).

The IEF for gas distribution gradually decreases 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 paragraph 3.3.2.2.

Since the 1990's, CO_2 and CH_4 emissions from oil and gas production, particularly fromflaring 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 emissions from Oil and gas exploration, production and processing, and 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 are taken 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 statistical 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, with detailed information on pipeline length per material. A 5-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 taken from the Methane Emission from Gas Distribution (*Methaanemissie door Gasdistributie*) annual report, commissioned by Netbeheer Nederland (Association of Energy Network Operators in the Netherlands) and compiled by KIWA (KIWA, multiple years). In the KIWA reports the CH_4 emissions in m^3 are calculated using a bottom-up method which 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 the small base of 7 measurements at one pressure level of leakage per hour for grey cast iron, and for 18 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 40 additional 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 led to a reduction in the calculated emissions of CH_4 for the period 1990–2014.

Oil and gas transmission
Emissions of CO_2 and CH_4 due to the transmission of natural gas (1B2b4) are taken from the VG&M ("*safety, health and environment*") part of the annual report of NV Nederlandse Gasunie. The emissions of CO_2 given in the annual reports are considered to be combustion emissions and 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, taken 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 the LDAR (Leak Detection and Repair) programme of Gasunie, new emissions data for CH_4 became available. Leakages at larger locations such as the 13 compressor stations were all fully measured. In addition, fugitive emissions of methane from each of those locations were added to the emissions 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 of those locations and added for the whole time series. These improvements were implemented for all submissions from the NIR 2016 onwards

The emissions of CO2 and CH4 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., 2023. 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 'Methodology Report on the Calculation of Emissions to Air from the Sectors Energy, Industry and Waste'; Honig et al., (2023).

3.3.2.3 Uncertainty and time series consistency

The uncertainty for flaring is 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 different 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, 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 made.

3.3.2.6 Category-specific planned improvements

No planned improvements.

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 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 different types of usage. The amount captured in 2020 was small; 1 Gg of CO_2 (fossil and biogenic) was captured and used in the production of bicarbonate. In 2021 no amount of captured CO_2 was used to produce bicarbonate. More information is included in section 7.4.

4 Industrial processes and product use (CRF sector 2)

Major changes in the Industrial processes and product use (IPPU) sector compared with the National Inventory Report 2022	
Emissions:	The total GHG emissions of the IPPU sector show a decrease (rounded from 9.0 Tg CO_2 eq. in 2020 to 8.8 Tg CO_2 eq. in 2021). This was the result of a decrease in primarily CO_2 emissions (c. -0.2 Tg)and N_2O emissions (c. -0.2 Tg CO_2 eq
New Key categories:	2B7 Soda ash production CO_2 2C3 Aluminium production CO_2
No longer a key category:	2B4 Caprolactam production N_2O 2A2 Lime production CO_2
Methodologies:	

4.1 Overview of 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 show the trends in total GHG emissions from the IPPU sector.

In 2021, IPPU contributed 4.8% to the total national GHG emissions (including LULUCF since this submission) in comparison with 8.9% in 1990. The sector is a major source of N_2O emissions, accounting for 13.4% of total national N_2O emissions in 2021; of which the major share (0.9 Tg CO_2 eq., or 12.5% of total N_2O emissions) comes 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 (in Tg CO_2 eq.).

Sector/category	Gas	1990	2020	2021	2021 vs 1990	Contribution to total in 2021 (%) by		
		Emissions in Tg CO_2 eq			%	sector	total gas	total CO_2 eq
2. Total Industrial Processes	CO_2	6.3	5.7	5.5	-11.9%	66.6%	3.8%	3.2%
	CH_4	0.4	0.4	0.4	14.4%	5.0%	2.2%	0.2%
	N_2O	6.5	1.2	1.0	-85.0%	11.8%	13.4%	0.6%
	HFC	4.7	1.1	1.2	-75.0%	14.2%	100.0%	0.7%
	PFC	2.4	0.1	0.1	-96.7%	1.0%	100.0%	0.0%
	SF_6	0.2	0.1	0.1	-41.9%	1.5%	100.0%	0.1%
	All	20.4	8.6	8.3	-59.5%	100.0%		4.8%
2A. Mineral industry	CO_2	1.4	1.1	1.1	-19.7%	13.7%	0.8%	0.7%
2B. Chemical industry	CO_2	4.1	4.2	3.9	-6.6%	46.6%	2.7%	2.2%
	CH_4	0.3	0.4	0.4	18.6%	4.3%	1.9%	0.2%
	N_2O	6.3	1.1	0.9	-85.6%	10.9%	12.5%	0.5%
	HFC	4.7	0.1	0.2	-94.8%	3.0%	20.9%	0.1%
	PFC	0.0	0.01	0.02		0.3%	27.4%	0.0%
	All	15.4	5.7	5.4	-65.1%	65.1%		3.1%
2C. Metal Production	CO_2	0.5	0.1	0.2	-63.4%	2.0%	0.1%	0.1%
	PFC	2.4	0.02	0.01	-99.4%	0.2%	18.3%	0.0%
	All	2.8	0.2	0.2	-93.6%	2.2%		0.1%
2D. Non-energy products from fuels and solvent use	CO_2	0.2	0.3	0.3	81.5%	4.1%	0.2%	0.2%
	CH_4	0.0	0.0	0.0	108.0%	0.0%	0.0%	0.0%
	All	0.2	0.3	0.3	81.5%	4.1%		0.2%
2E. Integrated circuit or semiconductor	PFC	0.02	0.03	0.04	84.1%	0.5%	54.4%	0.0%
2F. Product uses as substitutes for ODS	HFC	NO	1.0	0.9		11.2%	79.1%	0.5%
2G. Other	CO_2	0.0	0.0	0.0	-25.8%	0.0%	0.0%	0.0%
	CH_4	0.1	0.1	0.1	-7.5%	0.6%	0.3%	0.0%
	N_2O	0.2	0.1	0.1	-64.8%	0.9%	1.0%	0.0%
	SF_6	0.21	0.13	0.12	-41.9%	1.5%	10.6%	0.1%
	All	0.5	0.3	0.2	-47.4%	1.5%		0.1%
2H. Other process emissions	CO_2	0.1	0.0	0.0	-79.4%	0.2%	0.0%	0.0%
Indirect CO2 emissions	CO_2	0.9	0.4	0.4	-54.3%	5.1%	0.3%	0.2%
	CO_2	169.4	140.9	144.4				

Sector/category	Gas	1990	2020	2021	2021 vs 1990	Contribution to total in 2021 (%) by		
		Emissions in Tg CO_2 eq			%	sector	total gas	total CO_2 eq
National Total GHG emissions (incl. CO_2 LULUCF)	CH_4	36.0	19.2	19.0				
	N_2O	16.2	7.5	7.2				
	HFCs	4.7	1.1	1.2				
	PFCs	2.4	0.1	0.1				
	SF_6	0.2	0.1	0.1				
	All	228.9	168.9	172.0				

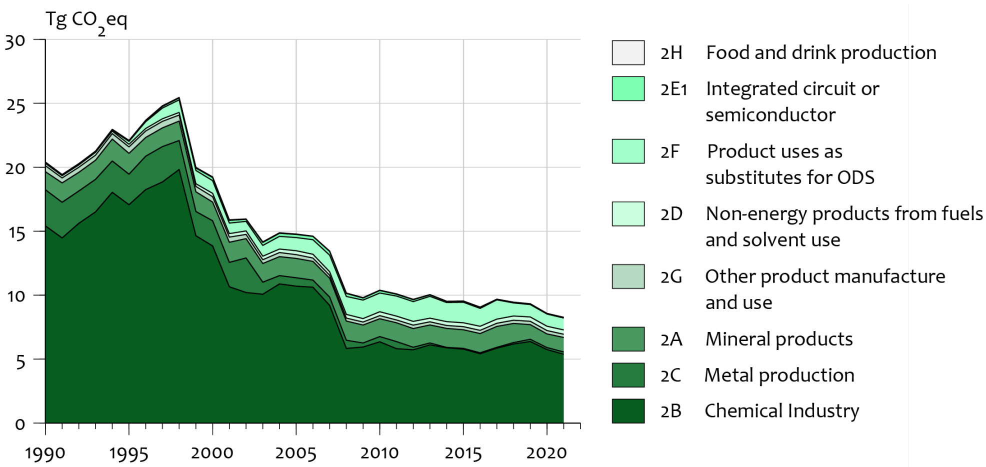

Figure 4.1 Sector 2 Industrial processes and product use – trend and emissions levels of source categories, 1990–2021.

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, total emissions are reported according to 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, as the ENINA Task Force has direct access to it. ENINA can also provide this information to official review teams after they have signed a confidentiality agreement.

For transparency and consistency reasons, GHG emissions from fuel combustion in industrial activities and product use are all reported in the Energy sector and all non-energy-related emissions from industrial activities (including those from feedstocks) in the IPPU sector. We acknowledge that this is not in line with the 2006 IPCC Guidelines but for national policy reasons (the requirement for a clear division between combustion and process emissions) there is a need to keep the current allocation. CO_2 from ammonia production (2B1) is an exception to this: both combustion and feedstock emissions are reported under 2B1.

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.

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).

Table 4.2 Overview of the sector Mineral Industry (2A), in the base year and the last two years of the inventory (in Tg CO_2 eq.).

Sector/category	Gas	1990	2020	2021	2021 vs 1990	Contribution to total in 2021 (%) 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	-19.7%	12.9%	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	11.1%	2.1%	0.1%	0.1%
2A3. Glass production	CO_2	0.1	0.1	0.1	-52.3%	0.8%	0.0%	0.0%
2A4a Ceramics	CO_2	0.1	0.1	0.1	-9.7%	1.4%	0.1%	0.1%
2A4b Other uses of Soda Ash	CO_2	0.1	0.1	0.1	75.6%	1.4%	0.1%	0.1%
2A4d Other	CO_2	0.5	0.6	0.6	32.4%	7.3%	0.4%	0.4%

Sector 2A comprises the following key categories:

2A1	Cement production	CO_2
2A4d	Other	CO_2

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 Honig et al., (2023).

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., 2023). Process emission data therefore were taken from the company's AER until 2020, as the company closed in June of that year. Since no cement production occurs after that year, NO is reported from emission year 2021 on.

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 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., 2023. From the 2015 submission onwards, the CO_2 figures are 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 are obtained from the ceramics trade organisation.

cc = default carbonate content of clay (0.1) 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 figure of 400 kton as a basis, then adding the import figures and deducting the export figures for the relevant year. For 1990–2000 and 2003 onwards, these figures were estimated by extrapolating from 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 3 components. CO_2 emissions are based on:
- *consumption of limestone for flue gas desulphurization (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 have been used to calculate CO_2 emissions for the period 1990–2000, CO_2 emissions were 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) (*CO2 emissions from the use of limestone and dolomite and from the use of other substances in the glass production sector are included in 2A3 - Glass production).

From 2000 onwards, data reported in the AERs of Tata Steel have been used to calculate CO_2 emissions from limestone and dolomite use in iron and steel production. For the period 1990–2000, CO_2 emissions were 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. The emissions are calculated using the IPCC default EF (limestone use: EF = 0.440 t/t; dolomite use: EF = 0.477 t/t).

CO_2 emissions from the use of limestone and dolomite and from the use of other substances in the glass production sector are included in 2A3 (Glass production).

4.2.3 Uncertainty and time series consistency

Uncertainty
The Approach 1 uncertainty analysis outlined in Annex 2 and shown in Table A2.4 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 other 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, though for ceramics (2A4a) and lime production (2A2) the activity data are also relatively uncertain; 50% and 75%, respectively.

The uncertainties of the IPCC default EFs used for some processes are not assessed. As these are minor sources of CO_2, however, 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 were made.

4.2.6 *Category-specific planned improvements*
- Although category 2A4b is only a minor contributor to the national total (0.1%) and appears to be below threshold (when taking into consideration consideration the necessary subtraction detailed below), the Netherlands has investigated possibilities to report in which chemical industries (excluding paper industry) soda ash is used. Related to this it is reported in the Methodology report (Honig et al., 2023), section 2.2.3.2 that in order to prevent double input (because soda ash is also used in glass production) the CO_2 emissions from soda ash usage for glass production should be subtracted from the total, because these are reported integrally. However, this procedure has not been implemented in the figures delivered so far, due to lack of data and because the small amount of CO_2 emissions and considerable margin of uncertainty associated with soda ash use. Half of the calculated 2A4b emissions stem from the glass industry, making the other contribution even less.
- As result of a review question it was investigated whether a split could be made between combustion and process emissions for mineral wool production (2A4). These process emissions amount to 20 Gg, which is below the threshold of significance, therefore it was decided not to report separately.

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 into 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. Until 2010, three companies, each with two HNO_3 production plants, were responsible for the N_2O emissions from nitric acid production in the Netherlands. Two plants of one company were closed in 2010 and one of these was taken over by one of the other companies. Since then, two companies, one with three and one with two HNO_3 production plants, 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 since 1952 has been manufactured by one company. This emission source is therefore 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 produced mainly 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.

Remarks:
- Adapic acid (2B3), glyoxal (2B4b), glyoxylic acid (2B4c) and calcium carbide (2B5b) are not produced in the Netherlands. As such the Netherlands does not report these emissions in the CRF under 2B4.
- CO_2 emissions resulting from the use of fossil fuels as feedstocks for the production of silicon carbide, carbon black, ethylene and methanol are included in the Energy sector (1A2c; see section 3.2.7 for details) because there is no information for splitting combustion and process emissions.
- Many processes related 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 6.7% of total national GHG emissions (including LULUCF) in 1990 and 3.1% in 2021.

Table 4.3 Overview of the sector Chemical industry (2B), in the base year and the last two years of the inventory (in Tg CO_2 eq.).

Sector/category	Gas	1990	2020	2021	2021 vs 1990	Contribution to total in 2021 (%) by		
		Emissions in Tg CO_2 eq			%	sector	total gas	total CO_2 eq
2B. Chemical industry	CO_2	4.1	4.2	3.9	-6.6%	44.0%	2.7%	2.2%
	CH_4	0.3	0.4	0.4	18.6%	4.1%	1.9%	0.2%
	N_2O	6.3	1.1	0.9	-85.6%	10.3%	12.5%	0.5%
	HFC	4.7	0.1	0.2	-94.8%	2.8%	20.9%	0.1%
	PFC	0.0	0.0	0.0		0.2%	27.4%	0.0%
	All	15.4	5.7	5.4	-65.1%	61.4%		3.1%
2B1. Ammonia production	CO_2	2.7	2.2	2.1	-20.9%	24.3%	1.5%	1.2%
2B2. Nitric acid production	N_2O	5.4	0.2	0.2	-96.7%	2.0%	2.5%	0.1%
2B4. Caprolactam production	N_2O	0.7	0.5	0.4	-44.2%	4.2%	5.1%	0.2%

Sector/category	Gas	1990	2020	2021	2021 vs 1990	Contribution to total in 2021 (%) by		
		Emissions in Tg CO_2 eq			%	sector	total gas	total CO_2 eq
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	0.6	65.8%	6.3%	0.4%	0.3%
	CH_4	0.3	0.4	0.4	18.6%	4.1%	1.9%	0.2%
2B9. Fluorochemical production	HFC	4.7	0.1	0.2	-94.8%	2.8%	20.9%	0.1%
	PFC	NO	0.0	0.0		0.2%	27.4%	0.0%
2B10. Other chemical industry	CO_2	1.0	1.4	1.2	12.7%	13.3%	0.8%	0.7%

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
2D2	Paraffin wax use	CO_2

Figure 4.2 shows the trend in CO_2-equivalent emissions for category 2B (Chemical industry) in the period 1990–2021.

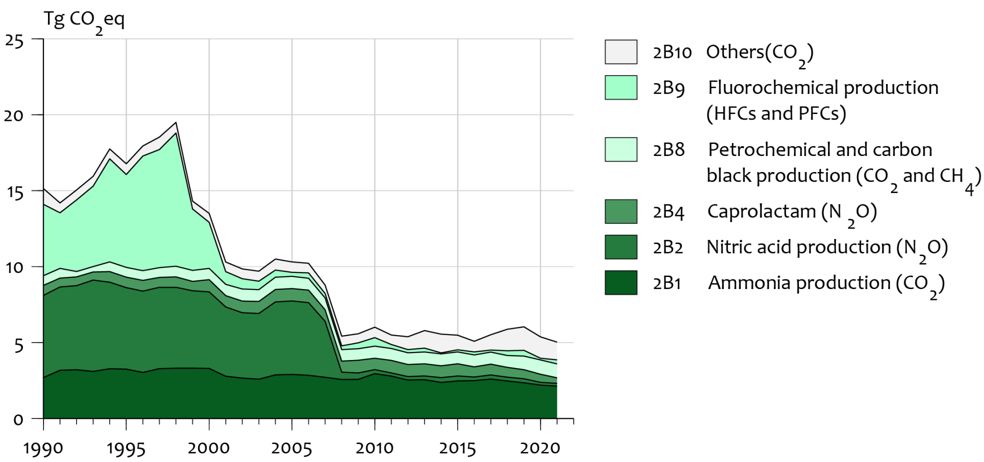

Figure 4.2 2B Chemical industry – trend and emissions levels of source categories, 1990–2021.

Mainly due to a reduction in HFC-23 emissions from HCFC-22 production, total GHG emissions from 2B (Chemical industry) decreased between 1990 - 2001. N_2O emissions remained fairly stable between 1990 – 2000, a period with no policy aimed at controlling these emissions. Between 2001 - 2007, total GHG emissions from 2B also remained stable. As figure 4.2 above and table 4.4 below show, the main decrease took place in 2008 as a result of a reduction in N_2O emissions from the production of nitric acid. From 2008 onwards, this process was 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	217	6286
1991	5486	584	217	629
1992	5538	576	221	6336
1993	6016	532	218	6766
1994	5698	697	231	6626
1995	5367	691	238	630
1996	535	706	246	630
1997	535	652	253	6258
1998	533	688	261	6276
1999	5096	614	268	5979
2000	504	803	275	6120
2001	4565	741	282	5588
2002	4301	770	289	5360
2003	4325	791	296	5414
2004	48	819	304	5925
2005	484	815	311	5964
2006	478	823	318	5926
2007	3680	766	325	4772
2008	477	731	333	1541
2009	421	837	340	1597
2010	258	752	347	1357
2011	208	823	324	1355
2012	226	796	345	1366
2013	244	799	327	1369
2014	317	777	336	1429
2015	329	802	299	1431
2016	240	671	338	1249
2017	266	713	344	1324
2018	251	646	306	1202
2019	264	600	340	1203
2020	178	534	376	1088
2021	180	367	356	903

Nitric acid production (2B2)

Technical measures (optimising the platinum-based catalytic converter alloys) implemented at one of the nitric acid plants in 2001 resulted in an emissions reduction of 9% compared with 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 with 2006. In 2008, the full effect of the measures was reflected in lower emissions; a reduction of 90% compared with 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 (like the NIR 2020), all significant reduction measures for N_2O emissions from nitric acid production in 2007 and 2008 are described, with details per plant.

Caprolactam production (2B4a) and Acrylonitrile production (2B8e)

In 2021, as a result of government funding a reduction measure was implemented in the caprolactam production plant, 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 shows the trend in HFC emissions from the categories HCFC-22 production and HFCs/PFCs from handling activities during the period 1990–2021. Emissions of HFC-23 increased by approximately 35% in the period 1995–1998 due to increased production of HCFC-22. However, in the period 1998–2000 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 production level is the secondary factor influencing the variation in emission levels between 2000–2008.

Due to the economic crisis, HCFC-22 production levels were much lower in the last quarter of 2008 and through 2009 resulting in lower HFC-23 emissions in both 2008 and 2009. 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 period 1992–2021 can be explained by the large fluctuations in handling activities which depend on the 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/PFCs	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	55	263
2006	297	57	355
2007	257	37	294
2008	225	23	247
2009	163	223	386
2010	414	146	560
2011	176	83	259
2012	133	75	208
2013	199	54	253
2014	38	27	65
2015	99	42	141
2016	133	68	200
2017	85	48	133
2018	186	128	314
2019	229	151	379
2020	81	30	112
2021	216	51	266

4.3.2 *Methodological issues*

For all chemical industry source categories, the methodologies used to estimate GHG emissions comply with the 2006 IPCC Guidelines, volume 3, as described in Honig et al. (2023: sections 2.2.3.1 to 2.2.3.6).

Country-specific methodologies are used for CO_2 process emissions from the chemical industry. The main characteristics are:

- 2B1 (Ammonia production): A method equivalent to IPCC Tier 3 is used to calculate CO_2 emissions from ammonia production in the Netherlands. The calculation is based on the consumption of natural gas and a country-specific EF. Data on the use of natural gas are obtained from Statistics Netherlands. Because there are only two ammonia producers in the Netherlands, the consumption of natural gas and the country-specific EF are confidential.
  Furthermore, according to the Guidelines, CO_2 stored in urea is subtracted from the production emissions. Emissions occurring in the sectors where urea is applied (agriculture, car-SCR, melamine

production), are allocated to those sectors. The CO_2 stored in urea is calculated by using production figures. As the Netherlands is a net exporter of fertilisers, the by far largest amount of the stored CO_2 is exported and emitted elsewhere by application. (CO_2 emission from melamine production is allocated to CRF category 2B8g.)
The 2B1 emissions in the Netherlands are covered by the EU-ETS. For ETS, the CO_2-storage 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 period 1990–1998 are not available, therefore these EFs were used to recalculate emissions for the period 1990–1998.
- 2B4a (Caprolactam production): From 2015 onwards, N_2O emissions are taken 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. (2023), 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' was included in the CRF tables from 2010 onwards, as soda ash production has stopped. See (Honig et al., 2023) 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 are based on measurements. For the periods 1990–1994 and 2010–2016, the emissions were recalculated with the help of the 2017 emission and production levels and the production levels in both periods. Emissions for the period 1995–2009 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 on, 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 and 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 taken from the company's AER. By this company, the HFC-23 load in the untreated flow is determined 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 taken from the company's AER.
- 2B10 (Other): Because no IPCC methodologies exist for these processes (and the 2019 Refinement-methodology for H2 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 a storage factor approach was incorrect. These ETS reports have recently been re-examined leading to a recalculation for this submission of the timeseries 1990-2018. More specifically, this resulted in a recalculation of emissions from 1990 to 2012, and 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, based on 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 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 have been obtained from the AERs and the emissions were 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 are available. Therefore, emissions for the period 1990–2003 are kept equal to those of 2004. Emissions for the period 2005–2012 have been determined by extrapolation between 2004 and 2013.

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

4.3.3 *Uncertainty and time series consistency*

Uncertainty

The Approach 1 uncertainty analysis outlined in Annex 2 (shown 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 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%, respectively).

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 emissions data for acrylonitrile production, thereby introducing further uncertainties for the period 1995–2009.

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 are included in the EU-ETS. For this purpose, the companies developed monitoring plans approved by the NEA (Dutch emission authority). In 2018, the companies' emissions reports (2017 emissions) were independently verified and submitted to the NEA where they were compared to 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 on the Chemelot industrial zone. Chemelot only reports emissions of the total estate to the ETS, not from individual companies. Therefore for this smaller producer no comparison could be made.

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.

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

4.3.5 Category-specific recalculations
No category specific recalculations were made.

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

4.4 Metal production (2C)

4.4.1 Source category description
The national inventory of the Netherlands includes emissions of GHGs 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 at the end of 2011) and Aldel (closed at 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.
  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 feroalloys.;
- 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 4.7 provides an overview of emissions, by proportion of the main source categories.

Table 4.7 Overview of the sector Metal production (2C), in the base year and the last two years of the inventory (in Tg CO_2 eq.).

Sector/category	Gas	1990	2020	2021	2021 vs 1990	Contribution to total in 2021 (%) by		
		Emissions in Tg CO_2 eq			%	sector	total gas	total CO_2 eq
2C. Metal Production	CO_2	0.45	0.13	0.17	-63.4%	1.9%	0.1%	0.1%
	PFC	2.37	0.02	0.01	-99.4%	0.2%	18.3%	0.0%
	All	2.83	0.16	0.18	-93.6%	2.1%	0.0%	0.1%
2C1. Iron and steel production	CO_2	0.04	0.02	0.08	90.9%	1.0%	0.1%	0.0%
2C3. Aluminium production	CO_2	0.41	0.11	0.08	-79.9%	0.9%	0.1%	0.0%
	PFC	2.37	0.02	0.01	-99.4%	0.2%	18.3%	0.0%

This sector comprises 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) decreased sharply because reduction measures (side feed to point feed) were taken (see Table 4.8). From then on, emissions depended mainly on the number of anode effects, and little on production level. PFC emissions decreased further after 2011 as a result of the closures of Zalcoand Aldel. The restart (under the name Klesch Aluminium Delfzijl, and Damco since 2017) resulted in increases in PFC emissions from 2015 on.

Table 4.8 Emissions of CF_4 and C_2F_6 from Aluminium production (2C3) (Gg CO_2 eq.).

Year	PFC14 (CF_4)	PFC116 (C_2F_6)	Total
1990	1839	535	1839
1991	1825	525	1825
1992	1659	474	1659
1993	1683	472	1683
1994	1614	453	1614
1995	1566	441	1566
1996	1745	474	1745
1997	1865	500	1865
1998	1372	446	1372
1999	1017	394	1017
2000	1066	413	1066
2001	1018	395	1018
2002	1565	642	1565
2003	349	117	349
2004	89	22	89
2005	74	18	74

Year	PFC14 (CF_4)	PFC116 (C_2F_6)	Total
2006	51	12	51
2007	82	19	82
2008	60	15	60
2009	36	9	36
2010	51	10	51
2011	71	15	71
2012	13	3	13
2013	8	2	8
2014	0	0	0
2015	5	1	5
2016	10	2	10
2017	10	2	10
2018	17	3	17
2019	20	4	20
2020	20	4	20
2021	12	2	12

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. (2023: 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 emissions 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 – from, amongst other things, the conversion of pig iron to steel – are also obtained from the C mass balance.

For the period 1990–2000, CO_2 emissions have been calculated by multiplying the average IEF (8.3 kg CO_2 per ton of crude steel produced) over the 2000–2003 period by the yearly crude steel production. From 2000 onwards, data reported in the C mass balance of Tata Steel have 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 (2020 submission), the CO_2 figure was directly taken 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 complete period 1990–2017. EFs are plant-specific and confidential and are based on measured data. From emission year 2018 onwards, the emission data has been taken from the ETS reports.

4.4.3 *Uncertainty and time series consistency*

Uncertainty

The Approach 1 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% for both 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%, with that of PFC from aluminium production at slightly over 40%.

Time series consistency

A consistent methodology has been used throughout the 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 of the AERs were 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*

- No category specific recalculations were made.

4.4.6 *Category-specific planned improvements*

As a result of the 2021 review (question I.24), it was planned to perform CH_4 process emission calculations from sinter production for this submission. We did not succeed in this because of lack of time, and made 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 4.9 presents an overview of emissions related to three sources in this category. 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.

CO_2 emissions from paraffin wax use (2D2) are identified as an Approach 2 level and trend key category in this category (see Annex 1).

Table 4.9 Overview of the sector Non-energy products from fuels and solvents use (2D), in the base year and the last two years of the inventory (in Tg CO_2 eq.).

Sector/category	Gas	1990	2020	2021	2021 vs 1990	Contribution to total in 2021 (%) 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	81.5%	3.9%	0.2%	0.2%
	CH_4	0.0	0.0	0.0	108.0%	0.0%	0.0%	0.0%
	All	0.2	0.3	0.3	81.5%	3.9%	0.0%	0.2%
2D1. Lubricant use	CO_2	0.1	0.1	0.1	8.9%	1.0%	0.1%	0.1%
2D2. Paraffin wax use	CO_2	0.1	0.2	0.2	108.0%	2.4%	0.1%	0.1%
2D3. Other non specified	CO_2	NO	0.03	0.03		0.4%	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 2021. CO_2 emissions from Urea use in diesel vehicles (2D3) increased from 0 to 30 kton between 2005-2021.

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., (2023), 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, ODU factors of 20% and 100% respectively have been used. CO_2 emissions from urea-based catalysts are estimated with a Tier 3 methodology using country-specific CO_2 EFs for different vehicle types. More detailed descriptions of the method and EFs used can be found in Geilenkirchen et al., (2023).

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

4.5.3 *Uncertainty and time series consistency*

Uncertainty

The Approach 1 uncertainty analysis outlined in Annex 2 and shown in Tables A2.1 and A2.2 provides estimates of the uncertainties by 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%; this leads to 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 over 100%.

Time series consistency
Consistent methodologies and activity data have been used to estimate emissions from these sources.

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
Since this submission, CO_2 emissions from urea use in cathalytic reduction in passenger cars are calculated, resulting in an increase over the whole series.

4.5.6 Category-specific planned improvements
No improvements are 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 thereforenot identified in the inventory.

Overview of shares and trends in emissions
The contribution of F-gas emissions from category 2E to the total national inventory of F-gas emissions was 0.01% in 1990 and 54.4% in 2021. The latter figure corresponds to 0.04 Tg CO_2 eq. and accounts for 0.03% of the national total GHG emissions in 2021 (Table 4.10).

Table 4.10 Overview of the sector Integrated circuit or semiconductor (2E) in the base year and the last two years of the inventory (in Tg CO_2 eq.).

Sector/category	Gas	1990	2020	2021	2021 vs 1990	Contribution to total in 2021 (%) by		
		Emissions in Gg CO_2 eq			%	sector	total gas	total CO_2 eq
2E1. Integrated circuit or semiconductor	PFC	23	31	43	84.1%	0.5%	54.4%	0.0%

This sector comprises no key categories.

Due to an increasing production level in the semiconductor manufacturing industry, PFC emissions increased from 25 Gg CO_2 eq. in the base year to

305 Gg CO_2 eq. in 2007. The decrease after 2007 was mainly caused by an intensive PFC (incl. NF_3) reduction scheme (see Table 4.11).

Table 4.11 Emissions trend from the use of PFCs (incl. NF_3) in Electronics industry (2E1)
(Gg CO_2 eq.).

	'90	**'95**	**'00**	**'05**	**'07**	**'08**	**'09**	**'10**	**'15**	**'18**	**'19**	**'20**	**'21**
PFCs	23	45	236	230	277	218	153	186	77	39	39	28	36

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., (2023), section 2.2.3.8.

Activity data on the use of PFCs in semiconductor manufacture were 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., 2023).

4.6.3 *Uncertainty and time series consistency*
Uncertainty
The Approach 1 uncertainty analysis outlined in Annex 2 provides estimates of the uncertainties per IPCC source category. The uncertainty in 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.

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 were no category specific recalculations.

4.6.6 *Category-specific planned improvements*
No improvements are 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.

In the Netherlands, many processes related 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 of F-gas emissions from category 2F to the national total of F-gas emissions was 0% in 1990 and 79.1% in 2021. This corresponds to 0.93 Tg CO_2 eq. and accounts for 0.5% of the national total GHG emissions in 2021 (see Table 4.12).

Table 4.12 Overview of the sector Product use as substitutes for ODS (2F) in the base year and the last two years of the inventory (in Tg CO_2 eq.).

Sector/category	Gas	1990	2020	2021	2021 vs 1990	Contribution to total in 2021 (%) by		
		Emissions in Tg CO_2 eq			%	sector	total gas	total CO_2 eq
2F. Product uses as substitutes for ODS	HFC	NO	0.96	0.93		10.6%	79.1%	0.5%
2F1. Stationary refrigeration and Mobile air-conditioning	HFC	0.0	0.82	0.80		9.1%	68.0%	0.5%
2F6. Other	HFC	0.0	0.13	0.13		1.5%	11.1%	0.1%

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

Starting in the 2019 submission, the calculation method (via a stock model) for Stationary refrigeration (2F1) was replaced. The new method uses 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 2019 because, due to delays in reporting, this is the most recent year for which emissions data are available. Due to the phasing-out of refrigerants with a high GWP, emissions decreased from 1.053 Tg in 2015 to 0.520 Tg in 2019 (see Table 4.13). 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 2020 and 2021 were kept equal to 2019.

With the new method, emission figures are available for:
- 4 sectors: Commercial, Industrial, Stationary aircos 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 cooling. Emissions from refrigerant management, filling, and dismantling are almost negligible.

Table 4.13 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	681	837
1998	160	49	773	982
1999	188	76	772	1036
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	1029
2006	666	312	160	1138
2007	737	333	222	1292
2008	810	352	242	1404
2009	868	368	210	1446
2010	899	372	191	1462
2011	920	377	273	1570
2012	952	382	213	1546
2013	1138	384	181	1703
2014	934	385	172	1492
2015	1029	386	167	1583
2016	815	386	170	1372
2017	918	378	178	1474
2018	521	363	167	1052

Year	2F1 Stationary refrigeration HFCs	2F1 Mobile air-conditioning: HFC134a	2F6 Other applications: HFCs	HFCs Total
2019	495	345	167	1006
2020	495	329	167	990
2021	495	303	167	964

4.7.2 *Methodological issues*

To comply with the 2006 IPCC Guidelines, volume 3, IPCC Tier 2 methods are used to estimate emissions from the sub-categories of 2F, as described in Honig et al. (2023), sections 2.2.3.9–2.2.3.11.

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

- Stationary refrigeration (2F1): until the 2016 submission, HFCs consumption data were obtained from the annual reports by PriceWaterhouseCoopers. From 2015 onwards no consumption data of HFCs are available.
- 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 of HFCs were obtained from annual reports by PriceWaterhouseCoopers. From 2015 onwards, no consumption data of HFCs are available. Therefore, until the 2021 submission, emissions from these sources were kept equal to the emissions of 2014. From the submission of 2022 onwards, a new estimation method is developed and will be used. Trends from Belgium and Germany are used to scale the 2014 emissions until 2021. This is described in Honig et al. (2023).

Stationary air conditioning (2F1):

From the 2019 submission onwards, the figures are used from the Refrigerants Registration System which includes information about leakage and, the filling of (new) installations and dismantling (From emission year 2013 on, as reported from the 2015 submission on, no data for the stock model was available anymore. During developing the new method, the 2013-2016 emissions were kept equal temporarily, and replaced by the new calculated emissions by the 2019 submission, when the new model was ready.).

The collection of data within the Refrigerants Registration System takes place as follows:

- Data at plant level (amounts of leakages, filling of (new) installations and dismantling) are registered continuously by mechanics of the installation companies.
- The figures are checked by the inspection authorities every other year.

- After 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 2019. The 2020 and 2021 figures are kept equal to the last year for which figures are available (2019). In the 2024 submission, the 2020 figures from the current submission will be replaced by the final figures for 2020.

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 is the case here, because the mix of high and lower GWP refrigerants is random through the years 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 2 years are kept at the same level. However: the last years a decreasing trend seems to appear. If this continues the next years, a Trend extrapolation method will be considered again.

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., 2023), as indicated in section 4.1.

4.7.3 Uncertainty and time series consistency

Uncertainty

The Approach 1 uncertainty analysis outlined in Annex 2 provides estimates of uncertainties per IPCC source category. Based on expert judgement, the uncertainty in HFC emissions from HFC consumption is estimated to be 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 period 1990–2012, and the Refrigerants Registration System method was used from 2013 onwards.

For the stock model method, activity data were 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 after the 2016 submission (reporting year 2014). From reporting year 2015 onwards, the annual sales figures were not sufficiently reliable to allow for a split into the annual filling of new installations and the refilling of existing installations. It was also not possible to divide the sales among the different 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 different 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 to calculate emissions; available from 2013 onwards. In this system, data about leakages, filling of new installations, dismantling, etc. are collected from the sectors commercial, industrial, and transport refrigeration and stationary air-conditioning. Data on leakages, filling of (new) installations, dismantling, etc. are not calculated but taken 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 we have and as complete as possible. In addition, the emissions calculated with the new method are lower than those from the old stock model method. The stock model gave higher emissions probably due to the assumption that usage figures were the same as the sales figures, and 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. However, in the 2021 submission, the Overlap splicing technique from the IPCC Guidelines was used to create a consistent time series for 1990–2019, and so the 1990-2012 series was recalculated. The formula used is described in Guidebook chapter 5 (Time series consistency), section 5.3.3.1. The overlap period used is 2013-2015.

Based on 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 2020 and 2021 has been applied; emissions have been kept equal to the 2018 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 have been available at a high reliability level.

4.7.5 Category-specific recalculations

As described in section 4.7.2, the 2019 figure of 2F1 (HFCs from stationary refrigeration) was replaced by the new calculated value.

4.7.6 Category-specific planned improvements

The Netherlands is still working 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 4.14 shows 2G emissions in the base year, as well as in the last two years of the inventory.

Table 4.14 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.). In contrast to other tables, emissions are shown in Gg instead of Tg.

Sector/category	Gas	1990	2020	2021	2021 vs 1990	Contribution to total in 2021 (%) by		
		Emissions in Gg CO_2 eq			%	sector	total gas	total CO_2 eq
2G. Other	CO_2	0.2	0.9	0.2	-25.8%	0.0%	0.0%	0.0%
	CH_4	58	52	53	-7.5%	0.6%	0.3%	0.0%
	N_2O	200	79	71	-64.8%	0.9%	1.0%	0.0%
	SF_6	213	128	124	-41.9%	1.5%	0.0%	0.1%

Sector/category	Gas	1990	2020	2021	2021 vs 1990	Contribution to total in 2021 (%) by		
		Emissions in Gg CO_2 eq			%	sector	total gas	total CO_2 eq
	All	471	260	248	-47.4%	1.5%	0.0%	0.1%
2G2. SF6 and PFCs from other product use	SF_6	213	128	124	-41.9%	1.5%	100.0%	0.1%
2G3. N2O from product uses	N_2O	197	68	68	-65.4%	0.8%	0.9%	0.0%
2G4. Other	CO_2	0.2	0.9	0.2	-25.8%	0.00%	0.00%	0.00%
	CH_4	58	52	53	-7.5%	0.6%	0.3%	0.0%
	N_2O	3	11	2	-31.8%	0.03%	0.03%	0.00%

This sector comprises no key categories.

In the Netherlands, many processes related 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 (included in 2G2).

Overview of shares and trends in emissions

Table 4.15 shows the trend in emissions from the use of SF_6 during the period 1990–2021.

Table 4.15 Emissions from the use of SF_6, 1990–2027 (Gg CO_2 eq.).

	'90	'95	'00	'05	'10	'15	'16	'17	'18	'19	'20	'21
SF_6	213	264	235	156	108	115	123	121	111	121	128	124

The decrease in SF_6 emissions after 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 65.4% in the period 1990–2021. 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 2021. 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 2021. CO_2, CH_4 and N_2O emissions from fireworks showed a peak in 1999 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 the only international test laboratory for power switches. Figures for emissions from circuit breakers were obtained from the yearly inventory by DNV. The methodologies used in earlier years is described in Honig et al., (2023), see sections 2.2.3.12 and 2.2.3.13.
The country-specific methods used for the sources Semiconductor manufacture, Sound-proof windows, and Electron microscopes are equivalent to 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: EF used for production is 33% (IPCC default); EF (leak rate) used during the lifetime of the windows is 2% per year (IPCC default);
- electron microscopes: confidential information from the only company.

Country-specific methodologies are used for the N_2O sources in 2G3. As the N_2O emissions in this source category are from non-key sources, the present methodology complies with the 2006 IPCC Guidelines. A full description of the methodology is provided in Jansen et al. (2019).

The major hospital supplier of N_2O for anaesthetic use reports the consumption data for anaesthetic gas in the Netherlands annually. NAV reports data on the annual sales of N_2O-containing spray cans.

The EF used for N_2O in anaesthesia is 1 kg/kg gas used. Sales and consumption of N_2O for anaesthesia are assumed to be equal each year. The EF for N_2O from aerosol cans is estimated to be 7.6 g/can (based on 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 are 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., 2022).
- Production of drinking water: 2.47 tons CH_4/10^6 m^3 (Visschedijk et al., 2022).
- Smoking cigarettes and cigars: CO_2: 294 kg/t; CH_4: 1.625 kg/t; N_2O: 0.065 kg/t (Visschedijk et al., 2022).

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 vary 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; this 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

- No category specific recalculations were made.

4.8.6 Category-specific planned improvements

SF6 emissions from electronics industry will be separated, and allocated to 2G2.

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 2021 are decreased by 79.4% compared to the emissions in 1990 (see Table 4.16).

Table 4.16 Overview of the sector Other process emissions (2H) in the base year and the last two years of the inventory (in Tg CO_2 eq.).

Sector/category	Gas	1990	2020	2021	2021 vs 1990	Contribution to total in 2021 (%) by		
		Emissions in Tg CO_2 eq			%	sector	total gas	total CO_2 eq
2H. Other process emissions	CO_2	0.07	0.02	0.01	-79.4%	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., (2023), 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), on the assumption that the carbon is fully oxidised to CO_2.

4.9.3 *Uncertainty and time series consistency*

Uncertainty

The Approach 1 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 c. 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*

No recalculations have been made.

4.9.6 *Category-specific planned improvements*

No improvements are planned.

5 Agriculture (CRF sector 3)

Major changes in the agriculture sector compared with the National Inventory Report 2022	
Emissions:	Total emissions from the agriculture sector decreased in 2021 to a level of c. 18.0 Tg CO_2 eq.
New Key categories:	3A2, 3A4 Other CH_4
No longer Key category:	3B1 Growing cattle N_2O, 3B1 Mature dairy cattle N_2O
Methodologies and recalculations:	• The feed intake of dairy cattle has been corrected for the years 2004-2020. As a result, the methane emissions from enteric fermentation decrease by 0.3% (3A). • The amount of manure pelleted has been estimated based on transport certificates. The new estimates increase the methane emission from manure management of dairy cattle by 0.001-0.005% (3B). • The final usage rates of artificial fertiliser and compost have been used for the year 2020. Final usage rates were lower, decreasing the N_2O emissions from agricultural soils (3D). • The area of cultivated organic soil has been updated in accordance with the LULUCF chapter. The update results in a decrease of 5% of the direct N_2O emissions from cultivated organic soils in the agriculture sector (3D).

5.1 Overview of 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 of the Agriculture sector subdivided in the relevant subcategories to the total greenhouse gas emissions in the Netherlands. Emissions are given for 1990, 2020 and 2021. Table 5.1 also provides the relative difference between 2021 and 1990, and the contribution of the different sources and gases 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 fertilizers (3I) and Other (3J) do not occur in the Netherlands. Throughout the period 1990-2021, Field burning of agricultural residues was prohibited in the Netherlands (article 10.2 of the Environmental Management Act, or '*Wet Milieubeheer*' in Dutch).

In this chapter the national emissions from agriculture and their trends are discussed. All emissions are calculated using the NEMA model (Netherlands Emission Model Agriculture). The methods used to calculate the emissions are described in Van der Zee *et al.,* (2023). The activity data used to calculate the emissions are summarised in Van Bruggen et al. (2023). The activity data that could not be included in the CRF is added to Van Bruggen et al. (2023). 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 (2012).

Table 5.1 Overview of emissions in the agriculture sector, in the base year 1990 and the last two years of the inventory (in Tg CO_2 eq.).

Sector/category	Gas	1990	2020	2021	2021 vs 1990	Contribution to total in 2021 (%) by		
		Emissions in Tg CO_2 eq			%	sector	total gas	total CO_2 eq
3. Agriculture	CO_2	0.2	0.1	0.1	-55.0%	0.5%	0.1%	0.0%
	CH_4	16.4	13.3	13.0	-20.6%	72.6%	68.8%	7.6%
	N_2O	8.5	5.0	4.8	-43.3%	26.9%	66.9%	2.8%
	All	25.2	18.4	18.0	-28.6%	100.0%		10.5%
3A. Enteric fermentation	CH_4	10.3	9.2	9.1	-12.3%	50.5%	47.8%	5.3%
3B. Manure management	CH_4	6.1	4.1	4.0	-34.7%	22.1%	21.0%	2.3%
	N_2O	0.8	0.7	0.7	-19.7%	3.7%	9.3%	0.4%
	All	6.9	4.8	4.6	-32.9%	25.9%		2.7%
3D. Agriculture soils	N_2O	7.7	4.3	4.2	-45.9%	23.2%	57.6%	2.4%
3G. Liming	CO_2	0.2	0.03	0.02	-86.9%	0.1%	0.0%	0.0%
3H. Urea application	CO_2	0.00	0.05	0.06	3803.8%	0.3%	0.0%	0.0%
National Total GHG emissions (incl. LULUCF)	CO_2	169.4	140.9	144.4	-14.8%			
	CH_4	36.0	19.2	19.0	-47.4%			
	N_2O	16.2	7.5	7.2	-55.3%			
	Total	228.9	168.9	172.0	-24.9%			

5.1.1 *Overview of shares and trends in emissions*

Figure 5.1 shows the trend in total GHG emissions from the sector Agriculture.

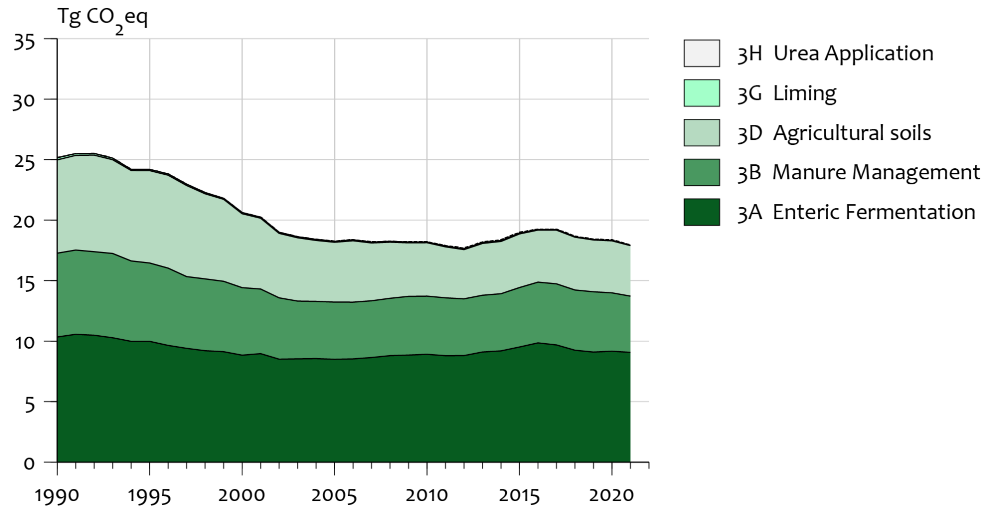

Figure 5.1 Sector 3 Agriculture – trend and emission levels of source categories, 1990–2021.

In 2021, agriculture contributed 10.7% of the national GHG emissions in comparison with 11.3% in 1990. This sector is a major contributor to both national total CH_4 and N_2O emissions; in 2021 agriculture accounted for 68.8% of the total CH_4 emissions and for 66.9% of the total N_2O emissions (Table 5.1).

Trend in carbon dioxide emissions

The CO_2 emissions from agriculture 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 fertilizer. CO_2 emissions peaked in 2012 after which they plateaued until 2016 when a strong decrease can be observed. In 2017 there was an increase in CO_2 emissions followed by a decrease in 2018. Between 2018 and 2021 CO_2 emissions remained stable with relatively small yearly fluctuations. The timeseries of CO_2 emissions from agriculture are available in section 9.6 of Van Bruggen *et al.,* (2023).

Trend in methane emissions

In broad terms the CH_4 emissions from agriculture show a decline from 1990 to 2005, after which the emissions increased again, peaking in 2016. After 2016 the emissions decreased. The trends in methane emissions are mainly explained by changes in the number of mature dairy cattle and pigs. The timeseries of CH_4 emissions are available in section 9.3 of Van Bruggen *et al.,* (2023).

Trend in nitrous oxide emissions

From 1990 - 2012, the Netherlands saw a decline in N_2O emissions due to a decrease in organic and inorganic N fertilizer application, a decrease in animal numbers, and a decrease in grazing. Emissions increased in 2013-2017, 2018 and 2019 show a decrease. Emissions increased in 2020 and decreased in 2021. The decrease in 2021 is mainly due to less animals being kept and lower nitrogen excretion rates. The timeseries of N_2O emissions are available in section 9.2 of Van Bruggen *et al.,* (2023).

5.1.2 *Overview of trends in activity data*

Animal numbers are the primary activity data used in all emission calculations for Agriculture. 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 less precise, are covered by the Identification and registration system. Table 5.2 presents an overview of the different animal categories. The entire timeseries of the animal numbers in the Netherlands can be found in annex 2 of Van Bruggen *et al.* (2023). More information on the determination of the animal numbers can be found in section 2 of Van der Zee *et al.* (2023).

Between 1990 and 2021, 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 of cattle (all categories) that can be kept in the Netherlands and resulted in a decrease of cattle numbers from 2017 to 2021.

The total number of sheep (ewes, rams and lambs) decreased by 46% between 1990 and 2021. Note that in the previous NIR, only ewes were accounted for to quantify the decrease.

The total number of swine decreased by 18% between 1990 and 2021. Increased production rates per animal resulted in a decrease of swine numbers until 2004, after which animal numbers increased. The increase levelled off after 2011 and was stable until 2015. Between 2016 and 2021, a slow decrease was observed. The number of young stock of swine (piglets up to 25 kg) has been stable between 1990 and 2021, showing that the productivity of the sows has increased.

There was an overall decrease in numbers of poultry of 1% between 1990 and 2021. 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 number of poultry in 2002. From 2011 onwards, poultry numbers stabilized, with small annual fluctuations.

The total number of goats increased by 958% between 1990 and 2021. 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 2021.

The total number of mules and asses increased by 16% between 1990 and 2021. Based on expert judgement, the number of mules and asses between 1990 and 2009 was set at 1000 animals. From 2010, animal numbers became available from the agricultural census.

The number of rabbits decreased by 59% between 1990 and 2021 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 after 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, all mink farms ceased operations as the production of fur from minks was banned. This resulted in a 20% decrease of mink between 1990 and 2020. From 2021 onwards, no mink is held in the Netherlands.

Emissions from alpacas in the Netherlands have not been estimated as there is no detailed information on their numbers. Alpacas are mostly kept as pets or as a tourist attraction. The emissions caused by alpacas are negligible. N.B.: To comply with the changes to the European Animal Health Regulation, information on alpaca farms will be registered in the near future. In 2022 the Identification and Registration system did not contain information on the number of camelids in the Netherlands in 2021.

Table 5.2 Animal numbers in 1990–2021 (x 1,000) (www.cbs.nl).

Animal category	1990	1995	2000	2005	2010	2015	2020	2021
Cattle	4,926	4,654	4,069	3,797	3,975	4,134	3,719	3,732
Mature dairy cattle	1,878	1,708	1,504	1,433	1,479	1,622	1,593	1,571
Other mature cattle	120	146	163	151	115	80	58	56
Growing cattle	2,929	2,800	2,402	2,213	2,381	2,432	2,068	2,105
Sheep	1,702	1,674	1,305	1,361	1,130	946	954	916
Ewes	790	771	680	647	558	523	562	532
Young stock and males	913	903	625	714	571	423	393	385
Swine	13,915	14,397	13,118	11,312	12,255	12,603	11,860	11,372
Swine (>25 kg)	8,724	8,801	8,015	6,749	7,131	7,005	6,447	6,203
Young stock (<25 kg)	5,191	5,596	5,102	4,563	5,124	5,598	5,414	5,169
Goats	61	76	179	292	353	470	633	643
Mature female goats	37	43	98	172	222	292	441	451
Young stock and males	23	33	80	120	131	178	192	193
Horses	370	400	417	433	441	417	410	417
Mules and asses	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
Other livestock								
Rabbits	786	488	392	360	299	381	335	321
Does	105	64	52	48	39	48	38	38
Young stock	681	424	340	312	260	333	297	283
Furbearing animals	554	463	589	697	962	1,023	435	NO

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 section 5.2 and 5.3). CH_4 emissions of sheep, goats and pigs are based on the average number of animals present multiplied with the default IPCC emission factors. N_2O emissions are based on the N excretion. The N excretion is 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. Therefore, for the calculation of N_2O emissions, the male and young sheep and goats and the piglets are omitted.

Detailed information on data sources can be found in chapter 2 in Van der Zee *et al.,* (2023).

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 utilized 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 per unit of feed intake, ruminants produce considerably more. Enteric fermentation from poultry is not estimated due to the negligible amount of CH_4 production in this animal category. The IPCC 2019 Guidelines do 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 9.1 Tg CO_2 eq in 2021 (-12.3% compared with 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 2021. Swine contributed 5% and the animal categories sheep, goats, horses and mules and asses 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 (in Tg CO_2 eq.).

Sector/category	**Gas**	**1990**	**2020**	**2021**	**2021 vs 1990**	**Contribution to total in 2021 (%) by**		
		Emissions in Tg CO_2 eq			**%**	**sector**	**total gas**	**total CO_2 eq**
3A. Enteric fermentation	CH_4	10.3	9.2	9.1	-12.3%	50.5%	47.8%	5.3%
3A1. Cattle	CH_4	9.2	8.2	8.1	-11.9%	45.0%	42.7%	4.7%
Mature dairy cattle	CH_4	5.8	6.0	6.0	2.8%	33.2%	31.5%	3.5%
Other mature cattle	CH_4	0.2	0.1	0.1	-48.4%	0.7%	0.6%	0.1%
Growing cattle	CH_4	3.1	2.0	2.0	-36.3%	11.1%	10.6%	1.2%
3A2. Sheep	CH_4	0.4	0.2	0.2	-46.2%	1.1%	1.1%	0.1%
3A3. Swine	CH_4	0.6	0.5	0.5	-18.3%	2.7%	2.5%	0.3%
3A4. Other livestock	CH_4	0.2	0.3	0.3	54.1%	1.7%	1.6%	0.2%

This sector comprises following key categories:

3A1	Mature dairy cattle	CH_4
3A1	Young cattle	CH_4
3A3	Swine	CH_4
3A2, 3A4	Other	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 in Van der Zee *et al.,* (2023). An overview of the activity data can be found in Statistics Netherlands (2011 through 2022); Van Bruggen *et al.,* (2023).

Cattle (3A1)

A Tier 3 method is used for the emission calculation of mature dairy cattle. For the calculation of the EF of mature dairy cattle, the Netherlands is split in 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 the diet. Data used between 1990 and 2012 are published in an annex to Van Bruggen *et al.,* (2014). A yearly update of cattle diets is published by Statistics Netherlands, (2014 through 2022). Table 5.4 shows the IEFs of the different cattle categories reported, including the subdivision into the NW and SE regions for mature dairy cattle. The IEF for growing cattle is a weighted average calculated from several sub-categories (Statistics Netherlands, 2022).

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
Mature dairy cattle	110.4	114.4	120.0	124.6	127.7	128.7	136.5	135.6
Of which NW region	111.0	115.4	121.7	126.0	129.6	130.9	136.6	135.1
Of which SE region	109.9	113.5	118.4	123.2	126.3	127.1	136.4	136.0
Other mature cattle	70.3	71.3	72.1	76.7	78.1	79.1	77.9	77.6
Growing cattle	38.3	38.6	35.4	34.4	35.0	36.4	33.5	33.9

For both mature dairy cattle and other mature cattle, EFs increased primarily because of an increase in total feed intake in the period 1990–2020. 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, leading to a higher gross energy intake of mature dairy cattle in 2021 compared to 1990, with a decrease in animal numbers (Statistics Netherlands, 2022). The IEFs of 2021 are lower than 2020 because the feed intake was lower.

For growing cattle, the decrease of the EF between 1990 and 2021 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 lessened, however, by an increase in EF for white veal calves, as they are fed increasing amounts of roughage to comply with animal welfare considerations.

Other livestock (3A2, 3A3 and 3A4)
According to the IPCC Guidelines, no Tier 2 method is needed if the share of a sub-source category is less than 25% of the total emission from a key source category. The animal categories sheep, swine, goats, horses, and mules and asses have a combined share in total CH_4 emissions from enteric fermentation of c. 11%. Therefore, the IPCC 2006 default (Tier 1) EFs are used for sheep, swine, goats, horses and mules and asses (8, 1.5, 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 Approach 1 uncertainty analysis explained in Annex 2 provides estimates of uncertainty according to IPCC source categories. The uncertainty of CH_4 emissions from enteric fermentation varies 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 at 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 published by Statistics Netherlands. Consistent methods are used to compile the census to ensure continuity of the collected data. EFs are either constant (default IPCC) or calculated/modelled from feed intake data collected through an annual survey.

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
An error was discovered in the input file of the feed of dairy cattle for the years 2004-2020. The compound feed was given in kg dry matter instead of kg product. The feed intake of dairy cattle has been recalculated for the years 2004-2020. The implementation of the correction results in a decrease of the CH_4 emissions from enteric fermentation from dairy cattle by 0.3% in the years 2004-2020.

5.2.6 Category-specific planned improvements
No improvements are 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 different types of manure management systems used.

In the Netherlands, CH_4 emissions from manure management contribute 2.3% 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 12.0% and 9.6% respectively, to the total GHG emissions of the agriculture sector in 2021. CH_4 emissions from manure management of poultry are a minor key source and have decreased drastically over time (-84.8% from 1990 to 2021).

In 2021, N_2O emissions from manure management contributed 0.4% to the national total GHG emissions and 3.7% 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 (in Tg CO_2 eq.).

Sector/category	**Gas**	**1990**	**2020**	**2021**	**2021 vs 1990**	**Contribution to total in 2021 (%) by**		
		Emissions in Tg CO_2 eq			**%**	**sector**	**total gas**	**total CO_2 eq**
3B. Manure management	CH_4	6.1	4.1	4.0	-34.7%	22.1%	21.0%	2.3%
	N_2O	0.8	0.7	0.7	-19.7%	3.7%	9.3%	0.4%
	All	6.9	4.8	4.6	-32.9%	25.9%		2.7%
3B1. Cattle (total)	CH_4	1.8	2.1	2.2	19.5%	12.0%	11.4%	1.3%
3B2. Sheep	CH_4	0.0	0.0	0.0	-46.2%	0.0%	0.0%	0.0%
3B3. Swine	CH_4	3.8	1.9	1.7	-54.2%	9.6%	9.1%	1.0%
3B4. Poultry	CH_4	0.5	0.1	0.1	-84.8%	0.4%	0.4%	0.0%
3B4. Other livestock	CH_4	0.0	0.0	0.0	-25.7%	0.1%	0.1%	0.0%
3B1. Cattle (total)	N_2O	0.3	0.3	0.3	-2.9%	1.6%	4.1%	0.2%
3B2. Sheep	N_2O	0.0	0.0	0.0	-77.6%	0.0%	0.0%	0.0%
3B3. Swine	N_2O	0.1	0.1	0.1	-34.9%	0.5%	1.1%	0.0%
3B4. Poultry	N_2O	0.0	0.0	0.0	-13.6%	0.1%	0.3%	0.0%
3B4. Other livestock	N_2O	0.0	0.1	0.1	134.3%	0.4%	0.9%	0.0%
3B5. Indirect emissions	N_2O	0.3	0.2	0.2	-40.6%	1.1%	2.8%	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

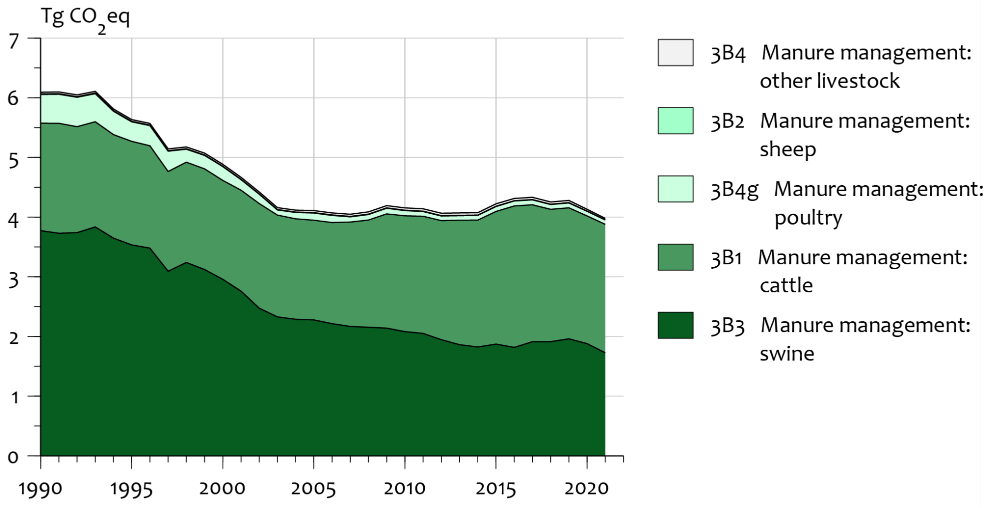

Figure 5.2 Category 3B Manure management – trend and emissions levels of source categories CH_4, 1990–2021.

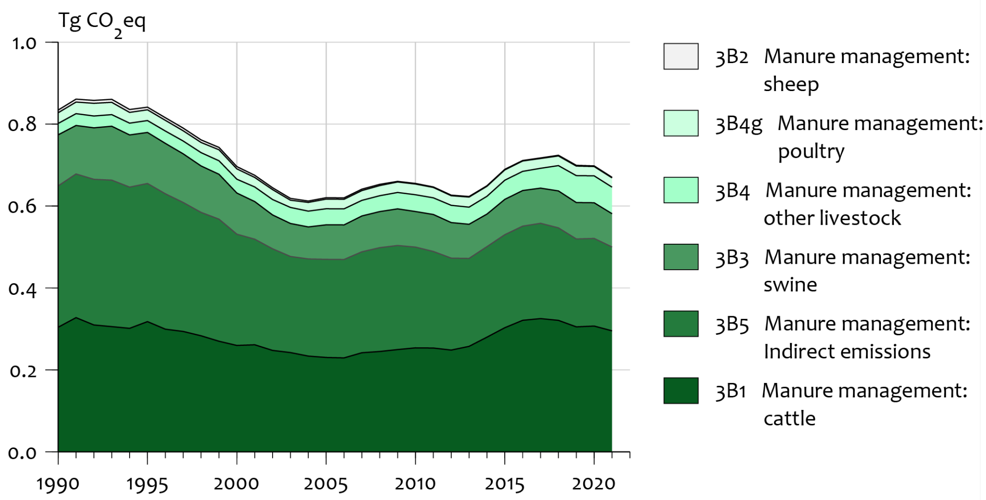

Figure 5.3 Category 3B Manure management – trend and emissions levels of source categories N_2O, 1990–2021.

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 different livestock categories are described in Statistics Netherlands (2012).

CH_4 from manure management
Between 1990 and 2021, emissions of CH_4 from manure management decreased by 34.7% (Figure 5.2). Emissions from cattle increased by 19.5%, while swine and poultry emissions decreased by 54.2% and 84.8% 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.,* 2023). 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.,* 2023). An increase in emissions can be seen between 2013 and 2017. This is due to an increase in number of cattle combined with higher VS excretion (Annex 2 and Annex 28 of Van Bruggen *et al.,* 2023). 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.,* 2022).

For poultry, the large decrease of 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*., 2023). 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*., 2023).

The decreasing trend in CH_4 emissions from swine is directly related to the decrease of volatile solids (VS) excretions by swine (Statistics Netherlands, 2022). 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). In the years 2017-2019, an increase in emissions can be seen as the VS excretion increased. In 2020 and 2021 VS excretion decreased again (Annex 28 of van Bruggen *et al.,* 2023).

N_2O from manure management
Nitrous oxide emissions are calculated using an N-flow model (Van der Zee *et al.*, 2023). 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 2.9% between 1990 and 2021. Sheep, swine and poultry emissions decreased by 77.6%, 34.9% and 13.6% respectively (Table 5.5). Decreasing livestock numbers and N excretions per animal influenced this trend. Emissions from other livestock increased between 1990 and 2021 by 134.0% (Table 5.5); this increase is mainly caused by the increase in number of goats. Between 1990 and 2013, the N excretion decreased due to an optimization 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 stabilized. In 2017, the N excretion increased again for cattle, which can be explained by a decrease in fed maize and an increase of fed grass; grass has a higher N content than maize. Besides the increased share of grass in the feed, nutrient requirements increased through a higher average milk production and body weight per cow (RVO, 2018). In 2021, the N excretion of cattle decreased as the roughages contained less nitrogen (Statistics Netherlands, 2022).

The Netherlands' manure and fertilizer 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 fertilizer, all part of the Dutch 'Manure and Fertilizers Act' conform the Nitrates Directive. This has also led to 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 40.6% from 1990 to 2021 (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.

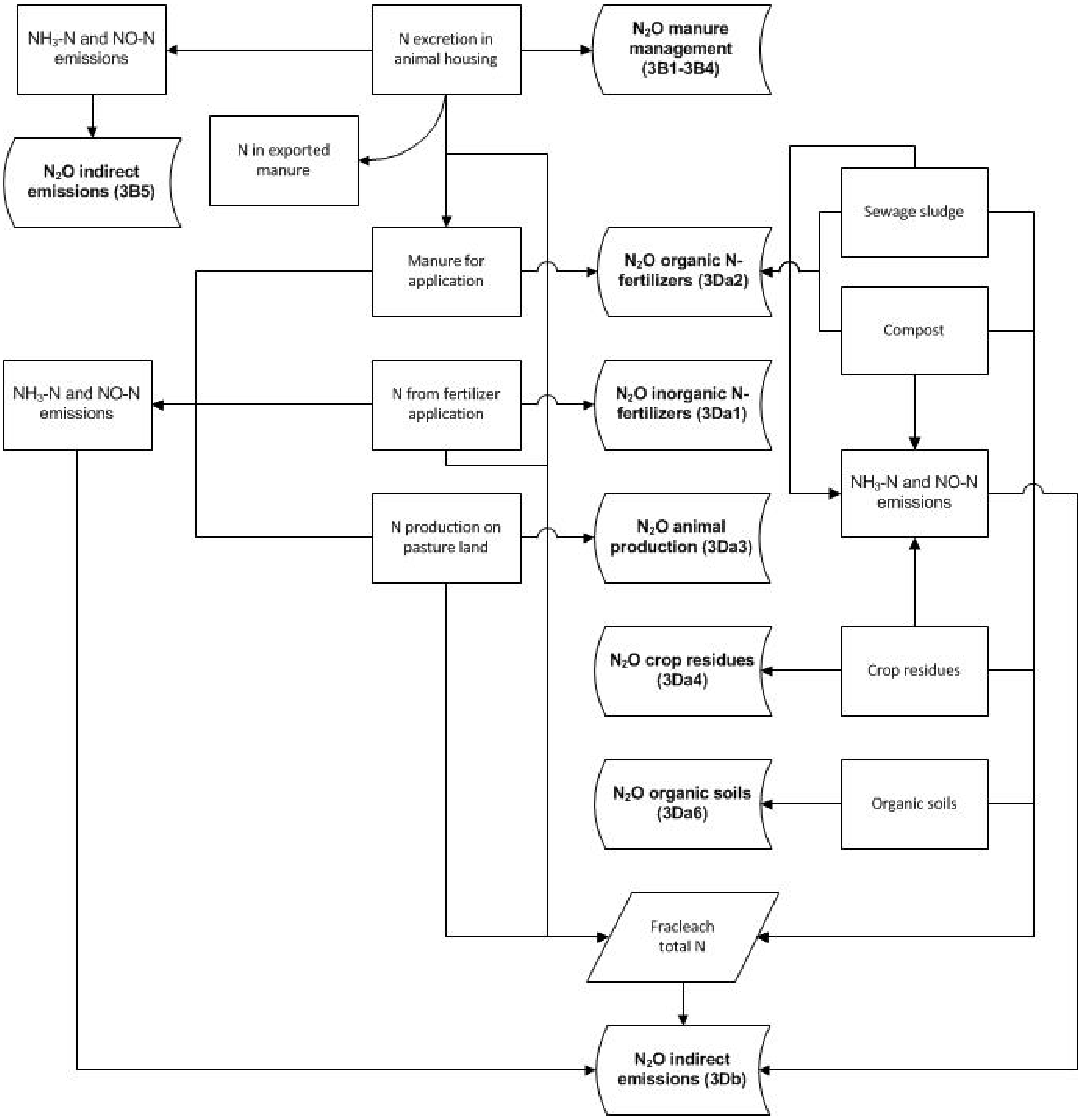

Figure 5.4 Schematic representation of N flows in agriculture and the allocation of emissions to source categories.

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 in Van der Zee *et al.,* (2023). An overview of the activity data can be found in Statistics Netherlands (2011 through 2022); Van Bruggen *et al.,* (2023). More information on housing systems used in the Netherlands can be found at https://www.infomil.nl/onderwerpen/landbouw/stalsystemen/stalbeschrijvingen/ (in Dutch).

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 different types of manure treatment used in the Netherlands can be found in Melse and Groenestein, (2016).

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 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. Regularly, this manure is 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 systems and manure produced on pasture while grazing, IPCC default values are used. The time that animals spend on pasture is calculated yearly by the Working group on Uniformity of calculations of Manure and mineral data (Statistics Netherlands, 2011-2022). A timeseries with the emission factors of liquid manure, solid manure and manure in pasture can be found in Annex 29 of Van Bruggen *et al.,* (2023). 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 kept in the storage 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.

Table 5.6 shows 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, 1990–2021.

Animal category	1990	1995	2000	2005	2010	2015	2020	2021
Cattle								
Mature dairy cattle	23.07	24.10	27.97	31.07	34.87	36.72	37.57	37.85
Other mature cattle	7.42	7.53	7.50	7.84	8.04	8.01	6.80	6.75
Growing cattle	6.87	7.04	6.62	6.30	7.05	7.88	7.84	8.09
Sheep*	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
Horses	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
Swine*	9.68	8.77	8.05	7.19	6.07	5.31	5.66	5.42
Swine excl. piglets	15.44	14.34	13.18	12.06	10.43	9.55	10.41	9.94
Fattening pigs	12.87	11.81	10.76	9.70	8.40	7.53	8.35	8.00
Breeding swine	26.09	25.08	23.60	22.47	20.18	19.27	20.57	19.75
Poultry	0.19	0.13	0.08	0.05	0.03	0.03	0.03	0.03
Other animals*	0.33	0.37	0.44	0.48	0.54	0.52	0.42	0.08

** 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.*

Cattle (3B1)
The IEF for the manure management of mature dairy cattle increased between 1990 and 2021 due to 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: the share of manure produced in liquid manure management systems compared with the amount of manure produced on pasture increased between 1990 and 2021 (Statistics Netherlands, 2022).

Swine (3B3)
Between 1990 and 2021, the IEF of 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 decreases because the feed composition changed over the years, increasing the overall digestibility. The IEF also decreases as the productivity of the sows increased between 1990-2021, thus dividing the emissions over 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 1% since 1990 combined with the shift towards solid manure management systems with a lower EF, led to an overall decrease in CH_4 poultry emissions.

Other animals (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. The category 'other livestock' includes rabbits (solid manure) and fur-bearing animals (liquid manure). The resulting IEF for this category therefore largely depends on the ratio between the two species each year. As rabbit numbers decreased and mink numbers increased over the entire time period except in 2020, the CH_4 IEF increased because a larger proportion of the manure consisted of liquid manure with a higher EF. In 2021 no fur-animal is kept in the Netherlands. The IEF of 2021 is thus the EF of the rabbits.

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 given in Van der Zee *et al.*, (2023). 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 period 1990 - 2006 and Statistics Netherlands, (2021) for the period from 2006 onwards.

N2O from manure management
Emissions of N_2O from manure management are calculated using the 2006 IPCC default EFs. As manure management does not constitute a key category for N_2O emissions, no higher Tier is required. An increase in IEF between 2010 and 2020 is the result of increased N excretion combined with a decrease in animal numbers (Table 5.7). This is caused by an 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, 1990–2021 (mln kg/year and kg N_2O/kg manure-N).

Animal category	1990	1995	2000	2005	2010	2015	2020	2021
Cattle								
Mature dairy cattle	0.34	0.36	0.32	0.34	0.34	0.35	0.40	0.39
Other mature cattle	0.19	0.22	0.20	0.18	0.17	0.18	0.22	0.21
Growing cattle	0.14	0.15	0.13	0.11	0.11	0.12	0.12	0.11
Sheep*	0.01	0.01	0.02	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
Horses	0.21	0.21	0.21	0.21	0.19	0.19	0.26	0.25
Mules and asses	0.11	0.11	0.11	0.11	0.10	0.10	0.13	0.13
Swine*	0.03	0.035	0.03	0.03	0.03	0.02	0.01	0.01
Poultry	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
Fur-bearing animals	0.01	0.01	0.01	0.01	0.01	0.01	0.01	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.,* (2022). 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 of 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 are collected in compliance with a Tier 2 method. The N_2O EFs used for liquid and solid manure management systems are IPCC defaults. The method used complies with the 2006 IPCC Guidelines.

5.3.3 *Uncertainty and time series consistency*

Uncertainty
The Approach 1 uncertainty analysis detailed in Annex 2 provides estimates of uncertainty according to IPCC source categories. The uncertainty for CH_4 from manure management varies 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 vary between 1% and c. 39%.

The uncertainty in the annual N_2O emissions from manure management is much higher; estimated at 64% - 100%, 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.,* (2023).

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 are collected 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.

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*

The amount of manure pelleted has been adjusted for the years 1998-2020. The change resulted in an increase of the CH_4 emissions from manure management of 0.001-0.005%. The new estimation is based on the P_2O_5 content reported on the mandatory transportation certificates instead of the P_2O_5 content calculated by the Working group on Uniformity of calculations of Manure and mineral data (WUM). The change increases the consistency of the calculations in NEMA as the export of manure pellets was already based on the P_2O_5 content reported on the transportation certificates. Prior to 1998 no manure pelleting occurred.

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.

5.4 Agricultural soils (3D)

5.4.1 *Source category description*

In 2021, agricultural soils were responsible for 23.2% of total GHG emissions in the agriculture sector. Total N_2O emissions from agricultural soils decreased by 45.9% between 1990 and 2021 (Table 5.8). In 2021, N_2O emissions from grazing decreased by 5.4% compared to 2020. Emissions from organic N fertilisers decreased by 5.6% due to a decrease in application in 2021 compared to 2020. Emissions from inorganic N fertilizers decreased by 1.5% in 2021 compared to 2020. Emissions from crop residues in 2021 were slightly reduced (0.5%) compared to 2020.

Table 5.8 Overview of the sector agricultural soils (3D) in the base year and the last two years of the inventory (in Tg CO_2 eq.).

Sector/category	Gas	1990	2020	2021	2021 vs 1990	Contribution to total in 2021 (%) by		
		Emissions in Tg CO_2 eq			%	sector	total gas	total CO_2 eq
3D. Agriculture soils	N_2O	7.7	4.3	4.2	-45.9%	23.2%	57.6%	2.4%
3Da. Direct N_2O emissions from agricultural soils	N_2O	6.3	3.8	3.7	-41.9%	20.3%	50.4%	2.1%
3Da1. Inorganic ferilizers	N_2O	1.8	1.0	1.0	-42.8%	5.6%	13.9%	0.6%
3Da2. Organic N fertilizers	N_2O	0.7	1.1	1.0	49.3%	5.7%	14.1%	0.6%
3Da3. Urine and dung from grazing animals	N_2O	2.7	0.8	0.7	-72.4%	4.1%	10.3%	0.4%
3Da4. Crop residues	N_2O	0.4	0.3	0.3	-29.0%	1.6%	4.1%	0.2%
3Da6. Cultivation of organic soils	N_2O	0.7	0.6	0.6	-20.5%	3.2%	8.1%	0.3%
3Db. Indirect N_2O Emissions from managed soils	N_2O	1.4	0.5	0.5	-63.4%	2.9%	7.2%	0.3%

This sector comprises 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 was caused by a relatively large decrease in N inputs into soil (from inorganic fertilizer and organic N fertilizer applications and 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 manure 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 fertilizers (3Da1);
- Organic N fertilizers (mainly animal manure, 3Da2);
- Urine and dung from grazing animals (3Da3);
- Crop residues (3Da4);
- Cultivation of organic soils (3Da6);
- Indirect N_2O emissions from managed soils (3Db).

Emissions from 3Da5 Mineralization/immobilization associated with losses/gains of soil organic matter have not been estimated yet. The LULUCF sector has included the emissions caused by changes in soil carbon content of cropland remaining cropland for the first time this year, as described in chapter 11.2 of the LULUCF methodology report (Arets *et al.*, 2023). The N losses associated with changes in soil carbon content and the ensuing N_2O emissions will be determined next year. Figure 5.5 shows the trend in total agricultural soils emissions.

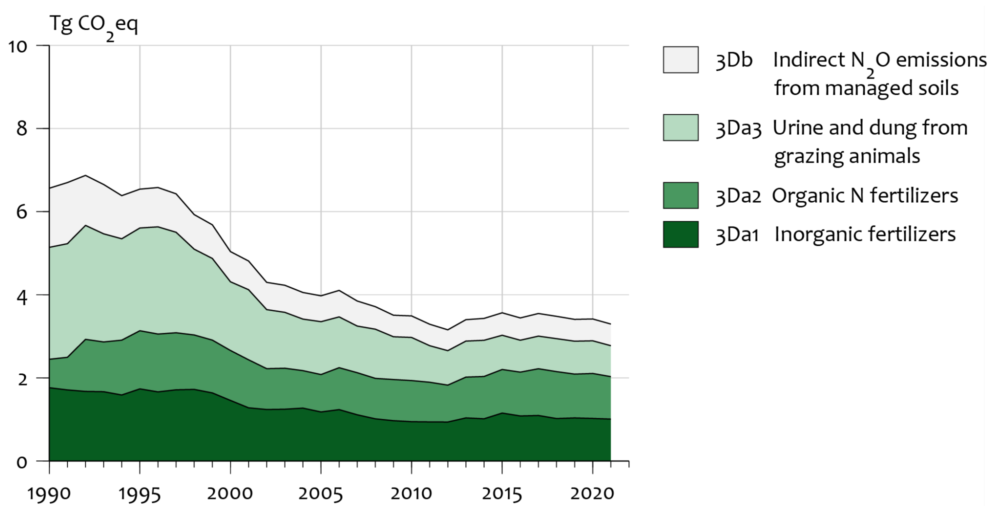

Figure 5.5 Category 3D Agricultural soils – trend and emission levels of source categories, 1990–2021.

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 has increased in the last decade, but this has stagnated in recent years. 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 for calculating 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 fertilizer, 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 37% between 1990 and 2021. This can be explained by the Netherlands' manure and fertilizer policy aimed at reducing N leaching and run-off. This policy regulates the amount of manure production and its application to soils 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 fertilizer, all part of the Dutch 'Manure and Fertilizers Act' conform the Nitrates Directive. Because the leaching fraction has also decreased over time, the amount of N leached or run off has been reduced by 46% since 1990.

The emissions of crop residues decreased between 1990 and 2021 by 29.0% (table 5.8), the same decreasing trend can be seen in the amount of crop residues left on the field. This is mainly because of a decrease in grassland renewal. The rate of grassland renewal decreased as a result of policy changes that encouraged permanent grassland (RVO, 2021).

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 volatilization during grazing, manure management, and manure application. Most of this data is estimated at a 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.,* (2023). 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.,* (2023).

Direct N_2O emissions (3Da)

An IPCC Tier 1/2 methodology is used to estimate direct N_2O emissions from agricultural soils.

The EF of inorganic N fertilizer application for direct N_2O emissions between 1990 and 1999 is based on a weighted mean of different inorganic N fertilizer types applied on both mineral and organic soils. The EFs for the application of animal manure or manure produced on pastureland during grazing between 1990 and 1999 are also based on weighted means of the EF for mineral and organic soils.

As arable farming hardly ever occurs on organic soils in the Netherlands, the EF for crop residues is based on mineral soils only. For the years 2000 to 2021, 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 with that the potential for N_2O emissions) in these soils is hardly affected by the type of agriculture practiced. For the years 2000 to 2021, 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).

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**		**1**
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**		**1**
Surface spreading		0.004	1
Incorporation into soil		0.009	1
Compost	**0.01**	**0.004**	**2**
Crop residues	**0.01**	**0.01**	**3**
Grassland renewal		**5.5***	**5**
Cultivation of organic soils		**0.02**	**3, 4**
Animal manure during grazing (cattle/swine/poultry)	**0.02**	**0.033**	**1**
Mineral soils		0.025	1
Organic soils		0.060	1

Source	Default IPCC	EF used	Reference
Animal manure during grazing (sheep/other animals)	**0.01**	**0.033**	**1**
Mineral soils		0.025	1
Organic soils		0.060	1

*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.

No experimental data of compost emissions are available. Based on expert judgement, the emission factor for compost was set equal to that of surface-applied manure, because compost is also surface-applied. The IPCC guidelines contain one emission factor for all N additions to the soil, the emission factor used is within the uncertainty range given 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.,* (2023) describes how the results of this paper were used to calculate the emission factors used in the inventory of the Netherlands. The EF of grassland renewal is based on the average of grassland renewal with and without ploughing up the land (Velthof *et al.,* 2010b).

The IEF of direct N_2O emissions from the application of animal manure on agricultural soils increased by 98% in the period 1990–2021 (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, 1990–2021.

	'90	**'95**	**'00**	**'05**	**'10**	**'15**	**'20**	**'21**
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 fertilizer application, partly countered by an increase in IEF because of the manure incorporation into the soil.

Emissions from animal manure application are estimated for two manure application methods: surface spreading (with a lower EF) and incorporation into soil (with 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 mineral soil – arable is negligible (Velthof and Rietra, 2018).

Indirect N_2O emissions (3Db)
An IPCC Tier 1 method is used to estimate indirect N_2O emissions from atmospheric deposition. Country-specific data on NH_3 and NO_x emissions (estimated at a Tier 3 level using NEMA) are multiplied by the IPCC default N_2O EF. The emissions can be found in chapter 9 of van Bruggen *et al.,* (2023).

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 a Tier 3 level). The leaching fraction can be found in section 4.2 of Van Bruggen *et al.,* (2023). The leaching fraction applied in the model reflects the specific characteristics of the Netherlands' agricultural soils, with relatively high water tables. A model (STONE) was adopted to assess this fraction, as described in Velthof and Mosquera (2011), with IPCC default values used for the N_2O EF.

5.4.3 *Uncertainty and time series consistency*

Uncertainty
The Approach 1 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 related 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*

The area of cultivated organic soils used for the LULUCF sector has been decreased by 5% for the entire timeseries in order to account for the area of ditches. This change results in a 5% decrease of the direct N_2O emissions from cultivated organic soils in the agriculture sector.

The Initiator model, which distributes the manure over cropland and grassland has been updated. Multiple small errors have been corrected. These corrections result in a different distribution of animal manure, pasturing animals and artificial fertilisers over planted cropland, unplanted cropland and grassland for the years 2000-2020. The changes in N_2O emissions range from −1.2% to +1%. Manure distribution for the years 1990-1999 has been calculated using the MAMBO-model. The errors in the Initiator model do not occur in the MAMBO-model, therefore no recalculation is needed for these years. Initiator and MAMBO distribute manure over the different land types according to the location of livestock and land use maps, taking into account the amount of manure that is allowed per soil type and land-use. More information on the Initiator model can be found in Kros *et al.,* (2019) The MAMBO model is described in Kruseman *et al.,* (2012).

Finally, final data on the use of artificial fertilisers and compost in 2020 differs from the preliminary numbers. This decreases the N_2O emissions in 2020.

5.4.6 *Category-specific planned improvements*

The LULUCF sector has updated its methodology this year to include changes in carbon stocks in croplands and agricultural grasslands. In 2023, it will be investigated how to quantify the emissions from 3Da5 Mineralization/immobilization associated with losses/gains of carbon stocks in soils.

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 86.9% between 1990 and 2021 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 (in Tg CO_2 eq.).

Sector/category	Gas	1990	2020	2021	2021 vs 1990	Contribution to total in 2021 (%) by		
		Emissions in Tg CO_2 eq			%	sector	total gas	total CO_2 eq
3G. Liming	CO_2	0.183	0.031	0.024	-86.9%	0.1%	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 consists mainly (30%–55% of the total) 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.

5.5.2 *Methodological issues*

Data on liming are derived from annually updated statistics on fertiliser use. The yearly 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 the IPCC Tier 1 methodology. More detailed descriptions of the methodologies and EFs used can be found in chapter 15 in Van der Zee et al., (2023).

5.5.3 Uncertainty and time series consistency

Uncertainty
The Approach 1 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 period 1990–2021 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

The final usage of limestone and dolomite in 2020 differs from the preliminary numbers resulting in an 1% increase of CO2 emissions in 2020.

5.5.6 Category-specific planned improvements

No category-specific improvements are currently planned.

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 3804% from 1990 to 2021 (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 (in Tg CO_2 eq).

Sector/category	Gas	1990	2020	2021	2021 vs 1990	Contribution to total in 2021 (%) by		
		Emissions in Tg CO_2 eq			%	sector	total gas	total CO_2 eq
3H. Urea Application	CO_2	0.002	0.050	0.059	3803.8%	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 fertilizer use. The yearly amounts of 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 in Van der Zee *et al.*, (2023).

5.6.3 *Uncertainty and time series consistency*

Uncertainty

The Approach 1 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*

The final usage of urea in 2020 differs from the preliminary numbers resulting in an 6% increase of CO2 emissions in 2020.

5.6.6 *Category-specific planned improvements*

No category-specific improvements are currently planned.

6 Land use, land use change and forestry (CRF sector 4)

Major changes in the LULUCF sector compared with the National Inventory Report 2022	
Emissions:	Total reported LULUCF emissions in 2021 increased by 4% compared with 2020. Compared with the base year, emissions in 2021 were 31% lower. As a result of methodological changes described in this NIR 2023, emissions in the LULUCF sector for the year 1990 increased by 7.6% compared with the NIR 2022. For 2020 they increased by 16.6%compared with the NIR 2022.
New Key categories:	4B Cropland CO_2 4C Grassland CH_4
Methodologies:	In the NIR 2023, three methodological changes have been implemented: 1) a Tier 3 model (RothC) using spatially explicit input data on soil management was implemented to calculate carbon stock changes in mineral soils in Cropland and agricultural grasslands, replacing the previous assumption of dynamic equilibrium , 2) Historic data on production, import, and export of harvested wood products (HWP) from 1960 onwards have been considered in calculating HWP emissions and removals, now also taking the legacy effect of pre-1990 HWP into consideration, and 3) a Tier 1 methodology with country specific emission factors was applied for assessing CH_4 emissions from drainage ditches in Forest land, Cropland and agricultural grassland on organic soils. These CH_4 emissions from drainage ditches were not considered before; previously these drainage ditches were considered part of the drained Cropland or Grassland with the CO_2 emissions associated with the Cropland and Grassland attached to them. Additionally, based on data from the 7th National Forest Inventory (NFI-7), harvest rates of round wood from forests were adjusted for the period from 2014 onwards. This has an effect on both carbon stock gains and carbon stock losses in living biomass in Forest land, but does not affect the net carbon stock change of living biomass. It also has an effect on the distribution of wood harvests over fuel wood (resulting in instantaneous oxidation) and industrial roundwood (input to HWP).

Finally, the emission factors for drained organic (peat and peaty) soils were corrected. New analyses assessing the effects of measures aimed at reducing emissions from peat meadows showed that the reduction of emissions over time could not be justified. In the current situation the emission factors for drained peat and peaty soils remain constant over time, while the area of peat and peaty soils decreases as a result of the ongoing oxidation of organic matter.

6.1 Overview of sector

6.1.1 General overview of shares and trends in sources and sinks

This chapter describes the 2023 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 mineralization 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. Other emissions of CH_4 from Wetlands are not estimated due to lack of data.

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 Arets et al. 2023).

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, etc. 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[4]). Since 1990, the agricultural land area has decreased by about 5% mainly because of conversion to settlements/infrastructure and nature.

[4] 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.

Table 6.1 shows the sources and sinks in the LULUCF sector in 1990, 2020 and 2021. For 1990 and 2021, total net emissions are 6.2 Tg CO_2 eq. and 4.3 Tg CO_2 eq., respectively. The results for 2020 have been added to give insights into annual changes.

Sector 4 (LULUCF) accounted for about 2.5% of total national CO_2-equivalent emissions in 2021.

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 2021 (7.2 Tg CO_2 in 1990). This drainage leads to peat oxidation and is due to agricultural and urban water management; it is the major contributor to the net emissions of Cropland (4B), Grassland (4C) and Settlements (4E). Additionally, drainage ditches added 8.7 Gg CH_4 (0.22 Tg CO_2 eq.) in 2021, compared to 10.9 Gg CH_4 (0.27 Tg CO_2 eq.) in 1990.

Forests constitute the major net CO_2 sink with -2.1 Tg CO_2 in 2021, which includes Forest land remaining forest land (4A1) and Land converted to forest land (4A2).

Table 6.1 Overview of the sector Land use, land use change and forestry (LULUCF) in the base year and the last two years of the inventory (in Tg CO_2 eq.). Emissions of CH_4 and N_2O are only given for the total as the subdivision over the separate land-use categories in most cases will result in emissions that are smaller than 0.1 Tg CO_2 eq.

Sector/category	Gas	1990	2020	2021	2021 vs 1990	Contribution to total in 2021 (%) by		
		Emissions in Tg CO_2 eq			%	sector	total gas	total CO_2 eq
4. Total Land use Categories	CO_2	5.8	3.8	4.0	-31.7%	92.4%	2.8%	2.3%
	CH_4	0.3	0.2	0.2	-20.1%	5.7%	0.2%	0.1%
	N_2O	0.1	0.1	0.1	-15.4%	1.9%	0.1%	0.0%
	All	6.2	4.1	4.3	-30.9%	100.0%		2.5%
4A. Forest land	CO_2	-2.5	-2.2	-2.1	-16.0%	-47.8%	-1.4%	-1.2%
4A1. Forest land remaining Forest Land	CO_2	-1.9	-1.7	-1.6	-16.5%	-36.3%	-1.1%	-0.9%
4A2. Land converted to Forest Land	CO_2	-0.6	-0.5	-0.5	-14.5%	-11.4%	-0.3%	-0.3%
	All	-2.5	-2.2	-2.1	-16.0%	-47.8%	-1.4%	-1.2%
4B. Cropland	CO_2	3.3	2.0	2.0	-39.0%	46.8%	1.4%	1.2%
4B1. Cropland remaining Cropland	CO_2	1.9	0.9	0.8	-56.6%	19.2%	0.6%	0.5%
4B2. Land converted to Cropland	CO_2	1.4	1.2	1.2	-14.9%	27.5%	0.8%	0.7%
	All	3.3	2.0	2.0	-39.0%	46.8%	1.4%	1.2%

Sector/category	Gas	1990	2020	2021	2021 vs 1990	Contribution to total in 2021 (%) by		
		Emissions in Tg CO_2 eq			%	sector	total gas	total CO_2 eq
4C. Grassland	CO_2	3.9	2.6	2.6	-34.0%	60.4%	1.8%	1.5%
4C1. Grassland remaining Grassland	CO_2	4.3	2.7	2.7	-36.7%	62.5%	1.9%	1.6%
4C2. Land converted to Grassland	CO_2	-0.3	-0.1	-0.1	-70.2%	-2.2%	-0.1%	-0.1%
	All	3.9	2.6	2.6	-34.0%	60.4%	1.8%	1.5%
4D. Wetlands	CO_2	0.0	0.0	0.0	-475.5%	-1.0%	0.0%	0.0%
4D1. Wetlands remaining Wetlands	CO_2	NO,IE,NA	NO,IE,NA	NO,IE,NA		0.0%	0.0%	0.0%
4D2. Land converted to Wetlands	CO_2	0.0	0.0	0.0	-475.5%	-1.0%	0.0%	0.0%
	All	0.0	0.0	0.0	-475.5%	-1.0%	0.0%	0.0%
4E. Settlements	CO_2	1.0	1.2	1.2	17.5%	27.3%	0.8%	0.7%
4E1. Settlements remaining Settlements	CO_2	0.2	0.4	0.5	111.0%	10.6%	0.3%	0.3%
4E2. Land converted to Settlements	CO2	0.8	0.7	0.7	-8.3%	16.7%	0.5%	0.4%
	All	1.0	1.2	1.2	17.5%	27.3%	0.8%	0.7%
4F. Other land	CO_2	0.1	0.2	0.2	82.4%	3.8%	0.1%	0.1%
4F1. Other land remaing other Land	CO_2			0.0				
4F2. Land converted to Other Land	CO_2	0.1	0.2	0.2	82.4%	3.8%	0.1%	0.1%
	All	0.1	0.2	0.2	82.4%	3.8%	0.1%	0.1%
4G. Harvested wood products	CO_2	-0.1	0.1	0.1	-282.4%	2.9%	0.1%	0.1%
National Total GHG emissions (incl. CO_2 LULUCF)	CO_2	169.4	140.9	144.4	-14.8%			
	CH_4	36.0	19.2	19.0	-47.4%			
	N_2O	16.2	7.5	7.2	-55.3%			
	Total	228.9	168.9	172.0	-24.9%			

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 (Arets et al., 2023).

The methodology of the Netherlands for assessing emissions from LULUCF is primarily based on the 2006 IPCC Guidelines (IPCC, 2006) and follows a carbon stock change approach 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 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’) are presented in a matrix (see Chapter 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 Arets et al., 2023). 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 in 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 separately monitored, and subsequent calculations of carbon stock changes differ from one another (see Arets et al., 2023).
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, 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.

Table 6.2 Carbon stock changes reported in the national inventory per land use (conversion) category.Pools for which carbon stock changes are reported are indicated in bold, 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.

From **To↓**	**FL**	**CL**	**GL**	**WL**	**Sett**	**OL**
FL	BG (T2) BL (T2) DW (T2) Litt (T2) MS (NA) OS (T2) FF (T1)	BG (T2) BL (T2) DW (NE[1]) Litt (NE[1]) MS (T2) OS (T2) FF (IE)	BG (T2) BL (T2) DW (NE[1]) Litt (NE[1]) MS (T2) OS (T2) FF (IE)	BG (T2) BL (T2) DW (NE[1]) Litt (NE[1]) MS (T2) OS (T2) FF (IE)	BG (T2) BL (T2) DW (NE[1]) Litt (NE[1]) MS (T2) OS (T2) FF (IE)	BG (T2) BL (T2) DW (NE[1]) Litt (NE[1]) MS (T2) OS (T2) FF (IE)
CL	BG (T1) BL (T2) DM (T2) MS (T2) OS (T2) WF (IE)	BG (NA, n.s. 6.5.1) BL (NA, n.s., 6.5.1) DM (NA, n.s., 6.5.1) MS (T3) OS (T2) WF (IE)	BG (T1) BL (T1) DM (NA, n.s., 6.5.1, 6.6.1) MS (T2) OS (T2) WF (IE)	BG (T1) BL (NO) DM (NA, n.s., 6.5.1, 6.7.1) MS (T2) OS (T2) WF (IE)	BG (T1) BL (NO) DM (NA, n.s. 6.5.1, 6.8.1) MS (T2) OS (T2) WF (IE)	BG (T1) BL (NO) DM (NA, n.s. 6.5.1, 6.9.1) MS (T2) OS (T2) WF (IE)
GL	BG (T1, T2) BL (T2) DM (T2) MS (T2) OS (T2) WF (IE)	BG (T1, T2) BL (T1, T2) DM (NA, 6.5.1, 6.6.1) MS (T2) OS (T2) WF (IE)	BG (T2) BL (T1, T2) DM (NO, NA, n.s 6.6.1) MS (T3) OS (T2) WF (T1)	BG (T1, T2) BL (NO) DM (NA, n.s 6.6.1, 6.7.1) MS (T2) OS (T2) WF (IE)	BG (T1, T2) BL (NO) DM (NA, n.s 6.6.1, 6.8.1) MS (T2) OS (T2) WF (IE)	BG (T1, T2) BL (NO) 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; 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.
[1)] see chapter 4.2.2 of Arets et al. (2023).

Forest land, Cropland, Grassland, and Settlements are key categories, the last three due to their significant 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 for 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 for 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 with 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 see Arets et al. (2023). 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 fertilizers, use of cover crops, removal of straw and soil carbon content. A consistent time series of the input data has been made for the period 2005-2021. The year 2005 was chosen as this is aligned with the start of the reference period for managed cropland and managed grassland accounting, following the EU LULUCF regulation. Moreover, no detailed data was available for the period before 2005. Additional research will be done to improve the time series 1990-2004 in the future. Calculations are performed at 4-digit zip code level, which are about 3400 units with agricultural land. Further details on the input data can be found below.Further details on the input data can be found below.

- Climate data: Monthly data for the period 1983-2021 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.
- Crop yield is based on harvest statistics from Statistics Netherlands (CBS), for main crops at provincial level and other crops at national level.
- Organic fertilizer supply is based on data from the Initiator model, which is also used in the National Emission Model for Agriculture (NEMA) for reporting of the Agriculture sector. A distinction is made between grazing and fertilizer application on grassland and arable land. Data is based on nitrogen applications and converted using average C/N ratios to carbon.

- Compost inputs are based on data for 2017 and equally distributed over arable land. This is only a small supply source of carbon compared to manure.
- Green manures and catch crops: For 2017 and 2021 detailed regional data from BRP is available, for 2018-2020 this is interpolated and for 2005-2016 national data from NEMA on total areas of catch crop after maize and after other arable crops was used.
- 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)[5]) for wheat and barley straw. 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 Soil Sampling Programme from 2018 (Knotters et al., 2022), but this considers spatial variation in soil carbon only to a limited extent. Therefore a new soil carbon map was created based on digital soil mapping, in which the data from the Soil Sampling Programme is used and linked to a whole 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 with the actual monthly climate data from the Dutch meteorological institute (KNMI). As the model is quite sensitive to the climate parameters, the annual variability of the SOC balance was quite large (-0.41 to +0.25 ton C/ha). Therefore, we opted to use the 5 year average SOC balance for C fluxes in the categories Cropland remaining Cand Grassland remaining grassland. This 5 year period is in line with the 5 year accounting periods of the EU LULUCF regulation and also with the national forest inventory, which is based on a 5 year cycle.

For the period before 2005 not all required input variables are available. To still get a consistent time series the average carbon stock change per soil type and land use type for the period 2005-2009 is applied to the period 1990-2004.

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 Arets et al., 2023).

For the Netherlands, the LSK national sample survey of soil map units (Finke et al., 2001) is the basis for quantifying carbon emissions from

[5] 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 were classified into 11 soil types and 4 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 transition period of 20 years 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 through the use of a 1970 land-use map. This also means that the 20 year transition period is included in land that converted to another land use before 1990.

Carbon stock changes in organic soils

Based on the definition of organic soils in the 2006 IPCC Guidelines, two types of organic soils are considered. Firstly, peat soils with a peat layer of at least 40 cm within the first 120 cm, and, secondly, 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 at 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 Arets et al., 2023 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 is 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 in 2040 was used (Erkens et al., 2021, for more details see Arets et al. 2023). 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 different 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 paragraph on "emissions and removals from drainage and rewetting and other management of organic soils" below. More detailed information is provided in Arets et al. (2023).

Based on the available datasets, two different approaches for calculating the EFs for peat soils and for peaty soils have been developed (see Arets et al., 2023). For CO_2 emissions from cultivated peat soils, the methodology is described in Kuikman et al. (2005). This method is based on subsidence as a consequence of 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 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} in both 1990 and 2004, indicating no changes in EF occurring over time. In previous submissions it appeared that the EF decreased over time, but new improved analyses showed that there is actually no significant reduction in the emissions factor over time.

For peaty soils, another approach was used based on 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 thickness of the peat layer 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. Based on 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 cannot be completely excluded that the old drainage systems from the agricultural sites are still active. Therefore, to account for possible emissions, the area of forest planted on organic soils 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 Arets et al., 2023). 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. On average for the period 1990–2017, 79% of the forests on peat soil were on nutrient-rich peat soils and 21% on nutrient-poor peat soils (see Arets et al., 2023); 100% of the forests on peaty soils were on nutrient-rich peaty soils. These ratios were subsequently applied to the Tier 1 EFs to get 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 Arets et al., (2023).

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 determined as drained Forest land, Cropland or Grasslands consists of drainage ditches. To these areas a country specific emission factor of 518 kg CH_4 ha^{-1} yr^{-1} is applied based on 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 2.4 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 (Arets et al., 2023). 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 Arets et al., (2023), 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 led to 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 extend and intensity of fires is becoming 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 wild fires are reported as IE.

6.1.3 *Changes this year and recalculations for years previously reported*

1) This year, three methodological changes have been implemented resulting in modifications to the carbon stock changes and associated emissions and removals along (part of) the time series:Change in method to calculate carbon stock changes in mineral soils for Cropland remaining cropland and Grassland remaining grassland under agricultural use
2) Change in method and use of input data for Harvested Wood Products (HWP)
3) Implementing a Tier 1 methodology with country specific emission factors for assessing CH_4 emissions from drainage ditches in Forest land, Cropland and agricultural grassland on organic soils.

Methodology change: carbon stock changes mineral soils
For Cropland remaining cropland and Grassland remaining grassland under agricultural use, changes in carbon stocks in mineral soils are now calculated dynamically with the RothC model. In previous submissions the Tier 1 assumption of dynamic equilibrium was applied, which implied that no net carbon stock changes were reported. The model provides dynamic carbon stock changes that differ over time (see part on mineral soil in section 6.1.2 above)

This methodological change implies recalculations for mineral soils in Cropland remaining cropland and Grassland remaining grassland for the whole time series (see Figure 6.1).

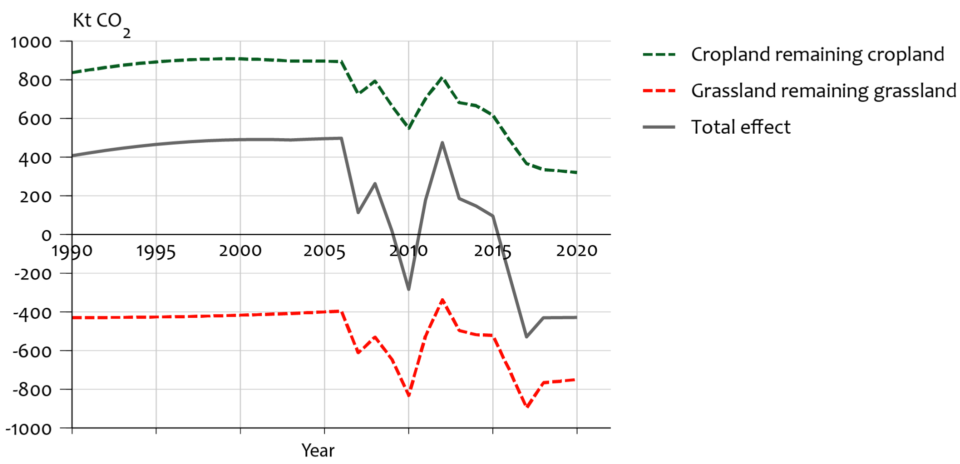

Figure 6.1 Effect of methodological change in mineral soils for Cropland remaining cropland and grassland remaining grassland. These are the differences compared to the 2022 submission where the pool – land use category combinations were dynamic equilibrium in carbon stock changes was assumed and which was reported as NA.

Methodological change: Harvested Wood Products
For the calculation of carbon stock changes in HWP, now also carbon inflows for the years before 1990 (from 1960 onwards) are included to take into consideration the legacy effect of previous inflows which contribute to carbon stock losses from HWP in subsequent years (following the first order decay). In previous inventories, the starting

point was input of HWP from 1990 onwards. Other elements of the methodology remained the same. This methodological change was implemented in response to recommendation L.19 from the review report of the NIR 2021 (L.9 in the draft 2022 review report).

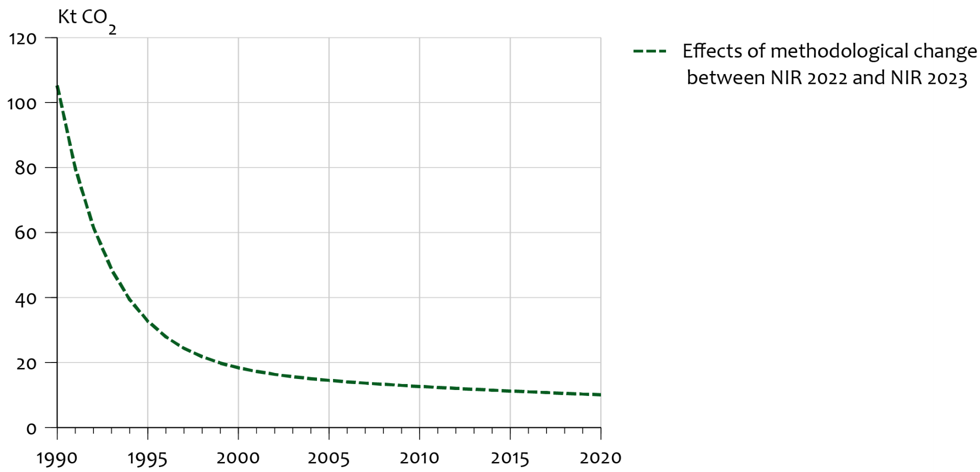

Figure 6.2 Effect of methodological change of including carbon inflows for the years before 1990, resulting in additional carbon stock losses (CO_2 emissions) following the first order decay function of those historic carbon inflows.

Methodological change: Implementing CH_4 emissions from drainage ditches

A Tier 1 methodology with country specific emission factors for assessing CH_4 emissions from drainage ditches in Forest land, Cropland and agricultural grassland on organic soils was implemented. This change was implemented in response to previous recommendations. For the description of the methodology see the paragraph on "*Emissions and removals from drainage and rewetting and other management of organic soils*" in section 6.1.2 above. Previously these CH_4 emissions from drainage ditches were not considered, but instead these drainage ditches were considered part of the drained Forest land, Cropland or Grassland with their CO_2 emissions associated with drained Forest land, Cropland and Grassland included .

As a result of this change, the area used for calculating carbon stock losses (CO_2 emissions) in drained organic soils decreased by 5% (as this area now is considered to be covered by drainage ditches for which CH_4 emissions are calculated). As a consequence, emissions from drained organic soils under Forest land, Cropland and Grassland as reported in CRF tables 4.A (Forest land), 4.B (Cropland) and 4.C (Grassland) decreased by 5% compared to the NIR2022, while for 5% of the drained areas CH_4 emissions from drainage ditches are reported in Table 4(II) in a sub-category "drainage ditches" under organic soils in Forest land, Cropland and Grassland. The differences with the NIR 2022 are indicated in Table 6.3.

Table 6.3 Differences with the reported emissions in the NIR2022. Drained land correction refers to the 5% decrease of CO_2 emissions from drained land area that is now considered drainage ditch area for which CH_4 emission are calculated.

	Drained land correction (kt CO_2)		Drainage ditches (kt CH_4)		(kt CO_2 eq.)		Total (kt CO2 eq)	
	1990	2020	1990	2020	1990	2020	1990	2020
Forest land	-3.9	-3.3	0.1	0.1	3.1	3.0	-0.9	-0.4
Cropland	-82.1	-41.7	2.7	1.7	68.7	41.4	-13.5	-0.3
Grassland	-268.0	-204.1	8.1	7.0	201.5	174.3	-66.5	-29.8
Total	-354.1	-249.1	10.9	8.7	273.3	218.6	-80.8	-30.5

Updated data
Harvest rates of round wood from forests were adjusted for the period from 2014 onwards based on data on the wood balance in forests from the 7th National Forest Inventory (NFI-7). With this wood balance the total fellings from Dutch forests can be determined and from this also the share of industrial round wood and fuel wood. See Annex 3 of the methodological background report (Arets et al., 2023). The previous data were estimated based on extrapolation of the data from the NFI-6 and these now have been replaced by the measured data from the NFI-7.

Since the harvested wood is part of the gross changes in carbon stocks it is considered simultaneously for calculating gross carbon stock gains as well as for calculating gross carbon stock losses in living biomass in addition to the net changes as calculated directly from the NFI data (see section 6.4.2 and Arets et al., 2023). As a result the updated data only have an effect on the calculated gross carbon stock gains and losses, but not on the net carbon stock changes in living biomass which determine the net emissions or removals.

Nevertheless, it has an effect on the distribution of wood harvests over fuel wood (resulting in instantaneous oxidation) and industrial roundwood as input to HWP. The updated data thus have a small effect on the carbon stock changes in HWP.

Correction of emission factors
Emission factors for drained organic (peat and peaty) soils were corrected in this 2023 inventory compared to the NIR 2022. New analyses assessing the effects of measures aimed at reducing emissions from peat meadow areas revealed an error in the calculation of the emission factor based on the 2014 soil map. Following the new calculations, the emission factors for drained peat and peaty soils remain constant over time, while the area of peat and peaty soils decreases as a result of the ongoing oxidation of organic matter. In the previous NIR the emission factors for peat soils decreased from 19.0 ton CO_2 ha^{-1} in 1990-2014 to 17.7 ton CO_2 ha^{-1} in 2014 after which the decreasing trend was extrapolated. After the correction the emission factor remains 19.0 ton CO_2 ha^{-1} over the whole time series. For peaty soils the emission factor gradually decreased from 13.0 ton CO_2 ha^{-1} in 1990-2014 to 12.0 ton CO_2 ha^{-1} in 2014 after which the decreasing

trend was extrapolated. After the correction the emission factor for peaty soils remains 13.0 ton CO_2 ha^{-1} over the whole time series.

As a result, emissions from drained organic soils from 2014 onwards are higher than those emissions reported in the NIR 2022. This effect increases from 29 kt CO_2 higher emissions in 2014 to 528 kt CO_2 in 2020.

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 their correspondence to the land use, land use change, and forestry categories that need to be covered. The Netherlands has defined the different land use categories in line with the descriptions given in the 2006 IPCC Guidelines. For more detailed information see Arets et al., 2023).

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, these 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 are not available. Currently, the situation on the topographical map is used as 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 stratified 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, in the Netherlands the main undergrowth of orchards 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 Arets et al., 2023).
  In the calculations, orchards are not spatially explicitly included. Instead, statistics on areas of orchards are used. See Arets et al., (2023) for details.

Wetlands (4D)
The Netherlands is characterised by wet areas. Many of these areas are covered by grassy vegetation and these are included under Grassland. Some wetlands are covered by rougher vegetation consisting of wild grasses or shrubs, and these are reported in the sub-category Nature, under Grassland. Forested wetlands (e.g. willow coppices) are included in Forest land.

Therefore, in the Netherlands, only reed marshes and open water bodies are included in the Wetland land use category. This includes natural open water in rivers, but also man-made open water in channels, 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.

Settlements (4E)
In the Netherlands, the main categories included under the category Settlements 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 therefore 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 used 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 (Arets et al., (2019, 2023); Kramer and Clement, (2015); Kramer et al., (2007, 2009a,b); Van den Wyngaert et al., 2012), resulting in four national-scale land use and land use change matrices covering the periods 1970-1990 (Table 6.4), 1990–2004 (Table 6.5), 2004–2009 (Table 6.6), 2009–2013 (Table 6.7), 2013–2017 (Table 6.8) and 2017-2021 (Table 6.9). The information concerning 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 Arets et al., (2023).

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 were 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 Arets et al., 2023 for more details).

The classification of forest areas on the underlying topographical maps used to compile the LULUCF maps accounts for management interventions to prevent harvested areas from being classified under Deforestation (D). Additional information on (planned) destination 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 that of 2014, as the new map is considered more accurate than the old one. The resulting array of trajectories was then 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 period 1970-1990. This procedure concerned 1.9% of the total land area.

The resulting array of trajectories was then aggregated so that only unique trajectories remained.
Please note that for comparison 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 6.4 Land use and land-use change matrix aggregated to the six UNFCCC land-use categories for the period 1970-1990 (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 6.5 Land use and land-use change matrix aggregated to the six UNFCCC land use categories for the period 1990–2004 (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 6.6 Land use and land-use change matrix aggregated to the six UNFCCC land use categories for the period 2004–2009 (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 6.7 Land use and land-use change matrix aggregated to the six UNFCCC land use categories for the period 2009–2013 (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 6.8 Land use and land-use change matrix aggregated to the six UNFCCC land use categories for the period 2013–2017 (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 6.9 Land use and land-use change matrix aggregated to the six UNFCCC land use categories for the period 2017–2021 (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 are derived from these land-use change matrices (see Arets et al. (2023) 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 inter-annual changes such as Cropland–Grassland rotations are not captured, e.g., 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 timewise and thus are better able to capture short-term rotations between Grassland and Cropland.

Between 1970-2013, forest area steadily increased, followed by the sharp decline between 2013-2017. In the period 2017-2021 there was also a net loss of forest area, but the gross changes show that deforestation rates more than halved compared to the period 2013-2017.

More detailed analyses of the land-use maps (see Schelhaas et al. 2021) show 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 was higher than that of deforestation. 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 foresees in 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[6]). 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 different carbon pools in Forest land;
- Land converted to Forest land (4A2): includes estimates of changes in land use to Forest land during the 20-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] Report on the 7th Forest Inventory with results only in Dutch. 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

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 (Arets et al., 2023). 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 are based on four National Forest Inventories (NFI) carried out in 1988–1992 (HOSP: Schoonderwoerd and Daamen, 1999), 2000–2005 (NFI-5: Daamen and Dirkse, 2005),2012–2013 (NFI-6: Schelhaas et al., 2014) and 2017-2021 (NFI-7: Schelhaas et al, 2022). As these most accurately describe 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 four moments in time; 1990 (HOSP), 2003 (NFI-5), 2012 (NFI-6) and 2021 (NFI-7).

Changes in carbon stocks in living biomass in forests were calculated using plot-level data from the HOSP, NFI-5 NFI-6 and NFI-7 inventories. 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 Arets et al., (2023).

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 three repeated measures, changes in biomass and carbon stocks were assessed for the periods 1990–2003, 2003–2012, and 2012-2021. 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 20 and 30 years ago. These are reported under Forest land remaining forest land, but the calculation of 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 Arets et al., 2023):

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 dbh as independent variable, provided in a study by Forrester et al. (2017) based on a European-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 Arets et al 2023 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 2003), 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 6.10 and Arets et al., 2023). These are weighted for the representative area of each of the NFI plots for each NFI.
3) Based on 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, above and belowground biomass are 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 four forest inventories, HOSP, NFI-5, NFI-6 and NFI-7) 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 Arets et al., 2023 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)[7], and annex 5 in Arets et al., 2023), result in a strong net increase in growing stock over time.

Table 6.10 Average Growing stock (GS; m^3 ha^{-1}), aboveground biomass (AGB; tonnes dry matter ha^{-1}), BCEF (tonnes d.m. per m^3 stemwood volume), net annual increment (NAI; m^3 ha^{-1} yr^{-1}), belowground biomass (AGB; 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).Values in between the years are linearly interpolated.

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	158	0.713	113	25
1991	161	0.714	115	25
1992	164	0.714	117	26
1993	167	0.715	120	26
1994	170	0.715	122	26
1995	174	0.716	124	27
1996	177	0.717	127	27
1997	180	0.717	129	28
1998	183	0.718	131	28
1999	186	0.719	134	28
2000	189	0.719	136	29
2001	192	0.720	138	29
2002	195	0.720	141	30
2003	199	0.721	143	30
2004	200	0.723	145	30
2005	202	0.726	147	31
2006	204	0.728	149	31
2007	206	0.730	151	32
2008	208	0.733	152	32
2009	210	0.735	154	32
2010	212	0.737	156	33
2011	214	0.739	158	33
2012	216	0.742	160	34
2013	217	0.744	162	34
2014	219	0.748	164	34
2015	220	0.751	165	35

[7] 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 an age, growing stock and harvests.

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})
2016	222	0.755	167	35
2017	223	0.759	169	36
2018	224	0.762	171	36
2019	226	0.766	173	36
2020	227	0.769	175	37
2021	229	0.773	177	37

Dead wood
Dead wood volume is available from the four 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 and is done for lying and standing dead wood (see Arets et al., 2023). For deadwood, a wood density was used equal to 60% of the values for fresh wood.

Litter
Analysis of carbon stock changes based on collected data has shown a probable build-up of litter in Dutch forest land. Data from around 1990, however, are extremely uncertain and, therefore, in order to be conservative, this highly uncertain sink is not reported (see Arets et al., 2023).

Nevertheless, when land is converted to Forest land transitions to Forest land remaining forest land, a litter layer will have formed in the 20 years of that forest area's existence. Therefore in units of Forest land that newly enter the category Forest land remaining Forest land in the reporting year, carbon stocks will increase to the average carbon stock in litter in Forest land remaining forest land. This is similar to the losses of carbon stocks in litter reported for units of land converted from Forest land to other land use categories (i.e. deforestation), see section 6.4.2.3 below.

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 different forest inventories. The gross gains in biomass between the inventories were thus 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 same 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 Arets et al., (2023) for more details.

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 period 1980–1992 has been used for all years from 1990 onwards (Arets et al., 2023).

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 6.10 and 6.11). These values change yearly 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 therefore 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 pointed to 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 Arets et al., (2023) 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, these 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 Arets et al., (2023), 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
Fertilizers 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 show that carbon stocks in newly planted forests reach the carbon stock of average forests in 30 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 30 years.

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 organic matter
The accumulation of dead wood and litter in newly established forest plots is not known, though it is definitely a carbon sink (see Arets et al., 2023). This sink is not reported in order to be conservative. However in the year that land converted to Forest land transitions to the Forest land remaining forest land category, an amount equal to the average carbon stock in litter in Forest land remaining forest land is reported as a carbon stock gain under Forest land remaining forest land.

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 above and below ground 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 Forest land remaining forest land established less than 30 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 chapter 4.2.2 in Arets et al., (2023).

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 6.11 Emission factors for deforestation (Mg C ha^{-1}).

Year	EF dead wood	EF litter
1990	0.41	57.8
1991	0.49	59.0
1992	0.57	60.1
1993	0.64	61.3
1994	0.72	62.4
1995	0.79	63.5
1996	0.87	64.7
1997	0.95	65.8
1998	1.02	66.9
1999	1.10	68.1
2000	1.17	69.2
2001	1.25	70.4
2002	1.33	71.5
2003	1.40	72.6
2004	1.45	72.0
2005	1.50	71.4
2006	1.55	70.8
2007	1.60	70.2
2008	1.64	69.5

Year	EF dead wood	EF litter
2009	1.69	68.9
2010	1.74	68.3
2011	1.79	67.7
2012	1.84	67.1
2013	1.88	66.4
2014	2.00	65.8
2015	2.11	65.2
2016	2.22	64.6
2017	2.34	63.9
2018	2.45	63.3
2019	2.56	62.7
2020	2.67	62.1
2021	2.78	61.4

Dead wood
Total emissions from the dead wood component after 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 Chapter 4.2.3 in Arets et al., (2023) and resulting emission factors in Table 6.11), which includes both standing and lying dead wood)).

Litter
Total emissions from the litter component after deforestation are calculated by multiplying the total area deforested by the average carbon stock in litter. Thus it is assumed that, with deforestation, all carbon stored in AGB and BGB is lost to the atmosphere. 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 a national level (Van den Wyngaert et al., 2012). Data for litter layer thickness and carbon in litter are available from five different datasets, but none of these can be used exclusively. Selected forest stands on poor and rich sands were also intensively sampled with the explicit purpose of providing conversion factors or functions. From these data, a stepwise approach was used to estimate the national litter carbon stock in a consistent way. A step-by-step approach was developed to match mean litter stock values with any of the sampled plots of the available forest inventories (HOSP, NFI-5 and NFI-6).

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 Arets et al., (2023): section 4.2.1). Carbon stock changes per area of litter pool of the area of deforestation is high compared with 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 Chapter 4.2.3 in Arets et al., (2023) and resulting emission factors in Table 6.11).

6.4.3 *Uncertainty and time series consistency*

Uncertainties

The Approach 1 analysis in Annex 2 shown in Table A2.4 provides estimates of uncertainty by IPCC source category. The Netherlands also applies an improved uncertainty assessment to the LULUCF sector with better representation of uncertainties in the land use matrix, using Monte Carlo simulations for combining different types of uncertainties (see chapter 14 in Arets et al., 2023, for details). The analysis combines uncertainty estimates of forest statistics, land use and land use change data (topographical data), and the method used to calculate the yearly 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 Arets et al. (2023) for details.

Time series consistency

To ensure time series consistency in Forest land remaining forest land, for all years up to 2021 the same approach is used for activity data, land use area, and emissions calculation. 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 is used for activity data, land use area, and emissions calculation 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 new methodology considering 5% drainage ditches in organic soils and the error correction of the emission factor for peat and peaty soils described in section 6.1.3 have resulted in recalculations for emissions from organic soils in Forest land.

6.4.6 *Category-specific planned improvements*

Currently available data do not allow the calculation of carbon stock changes in litter in newly established forests, and annual carbon stock changes in Forest land remaining Forest land are also considered to be an uncertain sink conservatively estimated to be zero (see section 4.2 in Arets et al., 2023). In the NFI-7, new litter data were collected. Currently additional data are collected on carbon content of the litter layer. Based on this it will be possible to relate litter thickness measurements from the NFI5, NFI6 and NFI7 to carbon content in the litter layer. Additional measurements are foreseen for 2023. The new methodology then is expected to be ready for use in the NIR 2024.

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). Based on 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 IEF 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, neither are carbon stock gains in DOM 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 20-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 Arets et al., (2023).

6.5.3 *Uncertainty and time series consistency*

Uncertainties

The Approach 1 analysis in Annex 2 Table A2.4 provides estimates of uncertainties for each IPCC source category. The Netherlands also applies an improved uncertainty assessment to the LULUCF sector with better representation of uncertainties in the land use matrix, using Monte Carlo simulations for combining different types of uncertainties (see Chapter 13 in Arets et al., (2023) for details). 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 Arets et al. (2023) for details.

Time series consistency

To ensure time series consistency for all years up to 2021, the same approach is used for activity data and land use area.

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*

The new methodology considering 5% drainage ditches in organic soils and the error correction of the emission factor for peat and peaty soils described in section 6.1.3 have resulted in recalculations for emissions from organic soils in Cropland along the whole time series.

- The new methodology regarding emissions and removals from management of mineral soils result in increased emissions from mineral soils in Cropland remaining cropland ranging from 896 kt CO_2 in 2005 to 321 kt CO_2 in 2020 (also see Figure 6.1).

See also section 6.1.3.

6.5.6 Category-specific planned improvements

No category-specific improvements are 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 the approach to calculating the carbon stock changes differs between them.

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 therefore 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 of 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 neither the carbon stock gains in DOM are 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 within the 20-year transition period changes from one Grassland (non-TOF) category to another (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) until the end of the 20 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 with conversions from other land use categories. The changes in carbon stocks in mineral soils will also be included using a 20 year transition period, similar to conversions between Forest land and Grassland (non-TOF).

6.6.2 *Methodological issues*

With regard to soil emissions a 20-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

Bijlage 1 *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 different vegetation types to the total Grassland (non-TOF) area (see Table 6.12).

Default values for dry matter and carbon factors are used to determine carbon stocks in living biomass in grassland vegetation and nature. Combined, these give 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[8] 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[9]. Between the measurement years (1997, 2002, 2007, 2012 and 2017), the age developments were interpolated and before and after linearly extrapolated based on 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 6.12). Areas of orchards published by Statistics Netherlands (CBS) between 1992 and 2016[10] and for 2017 onwards[11] are used to assess the area-weighted average carbon stocks in Grassland non-TOF (Table 6.12). 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 on net emissions (around -4 kt CO2), it was decided to not correct for this 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 Arets et al., (2023).

Table 6.12 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	24.2	22.7	550.1	1426.4	9129.1	1450.7	9679.2	6.67
1991	23.9	22.6	540.7	1419.7	9086.3	1443.7	9627.0	6.67
1992	23.6	22.5	531.8	1413.0	9043.3	1436.7	9575.1	6.66

8 https://opendata.cbs.nl/statline/#/CBS/nl/dataset/81735NED/table?ts=1517993072950
9 https://opendata.cbs.nl/statline/#/CBS/nl/dataset/81735NED/table?ts=1517993072950
10 https://opendata.cbs.nl/statline/#/CBS/nl/dataset/70671NED/table?fromstatweb
11 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)
1993	23.4	22.4	524.5	1406.2	9000.0	1429.7	9524.5	6.66
1994	23.4	22.3	521.1	1399.3	8955.5	1422.7	9476.6	6.66
1995	22.4	22.2	496.6	1393.3	8917.1	1415.7	9413.7	6.65
1996	22.2	22.1	490.4	1386.5	8873.5	1408.7	9363.9	6.65
1997	22.2	22.0	489.0	1379.4	8828.5	1401.7	9317.4	6.65
1998	21.6	21.9	473.9	1373.0	8787.4	1394.7	9261.3	6.64
1999	21.1	21.8	460.8	1366.5	8745.9	1387.7	9206.7	6.63
2000	19.8	21.7	428.8	1360.9	8709.9	1380.7	9138.7	6.62
2001	18.8	21.6	405.1	1354.9	8671.5	1373.7	9076.6	6.61
2002	18.5	21.5	397.8	1348.2	8628.4	1366.7	9026.2	6.60
2003	17.7	21.8	385.1	1342.0	8588.9	1359.7	8974.1	6.60
2004	17.6	22.1	389.0	1338.5	8566.6	1356.1	8955.6	6.60
2005	17.4	22.4	389.0	1335.2	8545.3	1352.6	8934.3	6.61
2006	17.4	22.7	396.0	1331.6	8522.0	1349.0	8918.0	6.61
2007	17.7	23.0	407.5	1327.7	8497.4	1345.4	8905.0	6.62
2008	17.9	23.3	416.0	1324.0	8473.8	1341.9	8889.8	6.62
2009	18.1	23.6	426.1	1312.1	8397.7	1330.2	8823.8	6.63
2010	17.8	23.8	423.9	1300.7	8324.5	1318.5	8748.4	6.64
2011	17.6	24.1	423.0	1289.3	8251.3	1306.8	8674.3	6.64
2012	17.2	24.4	419.1	1278.0	8178.9	1295.1	8598.0	6.64
2013	17.5	25.0	436.7	1292.5	8271.7	1309.9	8708.4	6.65
2014	17.5	25.6	449.2	1307.2	8365.8	1324.7	8815.0	6.65
2015	18.5	26.2	485.1	1321.7	8459.0	1340.2	8944.1	6.67
2016	19.1	26.8	512.4	1335.9	8549.8	1355.0	9062.1	6.69
2017	18.6	27.4	508.6	1344.5	8604.6	1363.0	9113.2	6.69
2018	18.4	28.0	515.3	1352.6	8656.9	1371.0	9172.2	6.69
2019	18.4	28.6	525.2	1360.7	8708.4	1379.1	9233.6	6.70
2020	18.0	29.2	535.0	1369.1	8762.1	1387.1	9287.2	6.70
2021	17.8	29.8	529.0	1377.5	8815.7	1395.2	9344.8	6.70

Trees outside forests
For Trees Outside Forests (TOF), no separate data on growth or increment are 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 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 area burned 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 for these no carbon stock losses and associated CO_2 emissions are calculated. 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, and the areas reported in CRF Table 3.D in the Agriculture sector. To improve transparency, a comparison between the different areas is presented in Table 6.13.

Table 6.13 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. All areas on 1 January of the years.

Year	Area grassland (non-TOF)			Area drained cultivated grassland		
	Peat	Peaty	Total	Peat	Peaty	Total
	kha					
1990	222.661	96.225	318.886	206.394	88.816	295.210
1991	221.075	95.660	316.735	204.924	88.286	293.211
1992	219.497	95.097	314.594	203.462	87.759	291.221
1993	217.929	94.536	312.465	202.007	87.234	289.241
1994	216.369	93.977	310.346	200.560	86.711	287.271
1995	214.818	93.420	308.238	199.121	86.191	285.311
1996	213.276	92.866	306.142	197.688	85.672	283.360
1997	211.742	92.313	304.056	196.264	85.156	281.420
1998	210.218	91.763	301.981	194.846	84.642	279.489
1999	208.702	91.215	299.917	193.437	84.131	277.567
2000	207.196	90.669	297.864	192.034	83.621	275.656
2001	205.698	90.125	295.822	190.639	83.114	273.754
2002	204.209	89.583	293.791	189.252	82.610	271.862

Year	Area grassland (non-TOF)			Area drained cultivated grassland		
	Peat	Peaty	Total	Peat	Peaty	Total
	kha					
2003	202.728	89.043	291.771	187.872	82.107	269.979
2004	201.158	88.512	289.670	186.412	81.579	267.991
2005	199.595	87.980	287.575	184.959	81.051	266.010
2006	198.039	87.447	285.486	183.512	80.523	264.035
2007	196.491	86.914	283.404	182.072	79.996	262.068
2008	194.950	86.379	281.329	180.639	79.468	260.107
2009	193.969	85.800	279.769	179.727	78.885	258.612
2010	192.997	85.217	278.214	178.823	78.299	257.122
2011	192.033	84.633	276.665	177.926	77.713	255.639
2012	191.076	84.046	275.122	177.038	77.124	254.162
2013	190.605	84.705	275.310	176.582	77.758	254.340
2014	190.483	85.293	275.776	176.446	78.323	254.768
2015	190.350	85.881	276.231	176.299	78.889	255.188
2016	190.205	86.471	276.676	176.141	79.457	255.598
2017	190.007	86.426	276.433	176.029	79.483	255.512
2018	189.805	86.384	276.189	175.913	79.511	255.424
2019	189.600	86.345	275.945	175.794	79.542	255.336
2020	189.390	86.309	275.699	175.670	79.577	255.247
2021	189.183	86.289	275.472	175.548	79.623	255.170

6.6.3 *Uncertainty and time series consistency*

Uncertainties

The Approach 1 analysis in Annex 2 Table A2.4 provides estimates of uncertainties by IPCC source category. The Netherlands also applies an improved uncertainty assessment to the LULUCF sector with better representation of uncertainties in the land use matrix, using Monte Carlo simulations for combining different types of uncertainties (see chapter 14 in Arets et al., (2023) for details). The uncertainty range for CO_2 emissions in category 4C Grassland (non-TOF) is calculated at 75%. For CH4 and N2O uncertainties are much higher, mainly due to uncertainties in emission factors, see Arets et al., (2023) for details. There is currently no Monte Carlo uncertainty assessment based on the TOF category, but uncertainties are likely to be similar to those of Forest land – except that the uncertainty related to the land use map may be larger as a result of the inherently small patches of TOF. A new Monte Carlo uncertainty assessment including TOF is foreseen in the NIR 2024.

Time series consistency

To ensure time series consistency, the same approach is used for activity data, land use area and emissions calculation for all years up to 2021. 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. Inter-annual changes in implied EFs in mineral soils are the result of changes 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 20-year transition periods for carbon stock changes in soils, further affects the inter-annual 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

The new methodology considering 5% drainage ditches in organic soils and the error correction of the emission factor for peat and peaty soils described in section 6.1.3 have resulted in recalculations for emissions from organic soils in Cropland along the whole time series.

The new methodology regarding emissions and removals from management of mineral soils result in increased removals from mineral soils in grassland remaining grassland ranging from -343 kt CO_2 in 2012 to -904 kt CO_2 in 2017 (also see Figure 6.1).

See also section 6.1.3.

6.6.6 Category-specific planned improvements

No improvements planned at the moment.

6.7 Wetlands (4D)

6.7.1 Source category description

The Wetland land use category mainly comprises 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, neither are carbon stock gains in DOM 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 of CH_4 from Wetland are not estimated due to a lack of data.

Emissions from fertilizer use in Wetland

The Wetland land use category mainly comprises 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.

6.7.3 *6.7.3 Uncertainty and time series consistency*

Uncertainties

The Approach 1 analysis in Annex 2Table A2.4 provides estimates of uncertainties according to IPCC source categories. The Netherlands also applies an improved uncertainty assessment to the LULUCF sector with better representation of uncertainties in the land use matrix, using Monte Carlo simulations for combining different types of uncertainties (see chapter 14 in Arets et al., (2023) for details).

The uncertainty range in the CO_2 emissions for 4D Wetlands is calculated at 75%; see Arets et al., (2023) for details.

Time series consistency

To ensure time series consistency, for all years up to 2021 the same approach has been used for activity data, land use area and emissions calculation.

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*

There are no category-specific recalculations. The new methodologies, new data and error corrections described in section 6.1.3 will result in a number of recalculations. See also section 6.1.3.

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, lowering of the groundwater table also leads to oxidation of peat that result 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, due 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 are 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 Settlement 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 fertilizer 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 Approach 1 analysis in Annex 2 Table A2.4 provides estimates of uncertainties for each IPCC source category. The Netherlands also applies an improved uncertainty assessment to the LULUCF sector with better representation of uncertainties in the land use matrix, using Monte Carlo simulations for combining different types of uncertainties (see chapter 14 in Arets et al., (2023), for details).

The uncertainty range in CO_2 emissions for 4E Settlements is calculated at 70%. For N2O uncertainties are much higher, due to uncertainties in emission factors, see Arets et al., (2023) for details.

Time series consistency
To ensure time series consistency, for all years up to 2021 the same approach is used for activity data, land use area and emissions calculation.

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*
The new methodologies, new data and error corrections described in section 6.1.3 will result in a number of recalculations.
See also section 6.1.3.

6.8.6 *Category-specific planned improvements*
No improvements are 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. This was, for a long time, 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 category Other land, 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 Approach 1 analysis in Annex 2 Table A2.3 provides estimates of uncertainties for each IPCC source category. The Netherlands also applies an improved uncertainty assessment to the LULUCF sector with better representation of uncertainties in the land use matrix, using Monte Carlo simulations for combining different types of uncertainties (see chapter 14 in Arets et al., (2023) for details).

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 Arets et al., (2023) for details.

Time series consistency

To ensure time series consistency, for all years up to 2021 the same approach is used for activity data, land use area, and emissions calculation.

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*

The new methodologies, new data and error corrections described in section 6.1.3 will result in a number of recalculations.
See also section 6.1.3.

6.9.6 *Category-specific planned improvements*

No improvements are planned.

6.10 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 of 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 chapter 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 in the different HWP pools is based on the data reported from 1961 onwards to the FAO for its statistics on imports, production, and exports of the different 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 different 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 6.14) 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 35-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., 2022). Using the production approach to HWP therefore implies that no gains in paper and paperboard are expected.

Table 6.14 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

For harvested wood products, no Approach 1 uncertainty estimate is currently available. The Netherlands has, however, included HWP in the improved uncertainty assessment of the LULUCF sector using Monte Carlo simulations for combining different types of uncertainties (see chapter 14 in Arets et al., (2023) for details).

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 Arets et al., (2023) 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 period 1990–2019 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
Input values for calculation of the HWP emissions and removals have been updated for the year 2021 based on data provided by Teeuwen et al. (2023).

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 with the National Inventory Report 2022	
Emissions:	In 2021, total GHG emissions from the Waste sector further reduced by 3,1% compared with 2020; and by 78.7% compared with 1990.
New Key categories:	5B Biological treatment of solid waste: composting CH_4 5D Wastewater treatment and discharge N_2O
Methodologies:	In Category 5D wastewater handling, the methods of the 2019 Refinement of the IPCC 2019 Guidelines are newly applied in the calculations. This results in the recalculation of CH_4 and N_2O emissions from Public WWTPs (category 5D1) as well as the calculation of 2 new sources: - Indirect CH_4 emissions from surface waters as a result of discharges of COD via domestic and industrial effluents (category 5D3) - N_2O emissions from aerobic biological industrial WWTPs (category 5D2)

7.1 Overview of 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 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 (in Tg CO_2 eq.).

Sector/category	Gas	1990	2020	2021	2021 vs 1990	Contribution to total in 2021 (%) by		
		Emissions in Tg CO_2 eq			%	sector	total gas	total CO_2 eq
5 Waste	CH_4	15.8	2.8	2.7	-82.8%	77.4%	14.3%	1.6%
	N_2O	0.7	0.8	0.8	8.0%	22.6%	11.0%	0.5%
	All	16.5	3.6	3.5	-78.7%	100.0%		2.0%
5A. Solid Waste Disposal	CH_4	15.3	2.5	2.4	-84.6%	67.1%	12.4%	1.4%
5A1. Managed Waste Disposal on Land	CH_4	15.3	2.5	2.4	-84.6%	67.1%	12.4%	1.4%
5B. Biological treatment of solid waste	CH_4	0.0	0.1	0.1	2762.0%	3.9%	0.7%	0.1%

Sector/category	Gas	1990	2020	2021	2021 vs 1990	Contribution to total in 2021 (%) by		
		Emissions in Tg CO_2 eq			%	sector	total gas	total CO_2 eq
	N_2O	0.0	0.1	0.1	1314.2%	2.3%	1.1%	0.0%
	All	0.01	0.21	0.22	1968.9%	6.2%		0.1%
5D. Wastewater treatment and discharge	N_2O	0.7	0.7	0.7	-2.1%	20.3%	9.8%	0.4%
	CH_4	0.4	0.2	0.2	-46.9%	6.4%	1.2%	0.1%
	All	1.1	0.9	0.9	-18.6%	26.6%		0.5%
Total national emissions (incl LULUCF)	CO_2	169.4	140.9	144.4	-14.8%			
	CH_4	36.0	19.2	19.0	-47.4%			
	N_2O	16.2	7.5	7.2	-55.3%			
	Total	228.9	168.9	172.0	-24.9%			

Table 7.1 shows the contribution of 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 and not 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., 2023), see also the reference in Annex 7.

The Waste sector accounted for 2.0% of total national emissions (including LULUCF) in 2021, compared with 7.2% in 1990. Emissions of CH_4 and N_2O accounted for about 77% and 23% of CO_2-equivalent emissions from the sector, respectively. Emissions of CH_4 from waste of which more than 67% originates from landfills (5A1 Managed waste disposal on land), accounted for 12.4% of total CH_4 emissions in 2021. 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).

Emissions from the Waste sector decreased by 78.7% between 1990 and 2021 (from 16.5 Tg CO_2 eq. in 1990 to 3.5 Tg CO_2 eq. in 2021; see Figure 7.1), mainly due to an 84.6% reduction in CH_4 from landfills. Between 2020 and 2021, CH_4 emissions from landfills decreased by 4.7%.

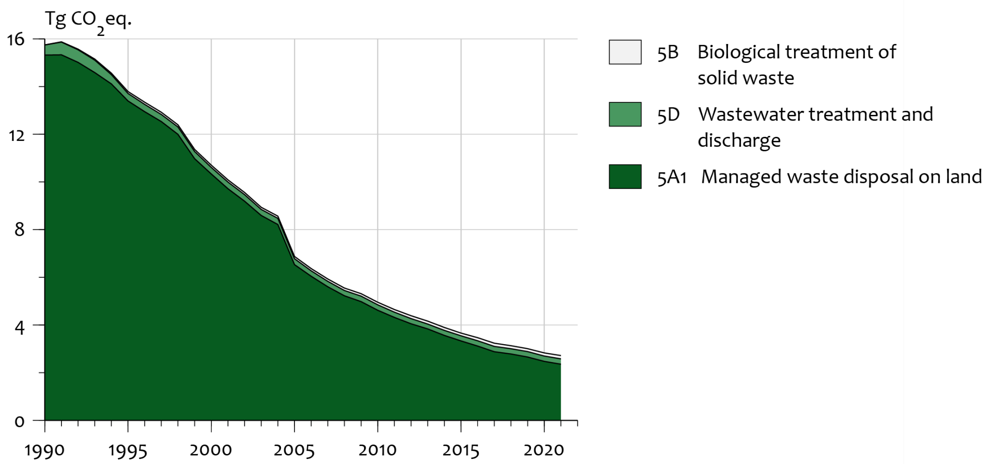

Figure 7.1 Sector 5 Waste – trend and emissions levels of source categories, 1990–2021.

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 13% in 2021).

As indicated above, emissions from waste incineration (5C) are included in category 1A1ai 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 2021, emissions accounted for approximately 2.8 Tg CO_2 eq. (2,671 Gg CO_2 and 0.42 Gg N_2O); see also Table 7.8.

7.2 Solid waste disposal on land (5A)

7.2.1 Category description

In 2021, there were 19 operational landfill sites. 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 both cases, 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 major 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 land-filled waste) and higher methane recovery rates from landfills (see sections 7.2.2 and 7.2.3).

The share of CH_4 emissions from landfills in the total national inventory of GHG emissions was 6.7% in 1990 and 1.4% in 2021. This decrease is partly due to the increase in recovered CH_4, from about 4% in 1990 to 13% in 2021 as indicated above. A second cause is the decrease in methane produced at solid waste disposal sites (SWDS) due to a decrease in the relative amount of methane in landfill gas from 57% to 50%.

In 2021, solid waste disposal on land accounted for 67.1% of total emissions from the Waste sector and 1.4% 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 old 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.[12] 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 2021, thereby 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., (2023).
Data on the amount of waste disposed at landfill sites derive mainly from the annual survey performed by the Working Group on Waste Registration (WAR) at all the landfill sites in the Netherlands. These data are documented in Rijkswaterstaat, (2023), which also gives the annual amount of CH_4 recovered from landfill sites.

In order to calculate CH_4 emissions from all landfill sites, for modelling purposes it is assumed 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

[12] 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), decreasing to 0.5 in 2005 (IPCC parameter) and remaining constant thereafter;
- 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 to 50% in 2005 (IPCC parameter) and remaining constant thereafter.
- Amount of recovered landfill gas, published in the annual report 'Waste processing in the Netherlands' (Rijkswaterstaat, 2023);
- 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 shows an overview of landfilled waste and its degradable organic carbon content (DOC).

Table 7.2 Amounts of waste landfilled and degradable organic carbon content.

Year	Amount landfilled (Mton)	Degradable organic carbon (kg/ton)
1945	0.1	132
1950	1.2	132
1955	2.3	132
1960	3.5	132
1965	4.7	132
1970	5.9	132
1975	8.3	132
1980	10.6	132
1985	16.3	132
1990	13.9	131
1995	8.2	125
2000	4.8	110
2005	3.5	62
2010	2.1	33
2011	1.9	31
2012	3.3	32
2013	2.7	33
2014	2.2	34
2015	2.3	43
2016	2.8	52
2017	2.9	56
2018	3.2	51

Year	Amount landfilled (Mton)	Degradable organic carbon (kg/ton)
2019	2.8	49
2020	2.4	43
2021	2.1	38

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 for 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 on (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 are supplied by the WAR and included in the annual report 'Waste processing in the Netherlands'. Information on how these data are gathered and the scope of the information used can be found in these reports, available since 1991 from the WAR (Rijkswaterstaat).

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 period 1945–1990 was determined at 132 kg/ton (Spakman et. al., 2003). In the period 1991–1997, the fraction degradable organic carbon (DOCf) value slowly declined due to the start of separate collection of organic waste 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 the 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 period 2000–2004, effects of the policy of reducing the amount of DOC being landfilled (especially in waste from households) resulted in a decrease of the DOC value from 110 kg/ton in 2000 to 74 kg/ton in 2004.

From 2005 onwards all landfilled waste is 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 10 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 shows the waste stream groups with their DOC values and the amount landfilled in 2021 . Table 7.4 shows the amount landfilled by waste group since 2005.

Table 7.3 Amount of waste landfilled in 2021 and DOC value of each group.

Waste stream group	**Amount landfilled (ton)**	**DOC value (kg/ton)**	**Total DOC landfilled (ton)**
Waste from households	20,319	182	3,698
Bulky household waste		192	
Commercial waste		182	
Cleansing waste	1,967	43.4	85
Fresh organic waste	53,753	112	6,020
Stabilised organic waste	264,670	130	34,407
Little organic waste	769,231	44	33,846
Contaminated soil	214,588	11.5	2,468
Dredging spoils	18,570	42.4	787
Inert waste	799,544	0	0
Wood waste	2,286	430	983
Total	**2,144,928**	**43**	**82,295**

Table 7.4 Amount of waste 2005-2021 by waste stream group (kiloton)

Waste stream group	**2005**	**2010**	**2015**	**2018**	**2019**	**2020**	**2021**
Waste from households	347	22	153	156	83	34	20
Bulky household waste	22	0	0	0	0	0	0
Cleanising waste	62	6	5	15	12	7	2
Waste that contains high content of DOC	97	26	80	169	78	61	54
Stabilised organic waste	555	159	167	563	571	351	265

Waste stream group	2005	2010	2015	2018	2019	2020	2021
Waste that contains low content of DOC	965	604	738	887	752	913	769
Contaminated soil	735	633	218	268	301	205	215
Dredging spoils	232	194	140	64	23	23	19
Inert Waste	486	481	841	1,115	986	815	800
Wood waste	7	0	0	0	3	1	2
Total	**3,509**	**2,126**	**2,342**	**3,237**	**2,808**	**2,409**	**2,145**

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. The IPCC default value for DOCf is 0.5.

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). It was therefore decided to use the IPCC default value of 0.5 from 2005 onwards.

Materials never decompose completely. For waste streams considered to be ‘biodegradable’, like the ‘organic wet fraction’ (OWF), a conversion of about 70% appears to be the maximum achievable. Under landfill conditions, this conversion is significantly lower. A practical test with the Bioreactor concept during the TAUW research (2011) shows that biogas production is approximately 25% of the potential maximum. In addition to the less favourable conditions in the landfill, the low value is explained by an overestimation of landfill degradability (by 10–15 percentage points) and aerobic degradation in the first stage after deposition (about 15 percentage points, based on a laboratory test). If these values are taken into account, approximately 46% of the carbon is decomposed within the test period (aerobic + anaerobic). In the long term, degradation may increase and an f value of 0.58 can be approximated. This f value, however, relates only to anaerobic degradation; there is no correction for aerobic degradation in the initial stage of the landfill process (Tauw, (2011): pp. 89–90).

Therefore, we acknowledge that the IPCC default value of 0.5 is quite accurate for the amount of waste that actually decomposes.

k-value

The k-value is used for 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 period 1989-2004, a country-specific value for k (0.094) was determined with a validation of a landfill gas model (Oonk, 1994). Due to changing waste composition as a result of waste policies in the early 90s, 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 an IPCC-default value of 0.05 for the k-value has been used in the Dutch model from 2005 onwards.

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 also too high, 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 physic-chemical 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 as defined in 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.

A few landfill sites are semi-aerobic. At three selected landfill sites, research is currently being undertaken 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 wastes 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 that there is 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 about 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).

Based on 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 period 1990–2004.

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 2021, the methane content and amount of recovered landfill gas at 4 landfill sites was estimated. Table 7.5 shows the amounts of recovered landfill gas, the average methane content, and the amount flared or used for energy purposes.

Table 7.5 Amount of landfill gas recovery.

Parameter	1990	1995	2000	2005	2010	2015	2020	2021
Free emission of landfill gas (million m3)	1,564	1,367	1,055	770	542	390	288	274
Free emission of methane (kton)	547	478	369	233	165	119	88	84
Recovered landfill gas (million m3)	64	182	162	130	102	60	51	46
Amount used for energy purposes (million m3)	48	136	119	98	79	43	23	20
Amount combusted in flares (million m3)	16	45	43	32	22	17	28	27
Percentage of methane in recovered landfill gas (%)	57,4	57,4	57,4	53,2	51,3	49,6	46,1	44,6
Amount recovered methane (kton)	25	71	63	47	35	20	16	14
Amount recovered methane useful applied (kton)	19	53	46	35	28	15	7	6
Amount recovered methane flared (kton)	6	18	17	12	8	6	9	8

Use of country specific values before 2005
The Netherlands used a landfill gas model with country-specific values between 1990 and 2004. 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 with 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 7.5. The integration time for the emissions calculation is defined as the period from 1945 to the year for which the calculation is made.

Table 7.6 Parameters used in the IPCC Tier 2 method that change over time (additional information on solid waste handling).

Parameter	1990	1995	2000	2005	2010	2015	2020	2021
Fraction DOC in landfilled waste	0.13	0.13	0.11	0.06	0.03	0.04	0.04	0.04
CH_4 generation rate constant (k)	0.09	0.07	0.07	0.05	0.05	0.05	0.05	0.05
Number of SWDS recovering CH_4	45	50	55	50	53	54	52	53
Fraction CH_4 in landfill gas	0.57	0.57	0.57	0.5	0.5	0.5	0.5	0.5

7.2.3 *Uncertainty and time series consistency*

Uncertainty

The Approach 1 uncertainty analysis in Annex 2 provides estimates of uncertainties by IPCC source category and gas. 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 0,3% 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 with the previous submission, minor errors for the years 2000 till 2020 in the data have been corrected in this submission.

7.2.6 Category-specific planned improvements

No planned improvements.

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 4.0 million tons in 2021. In 2021, 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 for 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., (2023).

The activity data for the amount of organic waste composted at industrial composting facilities derive mainly from the annual survey performed by the WAR at all industrial composting sites in the Netherlands (Rijkswaterstaat, 2022). 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 amount are based on 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., 2023).

Table 7.7 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

Year	organic waste from households (Mton)		Green waste from gardens and enterprises (Mton)	
	Composted	Digested	Composted	Digested
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

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 50% and 60% respectively. The uncertainty is mainly determined by uncertainties in the EF (50% for CH_4 and 60% 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 every four to five years against EFs in other European countries.

7.3.5 *Category-specific recalculations*
Compared with the previous submission no changes in the data have been corrected in this submission.

7.3.6 *Category-specific planned improvements*
No planned improvements.

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 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 the number of bonfires is known. An average volume is calculated based on 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, in so far they occur in Waste Incinerations plants (WIPs), are included in category 1A1 (Energy industries) as part of the source 1A1a (Public electricity and heat production), as 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 in Honig et al., (2023).

The activity data for the amount of waste incinerated derive 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, 2022). 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 Northwestern 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 7.8 shows 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 different waste streams.

Table 7.8 Composition of incinerated waste.

	1990	**1995**	**2000**	**2005**	**2010**	**2015**	**2020**	**2021**
Total waste incinerated (Gg)	2,780	2,913	4,896	5,503	6,459	7,564	7,572	7,504
Total waste incinerated (TJ)	22,746	27,903	51,904	55,058	63,818	75,299	71,742	70,605
Energy content (MJ/kg)	8.2	9.6	10.6	10.0	9.9	10.0	9.5	9.4
Fraction biomass (energy %)	58.2	55.2	50.4	47.8	53.1	54.2	53.5	53.7
Amount of fossil carbon (Gg)	164	221	433	561	675	780	739	728
Amount of biogenic carbon (Gg)	544	561	938	909	1,172	1,381	1,343	1,333

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 different components in the different waste streams. As stated above, for some waste streams the composition is updated yearly.

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 2021, 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 finally 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 of the amount and type of usage come from the annual survey of WIPs (Rijkswaterstaat, 2022). Detailed information can be found in Honig et al., (2022).

Based on 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. The Netherlands therefore 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., (2023). A comparison between the country-specific EFs and the IPCC defaults can also be found in this report. Table 7.9 shows the emissions from the waste incineration plants. The emission trend is directly related to the trend in the amount of waste processed.

Table 7.9 Emissions of incinerated waste.

(in Gg)	1990	1995	2000	2005	2010	2015	2020	2021
Total CO_2 emission	2,596	2,867	5,025	5,392	6,770	7,924	7,634	7,561
CO_2 captured and stored in a product	-	-	-	-	-	-	1	-
Fossil CO_2 emissions	601	810	1,586	2,058	2,473	2,861	2,709	2,671
Biogenic CO_2 emissions	1,995	2,058	3,439	3,334	4,296	5,063	4,925	4,889
N_2O emissions	0	0.1	0.1	0.1	0.1	0.2	0.4	0.4
Total GHG emissions (Gg CO_2 eq.)	620	839	1,647	2,129	2,562	2,975	2,821	2,782

7.4.3 *Uncertainty and time series consistency*

Uncertainty

Waste incineration

The Approach 1 uncertainty analysis is shown in Annex 2 which provides estimates of uncertainties by IPCC source category and gas. The uncertainty in the fossil CO_2 and N_2O emissions for 2021 from waste incineration is estimated at 7% and 99% respectively. The main factors influencing the uncertainties are the total amount being incinerated and the fractions of different 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).

The uncertainty in annual N_2O as well as CH_4 emissions from waste incineration under category 5C is substantive and estimated at more than 300%. The uncertainty in the activity data and the uncertainty in the corresponding EF for N_2O are estimated at 100% and 300%, respectively.

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 very good, due to the continuity of the data provided by the WAR.

7.4.4 Category-specific QA/QC and verification
The data on the amounts of waste incinerated are 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).

7.4.5 Category-specific recalculations
There are no category specific recalculations.

7.4.6 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 2021, only 0.5% 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 2021, 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 leads to CH_4 emissions.
After eventual on-site sludge digestion and dewatering processes, almost all sludges from domestic WWTP's are incinerated in mono-incinerators, or co-incinerated in either power plants or in cement factories. For a time-series of final treatment of sludges from domestic WWTP, see Statline Urban wastewater treatment (2022).

Subcategory **5D2 Industrial wastewater handling** includes CH_4 emissions from the operational anaerobic industrial WWTPs (IWWTPs) (2021: 50 plants) as well as N_2O emissions from aerobic biological industrial WWTP's (2021: 151 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 0.5% 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 has led to major changes in the height of the emissions compared to the previous NIR. This is explained in more detail in chapter 7.5.5.

N_2O emissions from category 5D (see Tables 7.1 and 7.9) contributed about 9.8% of total N_2O emissions in 2021 and 0.4% in total CO_2-equivalent emissions. In the period 1990–2021, N_2O emissions from domestic wastewater treatment (5D1) increased by 15%, while N_2O emissions from industrial wastewater treatment (5D2) decreased by 12%. Indirect N_2O emissions from surface waters (5D3) decreased by 67%. Overall, the N_2O emissions from category 5D decreased by 2%.

The contribution of wastewater handling to the national total of CH_4 emissions in 2021 was 1.2%, or 0.11% 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 stabilization system in one of the largest WWTPs. As the operation of the plant took a few years to optimize, venting emissions were higher in the introductory period (1991–1994) than under subsequent normal operating conditions. During the period 1990–2021, CH_4 emissions from category 5.D wastewater handling decreased by 47%. 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 shows the trend in GHG emissions from the different types of wastewater handling.

Table 7.9 Wastewater handling emissions of CH_4 and N_2O (Gg/year).

	1990	2000	2010	2015	2020	2021
CH_4 domestic WWTP[1)]	5.84	4.36	4.69	4.45	4.78	4.69
CH_4 industrial WWTP	0.29	0.39	0.38	0.38	0.41	0.41
CH_4 septic tanks	3.93	1.99	0.68	0.63	0.56	0.55
Indirect CH_4 from effluents	4.99	3.14	2.46	2.22	2.32	2.34
Net CH_4 emissions	15.05	9.88	8.21	7.69	8.08	7.99
CH_4 recovered[2)] and/or flared	33.0	40.6	40.0	44.4	47.3	47.9
N_2O domestic WWTP	2.05	2.13	2.21	2.24	2.35	2.35
N_2O industrial WWTP	0.19	0.18	0.14	0.17	0.16	0.16
Indirect N_2O from effluents	0.501	0.302	0.174	0.168	0.167	0.167
Total N_2O emissions	2.74	2.61	2.52	2.57	2.68	2.68

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 yearly questionnaires that cover all public WWTP's and is presented in StatLine (Statistics Netherlands, 2022); see also Statline for detailed statistics on wastewater treatment. Table 7.10 shows the development in the main activity data with respect to domestic wastewater treatment.

Data on anaerobic and aerobic industrial WWTP's also stem from Statistics Netherlands (Statistics Netherlands, 2022b) but the time-series only covers the period 1990-2016. The years 2017-2021 are as much as possible reconstructed with information from mainly company websites on the internet but most of the data are copied from 2016. In 2023 a new survey will result in actual timely data of the population industrial WWTP's for the year 2022. On basis of this new results, the data on 2017-2021 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 WWTP's are determined by measurements at all WWTP's. This is already long existing standard procedure and covers the whole time-series 1990-2021. All these data are collected by Statistics Netherlands.

From Table 7.10 it can be concluded that the DOC of treated domestic wastewater and sludge produced shows minor fluctuations over time in the last years. In 2021, methane emissions from domestic WWTP's decreased with 2.2% compared to 2020. Inter-annual 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., (2023).

Table 7.10 Activity data of domestic and industrial wastewater handling and discharges to surface water.

	Unit	1990	2000	2010	2015	2020	2021
Domestic (urban) WWTPs:							
Treated volume	Mm^3/yr	1,711	2,034	1,934	1,957	1,938	1,993
TOW as COD[1)] load	Gg/year	933	921	953	999	1,056	1,040
Nitrogen load	Gg/year	81.4	84.7	87.9	89.1	93.7	93.6
Sludge DOC as COD[1)2)]	Gg/year	365	431	476	505	533	529
Sludge dry solids to digesters	Gg/year	246	285	327	351	400	408
Biogas recovered [3)]	mio m^3/yr	74	87.9	98.5	107	130	137
Biogas flared	mio m^3/yr	8.96	6.15	7.36	7.41	9.79	10.4
Biogas vented	1,000 m^3/yr	2,524	284	1,066	82.3	131	81.1
Actual PE load WWTP[4)]	1,000	23,798	23,854	24,745	25,686	27,031	26,781
Industrial WWTPs:							
TOW as COD[1)] anaerobic WWTPs	Gg/year	144	194	192	190	206	206
Biogas recovered[3)]	Mio $m^3/year$					78.7 [5)]	77.5 [5)]
Nitrogen load to aerobic WWTPs	Gg/year	7.42	7.26	5.46	6.61	6.53	6.53
Septic tanks:							
Resident population [6)]	1,000	14,952	15,926	16,615	16,940	17,442	17,533
inhabitants with septic tank	% of pop.	4	1.9	0.62	0.57	0.49	0.48
Discharges to surface water:							
Nitrogen discharges[7)], total	Gg/yr	63.79	38.45	22.13	21.35	21.28	21.28
- Via effluents from UWWTP[8)]	Gg/yr	42.68	30.44	17.69	17.05	16.96	16.96
- Via industrial discharges[9)]	Gg/yr	12.71	4.51	2.36	2.29	2.02	2.02
- Via other direct discharges[10)]	Gg/yr	8.40	3.51	2.07	2.01	2.30	2.30
COD discharges, total	Gg/yr	178	112	87.8	79.2	83.0	83.7
- Via effluents from UWWTP's	Gg/yr	131	91.0	75.5	69.8	72.3	72.5
- Via industrial discharges	Gg/yr	46.8	21.1	12.3	9.48	10.7	11.1

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 2021, 99.5% 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 also sludges from smaller plants (in the vicinity) are digested.

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 in Honig et al. (2023). The calculation of emissions from these processes is described below in short.

1. Wastewater treatment process emissions
Methane emissions from the wastewater treatment process are calculated using a TIER 2 method with the default emission factor and country-specific activity data. The default emission factor for centralized 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 yearly survey conducted by Statistics Netherlands among the Water Boards and are based on monitoring at the WWTP’s following strict procedures. Data on influent COD are available for the years 1990 until present for each treatment plant.

Data on the sludge produced annually are available for the years 1990 until 2016, and for 2018 and 2020. Due to a re-evaluation of the statistical program, these data are only inventoried for even years from 2016 on. For odd years (starting 2017) the data of the previous year are used as a best estimate; see also section 2.3.2.4.2 in Honig et al., (2023).

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 is 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 in Honig et al., (2023).

Default activity data on the ingoing dry solids amount at public WWTPs with sludge digesters are derived from the yearly 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 2021, the amount of CH_4 emitted by the venting of biogas was 0.036 Gg CH_4, equaling 0.8% of total CH_4 emissions from the category Domestic wastewater. In the last decade, this value varied between 0.3% and 9%, i.e., so the venting of biogas in 2021 was 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 in Honig et al., (2023).

CH_4 emissions from anaerobic industrial wastewater treatment (5D2)
For industrial WWTP the calculation of the methane emissions has not changed yet as a result of adopting the 2019 refinement methods. First reason is that there were not enough resources to recalculate all the different 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 WWTP's will become available, making it possible to reconstruct the population of IWWTP's between 2016 and 2021. That will be the right moment 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. (2023).

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 standardized 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 are available from the Statistics Netherlands, (2018). TOW (expressed as COD) is thus calculated as:

TOW = P.E. * 0.8 * 40

With:

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 B_o of 0.25 kg/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 Bo * MCF * Mrind= 0.002 kg CH_4/kg COD. Further description of the method and the EF used can be found in section 2.3.2.4.5 in Honig et al. (2023).
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. Therefore, the activity data and resulting CH_4 emissions for 2021 are a copy of the 2020 values. As already addressed above, in 2023 a new survey will result in actual timely data of the population industrial WWTP's for the year 2022. On basis of this new results, the population IWWTP's for 2017-2021 will be reconstructed.

In 2021, 71% of the anaerobic capacity was installed within the food and beverage industry. Other sectors with anaerobic wastewater treatment are waste processing facilities (11%), the chemical industry (13%), and the paper and cardboard industry (5%).

Numerical estimate of the recovered CH_4 in anaerobic industrial wastewater treatment plants available for 2019-2021

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 (ePRTR) Reports. This could only be elaborated for 2019, 2020 and 2021 (see also table 7.10).

The total amount of IWWTP biogas recovered in 2021 equals 60.4 million m^3, but this only includes data from 31 of the 50 anaerobic IWWTPs, equaling 78% of total TOW treated. For the remaining 19 plants, no data are available, but based on the amount of TOW, this missing volume can be estimated at an extra 17.0 million m^3. Total recovery can then be estimated at 77.5 million m^3 biogas.

There is no specific information 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, 2023), a total recovery of 34.1 Gg CH_4 can be calculated for 2021. Applying a loss by leakage of 1% of total CH_4 recovered (Honig et al., (2023), this results in an emission of 0.341 Gg CH_4. This figure can be compared with the current CS method resulting in an emission of 0.411 Gg CH_4 (+19% higher). Given the uncertain factors of both methods, this difference seems acceptable.

CH_4 emissions from septic tanks (5D3)
Emissions of methane from septic tanks are calculated using IPCC default values for B0 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 in Honig et al. (2023).

Table 7.10 shows the time series of the percentage of the population connected to septic tanks. This percentage decreased from 4% in 1990 to 0.48% in 2020. These data derive from surveys, estimates and expert judgement by various organisations in the Netherlands, such as Rioned, (2009, 2016) 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)
This emission source is reported for the first time in this submission. 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 (IPCC, 2019).

The country-specific activity data on kg COD discharged per year via industrial and domestic effluents are 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 WWTP's and of all industrial discharges. Detailed information on the method and activity data can be found in section 2.3.2.4.8 in Honig et al. (2023).

N_2O emissions from centralized wastewater treatment (5D1)
N_2O emissions from domestic wastewater handling are recalculated with new methodology provided by the 2019 Refinement of the IPCC 2006 Guidelines (IPCC, 2019). The TIER 2 method uses a default emission factor of 0,016 kg N_2O-N/kg N and country-specific activity data on the total influent loads of nitrogen at all domestic WWTP's in the Netherlands. The activity data derive from the waste water statistics (see Statline) and are based on frequent monitoring of the incoming wastewater at all domestic WWTP's. Detailed information on the method and activity data can be found in section 2.3.2.4.2 in Honig et al. (2023).

The influent data on total-nitrogen includes the loads from households, from industrial and commercial activities as well as loads from urban run-off into the sewerage system. In equation 6.10 of the 2019 Refinement document, the total Nitrogen load in the influent thus can 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 2021, total Nitrogen in the influent equaled 93.6 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)
This emission source is reported for the first time in this submission. For the calculation of N_2O emissions from aerobic industrial wastewater treatment, a TIER 2 method is used based on the default emission factor of 0.016 kg N_2O-N/kg N and country-specific activity data on the total influent loads of nitrogen at all industrial aerobic WWTP's in the Netherlands.

The activity data stem from a time-series of aerobic industrial wastewater plants derived from statistics on industrial wastewater sludges (see Statline), as well as data of total nitrogen discharged from the Dutch PRTR database. For most of the IWWTP's an effluent load could be coupled. For the remaining installations, the effluent load was estimated based on 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 in Honig et al. (2023).

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 are derived from the waste water statistics (see Statline) and from the Netherlands' PRTR database. Most of the effluent loads of total Nitrogen are determined by frequent monitoring of treated waste water 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 thus can 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., (2023). 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. 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 tons of CH_4 per year, equaling 0.00085% of national methane emissions in 2016. Forthcoming CH_4 emissions are therefore reported as NE for 1990-2021.

7.5.3 *Uncertainty and time series consistency*

Uncertainty
The Approach 1 uncertainty analysis in Annex 2 provides estimates of uncertainties by IPCC source category and gas. The uncertainty in annual N_2O and CH_4 emissions from wastewater handling is estimated to be 160% 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 yearly 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 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%. For N2O the uncertaintity also varies per emission source and is estimated to be between 30% and 181%. All values are from IPCC (2019).

An international study (GWRC, 2011), in which the Dutch public wastewater sector participated, showed that N_2O EFs, in particular, are highly variable among 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; but at the same time the study provides no alternative method, 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, thereby 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 are 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 lead to the formation of CH_4 and N_2O in public WWTP.

7.5.5 *Category-specific recalculations*

In this submission the Netherlands introduced the methods according to the 2019 Refinement to the IPCC 2006 Guidelines (IPCC, 2019) for emissions sources in category 5D, resulting in 3 recalculations and 2 new emission sources.

For category **5D1 (domestic wastewater handling)** 3 major changes were introduced for the whole time-series 1990-2021:

1. N_2O emissions from centralized waste water treatment is now based on new activity data (Total nitrogen load in the influent, country-specific) and a new emission factor (default) from IPCC (2019).
2. Updated emission factor (default, from IPCC (2019)) in the calculation of CH_4 emission from the water-line of centralized waste water treatment.
3. CH_4 emissions from anaerobic sludge digestion is now based on new activity data (Total incoming dry solids weight) and corresponding new emission factor from IPCC (2019). Both are default.

For category **5D2 (industrial wastewater handling)** a new emission source was calculated as a result of the introduction of the 2019 Refinement (IPCC, 2019): the N_2O emission from aerobic biological industrial waste water treatment facilities. The calculation is based on country specific activity data (Total nitrogen load in the influent) and the default emission factor as introduced in the 2019 Refinement.

For category **5D3 (Indirect from wastewater effluents)** a new emission source was calculated as a result of the introduction of the 2019 Refinement (IPCC, 2019): the indirect CH_4 emission from surface waters as a result of discharges of domestic and industrial effluents. The calculation is based on Tier1 method using the default activity data (Total COD load discharged with domestic and industrial effluents) and the default emission factor.

Table 7.11. shows the difference in the emissions (per gas as well as total CO_2-equivalents) compared with the previous emissions for all 5D

emission sources per subcategory. This table also lists emission sources where the method remained unchanged.
The effect of adopting the methods of the 2019 Refinement on the height of the emissions is significant. Total CO_2-equivalents from category 5D increased in 1990 from 499 Gg to 1.148 Gg (+130%). Compared to the previous submission. total CO_2-equivalents in 2020 increased from 333 Gg to 937 Gg (+182%).

Table 7.11 Overall effect of introducing the 2019 Refinement methods in category 5D

(Sub)category		**Previous submission (Gg)**		**This submission (Gg)**		**Difference (%)**	
		1990	2020	1990	2020	1990	2020
5D1	CH_4 Centralized WWT	4.98	4.77	4.27	3.92	-14%	-18%
	CH_4 Anaerobic sludge digestion	2.08	3.65	0.493	0.800	-76%	-78%
	CH_4 Venting of biogas	1.07	0.0575	1.07	0.0575	0%	0%
	N_2O Centralized WWT	0.0762	0.0870	2.05	2.35	2598%	2604%
5D2	CH_4 Anaerobic industrial WWT	0.289	0.411	0.289	0.411	0%	0%
	N_2O Aerobic industrial WWT			0.186	0.164	New	New
5D3	CH_4 septic tanks	3.93	0.573	3.93	0.561	0%	-2%
	CH_4 indirect from effluents			4.99	2.32	New	New
	N_2O indirect from effluents	0.501	0.170	0.501	0.167	0%	-2%
5D	Total CH_4	12.4	9.45	15.0	8.08	22%	-15%
	Total N_2O	0.577	0.257	2.74	2.68	375%	943%
	Total CH_4 CO_2-eq	346	265	421	226	22%	-15%
	Total N_2O CO_2-eq	153	68.2	727	711	375%	943%
	Total CO_2-equivalents	499	333	1,148	937	130%	182%

Apart from above mentioned major changes there were also some smaller recalculations, due to final activity data on total N discharges. The indirect N_2O emissions from surface water as a result of the discharge of domestic and industrial effluents (5D3. Wastewater effluents) decreased in 2020 with 0.003 Gg N_2O (-1.8%) compared to the previous submission.
Due to revised estimate of the % of habitants connected to septic tanks for 2020. the CH_4 emission from septic tanks decreased with 0.011 Gg CH_4 (-2.0%).

7.5.6 *Category-specific planned improvements*

There are category-specific improvements planned for the next submission. For N_2O emissions from domestic wastewater handling it will be considered if recent published literature can be used to replace the emission factor from IPCC (2019).

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 CH4 from surface waters as a result of discharge of wastewaters it will be investigated whether a distinction between type of surface water (stagnant waters versus rivers) can be introduced in the method.

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. Indirect CO_2 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 0.92 Tg in 1990 to 0.50 Tg in 2021, 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 (in Tg CO_2 eq.).

Sector/category	Gas	1990	2020	2021	2021 vs 1990	Contribution to total in 2021 (%) by		
		Emissions in Tg CO_2 eq			%	sector	total gas	total CO_2 eq
Indirect CO_2 emissions	CO_2	0.9	0.4	0.5	-45.2%	5.7%	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 are obtained from the Dutch PRTR.

9.3 Uncertainty and time series consistency

Based on 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 are no category-specific recalculations.

9.6 Category-specific planned improvements

No improvements are planned.

10 Recalculations and improvements

Major recalculations and improvements compared with the National Inventory Report 2022

For the NIR 2023, the most recent data (2021) have 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. These include error corrections of previous submissions, resulting in changes in emissions over the entire 1990–2020 period.

Other 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.

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 2023, the Netherlands used the CRF Reporter software v6.0.10_AR5.

The 2022 ERT review of the UNFCCC and the EU review reports suggested there was still room for improvement in the Dutch GHG inventory. To the extent possible, the review recommendations have (where deemed necessary) been incorporated in this NIR and CRF, and accordingly, in the methodology reports.

In Annex 10, the UNFCCC review issues are listed including the actions undertaken to resolve them. Please note that Annex 10 is based on the preliminary main findings report as the final review report was not yet available.

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 2023 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 with the NIR 2022) 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.
  - In 2022 an important change in the energy statistics (for 1990-2020) was induced as improved estimates of the diesel use in mobile machinery became available (updated emission model). The fuel use by mobile machinery is calculated higher than in previous submissions. This change implicated an increase in emissions from diesel use from mobile machinery most visible in 1.A.2.g.vii (+968 kton in 1990 to +72 kton CO_2 in 2020).
  - The CO_2, CH_4 and N_2O emissions from road transport have also been recalculated (reduced) for the years 2015 to 2020 as a result of a change in the treatment of the statistical difference in the energy balance.
  - Besides these overarching corrections of the energy statistics an error was detected in the emission estimate of one of the Dutch refineries for 2020. The CO_2 emission in the category 1A1b is reduced by 3% (-250 kton CO_2) in 2020 compared to the previous submission.
  - Update of the model to calculate the residential wood combustion (biomass) which led to changes in the emissions in 1A4bi for the years 1990-2020. Depending on the heating degree days in the year the changes vary between -161 kton CO_2 to +427 kton CO_2 from biomass.

The above recalculations and error correction changed the total CO_2 eq. emissions in the Energy sector 1A category by +0.54 % in 1990 to -0.9 % in 2020 compared to previous submission.

- *IPPU sector:*
  - Due to improvement in the energy statistics the emission from lubricant use (2D) changed compared to the previous submission.
  - The same holds for the ureum use in transport (2007-2020), also reported in 2D3.
  - Recalculation of the HFC emission in 2F1 for the years 2019 and 2020.

The above recalculations changed the total CO_2 eq. emissions in the IPPU sector by less than 0.001 % in 1990 to 3.2 % in 2020 compared to previous submission.

- *Agriculture sector:*
  - Recalculation of the CH_4 emissions in 3A from 2004 to 2020 due to a correction of the feed data for dairy cattle.
  - Improved activity data on the amount of processed manure leading to increased CH_4 emissions in the years 1998 to 2020 in 3B.

    - New data on the distribution of manure, pasturing animals, and artificial fertilisers on grassland and arable land led to reduced N_2O emissions in 3D for the years 2000 to 2020.
    - Recalculation of the direct N_2O emissions reported under 3D due to the recalculations in the LULUCF sector. This affected the complete timeseries.

The above recalculations changed the total CO_2 eq. emissions in the Agriculture sector by -0.16 % in 1990 and by -0.43 % 2020 compared to previous submission.

- *LULUCF sector:*
    - This year, three methodological changes have been implemented resulting in modifications to the carbon stock changes and associated emissions and removals along (part of) the time series:
        - Change in method to calculate carbon stock changes in mineral soils for cropland remaining cropland (4B) and grassland remaining grassland (4C) under agricultural use
        - Change in method and use of input data for Harvested Wood Products (HWP; 4.Gs1)
        - Implementing a Tier 1 methodology with country specific emission factors for assessing CH_4 emissions from drainage ditches in cropland and agricultural grassland on organic soils 4(II).
    - Next to the methodological changes, a correction of the emission factors for drained organic soils was implemented for all years from 2014 onwards.
    - Additionally, based on data from the 7th National Forest Inventory (NFI-7), harvest rates of round wood from forests were adjusted for the period from 2014 onwards. This has an effect on both carbon stock gains and carbon stock losses in living biomass in forest land, but does not affect the net carbon stock change of living biomass. It also has an effect on the distribution of wood harvests over fuel wood (resulting in instantaneous oxidation) and industrial roundwood (input to HWP).

The above recalculations changed the total CO_2 eq. emissions in the LULUCF sector by 8.3% in 1990 and by 17.6 % in 2020 compared to previous submission.

- *Waste sector:*
    - Compared with the previous submission, a major recalculation of the CH_4 and N_2O emissions from Public WWTPs (category 5D1) for the years 1990 to 2020 was performed. This is related to the 2019 Refinements of the 2006 IPCC guidelines
    - Furthermore two new sources are included in the inventory as of now:
        - Indirect CH_4 emissions from surface waters as a result of discharges of COD via domestic and industrial effluents (category 5D3).
        - N_2O emissions from aerobic biological industrial WWTPs (category 5D2)

The above recalculations and the addition of two news sources to the inventory changed the total CO_2 eq. emissions in the Waste sector by 4.1% in 1990 and by 19.8 % in 2020 compared to previous submission.

Additional to the above changes, every year small changes in emissions occur (compared to the previous submission) due to the availability of final statistics for activity data (for this submission in 2020 and in some cases 2019).

Changes in source allocation
No changes in source allocation were needed for this 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. Table 10.1 shows the changes in emissions per relevant sector combined for all gases in Gg CO_2 eq., compared with the 2022 submission, as a result of the recalculations. Please note that the data differ from the recalculations as displayed in the CRF files. Due to a bug in the CRF Reporter the emissions of F-gases from the previous submission were not correctly recalculated with the AR5 GWPs.

For the base year 1990, the recalculations resulted in an increased emission total compared with the previous submission of 1.17% (including LULUCF and indirect CO_2).
For 2020, the recalculated emissions increased by 0.63% in comparison with the previous submission (including LULUCF and indirect CO_2).

The increase in annual total national emissions due to the recalculations never surpass 1.1% in the period 1990-2022.

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., 2023).

Table 10.1 Summary of recalculations for the period 1990–2020 (Gg CO_2 eq.).

Gas(es)		**1990**	**2000**	**2010**	**2015**	**2019**	**2020**
CO_2, CH_4, N_2O	1.A.1. Energy Industries	0.0	0.0	0.0	-5.2	-45.3	-547.2
CO_2, CH_4, N_2O	1.A.2. Manufacturing industries	973.6	857.2	642.6	607.8	359.7	318.8
CO_2, CH_4, N_2O	1.A.3. Transport	-193.2	23.3	27.1	-1107.2	-1013.0	-955.0
CO_2, CH_4, N_2O	1.A.4. Other sectors	80.5	54.4	195.0	166.3	189.4	31.0
CO_2	1.B.1. Solid fuels	0.0	0.0	0.0	0.0	0.0	-0.9
CO_2	2.D IPPU (Non-energy products)	-0.8	-0.7	-7.5	-11.3	4.0	2.7
CO_2, CH_4, N_2O	2. IPPU Other	0.0	0.0	0.0	0.0	0.1	-0.2
HFC	2. IPPU 2.B.9. & 2.F.1 & 2.F.6.	0.0	111.3	371.8	407.0	285.1	267.0
PFC	2. IPPU 2.C.3 & 2.E.1.	0.7	7.9	9.4	7.9	4.9	-7.5
CH_4	3.A Enteric Fermentation	0.0	0.0	-14.2	-15.3	-14.8	-16.8
N_2O	3.B Manure management	0.0	0.2	-0.1	-1.2	0.1	-1.0
N_2O	3.D Agricultural soils	-41.1	-30.1	-42.3	-35.5	-63.9	-65.2
CO_2	3.G Liming	0.0	0.0	0.0	0.0	0.0	0.4
CO_2	3.H Urea application	0.0	0.0	0.0	0.0	0.0	2.7
CO_2, CH_4, N_2O	4 LULUCF	480.3	532.7	180.7	900.7	602.9	621.2
CH_4	5.A Solid waste disposal	0.0	0.0	0.0	0.0	-1.3	-5.0
CH_4, N_2O	5.D Waste water Handling	649.2	608.9	593.7	596.9	622.7	604.3
Total Difference		1949.3	2165.2	1956.3	1510.8	930.4	249.3
	*Total emissions NIR 2022 **	226,986	223,516	217,834	198,365	184,613	168,680
	Total emissions NIR 2023*	228,935	225,681	219,790	199,876	185,544	168,929

*: including LULUCF and indirect CO_2 emissions

Table 10.1 is not showing the emissions changes per individual gas. Therefore in Table 10.2 the changes per individual gas and per sector in 1990 and 2020 are shown.

Table 10.2 Summary of recalculations per gas and sector (Gg CO_2 eq.), 1990 and 2020.

CO_2	**1990**	**2020**
1 Energy	859.0	-1170.5
2 IPPU	-0.8	2.5
3 Agriculture	0.0	3.1
4 LULUCF	174.3	376.4
5 Waste	NA	NA
Indirect emissions	0.0	0.0
CH_4		
1 Energy	0.3	30.2
2 IPPU	0.0	0.0
3 Agriculture	0.0	-16.8
4 LULUCF	306.1	244.8
5 Waste	75.4	-43.5
N_2O		
1 Energy	1.6	-12.9
2 IPPU	0.0	0.0
3 Agriculture	-41.1	-66.2
4 LULUCF	-0.1	-0.1
5 Waste	573.7	642.8
HFCs		
2 IPPU	0.0	267.0
PFCs		
2 IPPU	0.7	-7.5
SF_6		
2 IPPU	0.0	0.0

10.3 Implications for emissions trends, including time series consistency

The recalculations and error corrections have further improved both the accuracy and the time series consistency of the estimated emissions. Table 10.3 shows the changes made due to the recalculations for 1990, 2000, 2010, 2015, 2019 and 2020 (compared with the NIR 2022). It appears from table 10.3 that the recalculations (including LULUCF) changed national emissions in 2019 and 2020 to a small extent (0.5% and 0.1%, respectively), compared with the previous NIR. Changes to the 1990 emissions (base year) are in the same order of magnitude (0.9%).

Table 10.3 Differences between the NIR 2022 and NIR 2023 for the period 1990–2020 due to recalculations (Units: ***Tg CO_2 eq****.; for F-gases:* ***Gg CO_2 eq.****).*

		1990	2000	2010	2015	2019	2020
CO_2 [Tg]	NIR 2023	168.5	177.3	187.1	168.9	156.4	140.5
	NIR 2022	167.5	176.2	186.3	168.6	156.5	141.3
	Difference	0.6%	0.7%	0.4%	0.2%	-0.1%	-0.6%
CH_4 [Tg]	NIR 2023	36.0	27.4	21.9	20.5	19.5	19.2
	NIR 2022	35.7	27.1	21.7	20.3	19.3	19.0
	Difference	1.1%	1.1%	1.2%	1.1%	1.2%	1.1%
N_2O [Tg]	NIR 2023	16.2	14.4	7.9	8.1	7.7	7.5
	NIR 2022	15.6	13.9	7.3	7.5	7.1	7.0
	Difference	3.4%	4.1%	7.7%	7.5%	8.1%	8.1%
PFCs [Gg]	NIR 2023	2,397.3	1,723.2	299.9	104.0	118.2	65.3
	NIR 2022	2,396.6	1,715.2	290.5	96.1	113.3	72.8
	Difference	0.0%	0.5%	3.3%	8.3%	4.3%	-10.2%
HFCs [Gg]	NIR 2023	4,697.2	4,029.0	1,977.9	1,730.7	1,302.8	1056.6
	NIR 2022	4,697.2	3,917.7	1,606.1	1,323.7	1,017.7	789.6
	Difference	0.0%	2.8%	23.1%	30.7%	28.0%	33.8%
SF6 [Gg]	NIR 2023	213.1	234.6	108.1	115.1	120.7	128.4
	NIR 2022	213.1	234.6	108.1	115.1	120.7	128.4
	Difference	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Total [Tg CO_2-eq.]	NIR 2023	228.9	225.7	219.8	199.9	185.5	168.9
	NIR 2022	227.0	223.5	217.8	198.4	184.6	168.7
	Difference	0.9%	1.0%	0.9%	0.8%	0.5%	0.1%

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 an annual process of a general public review and a peer review.

The annual peer review 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 2022 (CE Delft, 2022) focused on the emissions from the Energy sector, excluding the reference approach and the transport sector. The review concluded that, overall, the calculations on energy emissions in the Dutch NIR 2022 are in line with the 2006 IPCC Guidelines (IPCC, 2006), with the NIR found to be a solid exposition of Dutch GHG and how figures are established. However, the review suggested adding more background information, i.e. on allocation issues and use of emission factors. These suggestions are implemented in this NIR 2023 as well as in the methodology report (Honig, 2023).

Peer reviews in past years have focused on the following sectors and categories:
- LULUCF (South Pole, 2021)
- Waste and wastewater (Oonk, 2020)
- Transport (VITO, 2019);
- Reference approach and waste incineration (CE, 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
An UNFCCC review was conducted on the NIR 2022. The draft review report was received in the autumn of 2022 and is used to structure Annex 10, which includes responses to each of the findings. Annex 10 does not include the findings already resolved during the review.

2022 annual ESD review
The NIR 2022 was scrutinized during the 2022 annual ESD review by the EU, in line with Article 19(1) of Regulation (EU) No 525/2013 (the 'Monitoring Mechanism Regulation', MMR)[13]. The reviewers carried out checks to verify the transparency, accuracy, consistency, comparability, and completeness of the national GHG inventory for the year 2020 submitted in 2022 by the Netherlands pursuant to Articles 7(1) and 7(3) of Regulation (EU) No 525/2013.

The review consisted of two steps. The initial checks in step 1 were performed by the EU inventory team (European Environment Agency (EEA), European Topic Centre on Climate Change Mitigation and Energy (ETC/CME), Joint Research Centre (JRC) and Eurostat).

[13] 2020 Comprehensive Review of National Greenhouse Gas Inventory Data, pursuant to Article 4(3) of Regulation (EU) No 2018/842 and to Article 3 of Decision No 406/2009/EC. The Netherlands. 30 August 2020, EEA, 0201/2019/814628/SER/CLIMA.C.2

No unresolved issues have been forwarded to step 2.

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), 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;
- 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. Compared to the previous submission (NIR 2022) we now included the N_2O emissions from industrial wastewater treatment (5D2) to the inventory.

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 are confidential and not reported when a source category comprises three or fewer companies. During (in-country) reviews, however, these 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.

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 annual update of the QA/QC programme (RVO, 2022).

QA/QC programme
The QA/QC programme for this year (RVO, 2022) continues the assessment of long-term improvement options based on the consequences of the 2006 IPCC Guidelines on reporting from 2015 onwards. Improvement actions for new methodologies and changes of EF will be performed in 2022 and are governed by the annual Work Plan (RIVM, 2022).

Acknowledgements

Many colleagues from a number of organisations – Statistics Netherlands (CBS), Wageningen Environmental Research (WenR), Netherlands Enterprise Agency (RVO), Netherlands Environmental Assessment Agency (PBL), National Institute for Public Health and the Environment (RIVM) and Netherlands Organisation for Applied Scientific Research (TNO) – have been involved in the annual update of the Netherlands Pollutant Release and Transfer Register (NL-PRTR), also called the Emission Registration (ER) system, which contains emissions data on about 375 pollutants. The emissions calculations, including those for greenhouse gas (GHG) emissions, are performed by members of the PRTR Task Forces. This is a major task, since the Netherlands' inventory contains details of many emissions sources. These calculations form the basis for this National Inventory Report 2023 (NIR 2023).

The emissions and activity data of the Netherlands' inventory were 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 (Land use), Bas van Huet (Waste), Kathleen Geertjes, Stijn Dellaert, Kevin Felter and Maarten 't Hoen (Transport), Romuald te Molder and Jolien van Huijstee (key categories and uncertainty analysis), Rianne Dröge (Energy and uncertainty assessment), Johanna Montfoort (Fugitive emissions), Erik Honig (Industrial processes and product use, Kees Baas (Wastewater handling), 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 coordinated (with the support of Alexander de Jong) the filling of the CRF tables.

This group also provided activity data and additional information for the CRF tables in cases where these were not included in the data sheets submitted by the PRTR Task Forces.

We are particularly grateful to Guido Hollman, Alexander de Jong, René Koch, Bert Leekstra, Dirk Wever and Jacqueline Wanders for their contributions to data processing, chart production and quality control.

We greatly appreciate the contributions of each of these groups and individuals to this National Inventory Report and supplemental CRF tables, as well as those of the external reviewers who provided comments on an earlier draft of this report.

Annex 1 Key categories

A1.1 Introduction

As explained in the 2006 Guidelines (IPCC, 2006), a key source category is prioritized 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, 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).

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 IPCC Approach 1 method consists of ranking the list of source category/gas combinations according to their contribution to national total annual emissions and to the national total trend. The categories at the top of the tables in this annex are the key sources, the total of whose emissions add up to 95% of the national total. This results in 39 categories for annual level assessment (emissions in 2021) and 48 categories for the trend assessment out of a total of 124 source categories.

The second step of the IPCC Approach 1 method in 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 (for details of the uncertainty analysis see the methodology reports (RIVM reports 2023-0035, 2023-0041, 2023-0046, Geilenkirchen et al., 2023 and Arets et al., 2023). 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 first and second step of the Approach 1 level and trend assessments are summarised in Table A1.1. A combination of step 1 and 2 for the level and trend assessment, shows a total of 61 key categories.

As expected, the incorporation of uncertainty in the level and trend assessments increase the importance of highly uncertain sources. With step two added, 10 additional key categories are identified, as shown in table A1.1.

Table A1.1 Additional key categories after incorporation of uncertainty data

1A4b	Residential:all fuels	CH_4	Key(L2)
2B7	Soda ash production	CO_2	Key(T2)
2B8	Chemical industry: Petrochemical and carbon black production	CH_4	Key(L2,T2)
2D2	Paraffin wax use	CO_2	Key(L2,T2)
3A3	Swine	CH_4	Key(L2)
3B5	Indirect emissions	N_2O	Key(L2,T2)
4B	Cropland	N_2O	Key(L2)
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)

This Annex 1 also includes information on key categories in 1990; Table A1.3 shows the results.

The 2021 inventory contains, in comparison with 1990, 10 additional key categories on the basis of a level assessment (incl. LULUCF). Please note that a trend assessment for 1990 key categories is not relevant.

*Table A1.2 Key source list identified by the Approach 1 level and trend assessments for **2021** emissions (**including** LULUCF sources)*

IPCC	Source category	Gas	Key source	Approach 1 level recent year	Approach 1 trend	Approach 1 level recent year (incl. uncertainty)	Approach 1 trend (incl. uncertainty)
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	Non key	0	0	0	0
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(L,T)	1	1	1	1
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 exl 1A3b	Other	CH_4	Non key	0	0	0	0
1A3 exl 1A3b	Other	N_2O	Non key	0	0	0	0
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

IPCC	Source category	Gas	Key source	Approach 1 level recent year	Approach 1 trend	Approach 1 level recent year (incl. uncertainty)	Approach 1 trend (incl. uncertainty)
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	Liquids excl. 1A4c	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,T1)	1	1	1	0
1A4a	Commercial/Institutional: all fuels	CH_4	Non key	0	0	0	0
1A4b	Residential gaseous	CO_2	Key(L,T)	1	1	1	1
1A4b	Residential:all fuels	CH_4	Key(L2,)	0	0	1	0
1A4c	Agriculture/Forestry/Fisheries: liquids	CO_2	Key(L1,)	1	0	0	0
1A4c	Agriculture/Forestry/Fisheries: gaseous	CO_2	Key(L,T)	1	1	1	1
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
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

IPCC	Source category	Gas	Key source	Approach 1 level recent year	Approach 1 trend	Approach 1 level recent year (incl. uncertainty)	Approach 1 trend (incl. uncertainty)
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	Non key	0	0	0	0
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(L1,T1)	1	1	0	0
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	Non key	0	0	0	0
2B7	Soda ash production	CO_2	Key(,T2)	0	0	0	1
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,T2)	0	0	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
2C3	Aluminium production	PFC	Key(,T)	0	1	0	1
2D1	Lubricant use	CO_2	Non key	0	0	0	0
2D2	Paraffin wax use	CO_2	Key(L2,T2)	0	0	1	1
2D2	Non-energy products from fuels and solvent use: 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

IPCC	Source category	Gas	Key source	Approach 1 level recent year	Approach 1 trend	Approach 1 level recent year (incl. uncertainty)	Approach 1 trend (incl. uncertainty)
2F1	Refrigeration and airconditioning	HFC	Key(L,T)	1	1	1	1
2F6	Other	HFC	Non key	0	0	0	0
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	SF6 use	SF6	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,T1)	1	1	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	Non key	0	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
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

IPCC	Source category	Gas	Key source	Approach 1 level recent year	Approach 1 trend	Approach 1 level recent year (incl. uncertainty)	Approach 1 trend (incl. uncertainty)
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,T1)	1	1	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,T)	1	1	1	1
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
4F	Other Land	N_2O	Non key	0	0	0	0
4G	Harvested wood products	CO_2	Non key	0	0	0	0
4H	Other	N_2O	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

IPCC	Source category	Gas	Key source	Approach 1 level recent year	Approach 1 trend	Approach 1 level recent year (incl. uncertainty)	Approach 1 trend (incl. uncertainty)
5D	Wastewater treatment and discharge	CH_4	Non key	0	0	0	0
5D	Wastewater treatment and discharge	N_2O	Key(L,T)	1	1	1	1
6	Indirect CO_2	CO_2	Key(L1,T1)	1	1	0	0
	SUM			39	48	40	39

*Table A1.3 Key source list identified by the Approach 1 level assessments for **1990** emissions (**including** LULUCF sources)*

IPCC	Source category	Gas	Key source	Approach 1 level 1990 incl. uncertainty	Approach 1 level 1990 incl. uncertainty
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	Non key	0	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(L,)	1	1
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 exl 1A3b	Other	CH_4	Non key	0	0
1A3 exl 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
1A3b	Road transportation: LPG	CO_2	Key(L1,)	1	0
1A3b	Road transportation: gaseous	CO_2	Non key	0	0

IPCC	Source category	Gas	Key source	Approach 1 level 1990 incl. uncertainty	Approach 1 level 1990 incl. uncertainty
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	Liquids excl. 1A4c	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
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

IPCC	Source category	Gas	Key source	Approach 1 level 1990 incl. uncertainty	Approach 1 level 1990 incl. uncertainty
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(L1,)	1	0
2B10	Other	N_2O	Non key	0	0
2B2	Nitric acid production	N_2O	Key(L,)	1	1
2B4	Caprolactam production	N_2O	Key(L1,)	1	0
2B7	Soda ash production	CO_2	Key(L2,)	0	1
2B8	Petrochemical and carbon black production	CO_2	Key(L2,)	0	1
2B8	Chemical industry: Petrochemical and carbon black production	CH_4	Non key	0	0
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(L,)	1	1
2D1	Lubricant use	CO_2	Non key	0	0
2D2	Paraffin wax use	CO_2	Non key	0	0
2D2	Non-energy products from fuels and solvent use: 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
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

IPCC	Source category	Gas	Key source	Approach 1 level 1990 incl. uncertainty	Approach 1 level 1990 incl. uncertainty
2G2	SF6 use	SF6	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	Non key	0	0
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
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

IPCC	Source category	Gas	Key source	Approach 1 level 1990 incl. uncertainty	Approach 1 level 1990 incl. uncertainty
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
4G	Harvested wood products	CO_2	Non key	0	0
4H	Other	N_2O	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	Key(L,)	1	1
6	Indirect CO_2	CO_2	Key(L,)	1	1
	SUM			39	37

A1.2 Changes in key categories compared with previous submission

Due to the use of emissions data for 2021, there are a some changes in key categories in comparison with the previous NIR.
Five categories that were key in the previous submission are no longer a key source:

1A3b	Road transportation	N_2O
2A2	Lime production	CO_2
2B4	Caprolactam production	N_2O
3B1	Growing cattle	N_2O
3B1	Mature dairy cattle	N_2O

The Netherlands includes 10 extra key categories compared to the key source analysis in 2022:

1A1	Energy Industries: all fuels	N_2O
1A3b	Road transportation: gaseous	CO_2
1A3e	Other	CO_2
2B7	Soda ash production	CO_2
2C3	Aluminium production	CO_2
3A2, 3A4	Other	CH_4
4B	Cropland	CO_2
4C	Grassland	CH_4
5B	Biological treatment of solid waste: composting	CH_4
5D	Wastewater treatment and discharge	N_2O

A1.3 Changes in key categories 2021 compared with 1990

Table A1.4 shows the result of a comparison of the key categories in 1990 (level) and 2021 (level and trend). A comparison on the basis of a level assessment, shows 2 additional key categories in 2021 compared to 1990. Six additional source categories (shaded in table A1.4) are added, when also the trend analysis is taken into account.

Table A1.4 additional key categories in 2021 (compared to 1990)

1A1	Energy Industries: all fuels	N_2O	Key(T)
1A1a	Public Electricity and Heat Production: other fuels: waste incineration	CO_2	Key(L,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)
2B10	Other	N_2O	Key(L2,T)
2B8	Chemical industry: Petrochemical and carbon black production	CH_4	Key(L2,T2)
2C3	Aluminium production	CO_2	Key(T1)
2D2	Paraffin wax use	CO_2	Key(L2,T2)
2F1	Refrigeration and airconditioning	HFC	Key(L,T)
3A2, 3A4	Other	CH_4	Key(L1)
3B4	Poultry	CH_4	Key(T)
4C	Grassland	CH_4	Key(L2)
4F	Other Land	CO_2	Key(L2,T2)

A1.4 Approach 1 key source and uncertainty assessment

In Table A1.5 the source ranking is done according to the contribution to the 2021 annual emissions total and in Table A1.6 according to the base-year-to-2021 trend. This results in 40 level key sources and 50 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.)*

IPCC Category		Gas	2021 estimate (Gg CO_2 eq.)	Level assessment %	Cumulative total %
1A4b	Residential gaseous	CO_2	16918.4	9.6	9.6
1A1a	Public Electricity and Heat Production: solids	CO_2	16718.0	9.5	19.1
1A1a	Public Electricity and Heat Production: gaseous	CO_2	15334.4	8.7	27.8
1A2	Manufacturing Industries and Construction: gaseous	CO_2	14544.9	8.3	36.1
1A3b	Road transportation: diesel oil	CO_2	13118.4	7.4	43.5
1A3b	Road transportation: gasoline	CO_2	10660.1	6.1	49.6
1A2	Manufacturing Industries and Construction: liquids	CO_2	9212.9	5.2	54.8
1A4c	Agriculture/Forestry/Fisheries: gaseous	CO_2	7425.7	4.2	59.0
1A1b	Petroleum Refining: liquids	CO_2	6946.3	3.9	63.0
1A4a	Commercial/Institutional: gaseous	CO_2	6321.1	3.6	66.5
3A1	Mature dairy cattle	CH_4	5966.2	3.4	69.9
1A2	Manufacturing Industries and Construction: solids	CO_2	3957.8	2.2	72.2
3Da	Direct emissions from agricultural soils	N_2O	3650.8	2.1	74.3
1A1a	Public Electricity and Heat Production: other fuels: waste incineration	CO_2	2671.2	1.5	75.8
4C	Grassland	CO_2	2604.4	1.5	77.3
1A1b	Petroleum Refining: gaseous	CO_2	2524.4	1.4	78.7
5A	Solid waste disposal	CH_4	2356.3	1.3	80.0
2B1	Ammonia production	CO_2	2131.6	1.2	81.2
4A	Forest Land	CO_2	2059.6	1.2	82.4
4B	Cropland	CO_2	2017.0	1.1	83.5
3A1	Young cattle	CH_4	2000.4	1.1	84.7
1A4c	Agriculture/Forestry/Fisheries: liquids	CO_2	1821.1	1.0	85.7
3B3	Swine	CH_4	1726.3	1.0	86.7
3B1	Mature dairy cattle	CH_4	1665.2	0.9	87.6
1A4c	Agriculture/Forestry/Fisheries: all fuels	CH_4	1347.2	0.8	88.4

IPCC Category		Gas	2021 estimate (Gg CO_2 eq.)	Level assessment %	Cumulative total %
1A1c	**Manufacture of Solid Fuels: gaseous**	**CO_2**	**1290.4**	**0.7**	**89.1**
4E	**Settlements**	**CO_2**	**1175.6**	**0.7**	**89.8**
2B10	**Other**	**CO_2**	**1169.4**	**0.7**	**90.5**
1A1c	**Manufacture of Solid Fuels: solids**	**CO_2**	**1151.3**	**0.7**	**91.1**
1B2	**Fugitive emissions from oil and gas operations**	**CO_2**	**1051.5**	**0.6**	**91.7**
2F1	**Refrigeration and airconditioning**	**HFC**	**797.7**	**0.5**	**92.2**
1A3d	**Domestic navigation**	**CO_2**	**772.5**	**0.4**	**92.6**
5D	**Wastewater treatment and discharge**	**N_2O**	**711.3**	**0.4**	**93.0**
2A4d	**Other**	**CO_2**	**637.3**	**0.4**	**93.4**
1A4	**Liquids excl. 1A4c**	**CO_2**	**627.8**	**0.4**	**93.7**
2B8	**Petrochemical and carbon black production**	**CO_2**	**556.5**	**0.3**	**94.1**
3Db	**Indirect emissions from managed soils**	**N_2O**	**520.7**	**0.3**	**94.3**
3A2, 3A4	**Other**	**CH_4**	**506.0**	**0.3**	**94.6**
6	**Indirect CO2**	**CO_2**	**502.7**	**0.3**	**94.9**
3A3	**Swine**	**CH_4**	**477.6**	**0.3**	**95.2**
3B1	Growing cattle	CH_4	476.9	0.3	95.5
1A4b	Residential:all fuels	CH_4	414.4	0.2	95.7
2B4	Caprolactam production	N_2O	367.1	0.2	95.9
2B8	Chemical industry: Petrochemical and carbon black production	CH_4	357.8	0.2	96.1
2B10	Other	N_2O	355.7	0.2	96.3
1A1a	Public Electricity and Heat Production: liquids	CO_2	321.0	0.2	96.5
1A3b	Road transportation: LPG	CO_2	266.6	0.2	96.6
1A1	Energy Industries: all fuels	N_2O	264.9	0.2	96.8
1B2b	Natural gas	CH_4	263.7	0.1	96.9
2B	Fluorochemical production	HFC	244.6	0.1	97.1
5D	Wastewater treatment and discharge	CH_4	223.6	0.1	97.2
2D2	Paraffin wax use	CO_2	213.3	0.1	97.3
3B5	Indirect emissions	N_2O	204.8	0.1	97.4
4C	Grassland	CH_4	195.1	0.1	97.6
1A3b	Road transportation: gaseous	CO_2	186.9	0.1	97.7

IPCC Category		Gas	2021 estimate (Gg CO_2 eq.)	Level assessment %	Cumulative total %
1A3b	Road transportation	N_2O	186.1	0.1	97.8
2A2	Lime production	CO_2	180.8	0.1	97.9
2B2	Nitric acid production	N_2O	179.5	0.1	98.0
1A1	Energy Industries: all fuels	CH_4	165.3	0.1	98.1
3B1	Mature dairy cattle	N_2O	164.9	0.1	98.2
1A5b	Military use: liquids	CO_2	164.5	0.1	98.3
4F	Other Land	CO_2	163.9	0.1	98.3
5B	Biological treatment of solid waste: composting	CH_4	137.0	0.1	98.4
1B2c	Venting and flaring	CH_4	132.8	0.1	98.5
2F6	Other	HFC	130.2	0.1	98.6
3B1	Growing cattle	N_2O	127.3	0.1	98.6
2A4a	Ceramics	CO_2	126.6	0.1	98.7
4G	Harvested wood products	CO_2	125.1	0.1	98.8
2G2	SF6 use	SF6	123.9	0.1	98.9
3A1	Other mature cattle	CH_4	121.6	0.1	98.9
2A4b	Other uses of soda ash	CO_2	120.4	0.1	99.0
1A3e	Other	CO_2	93.0	0.1	99.1
2D1	Lubricant use	CO_2	92.1	0.1	99.1
3B4	Other livestock	N_2O	87.5	0.0	99.2
2C1	Iron and steel production	CO_2	83.4	0.0	99.2
2C3	Aluminium production	CO_2	82.3	0.0	99.2
5B	Biological treatment of solid waste: composting	N_2O	82.0	0.0	99.3
3B3	Swine	N_2O	81.1	0.0	99.3
1A2	Manufacturing Industries and Construction:all fuels	CH_4	75.5	0.0	99.4
3B4	Poultry	CH_4	73.1	0.0	99.4
1B1b	Solid fuel transformation	CO_2	71.3	0.0	99.5
2G	Other product manufacture and use	N_2O	70.5	0.0	99.5
2A3	Glass production	CO_2	68.0	0.0	99.5
1A3b	Road transportation	CH_4	64.3	0.0	99.6
3H	Ureum use	CO_2	59.1	0.0	99.6

IPCC Category		Gas	2021 estimate (Gg CO_2 eq.)	Level assessment %	Cumulative total %
1A3c	Railways	CO_2	55.8	0.0	99.6
2G	Other product manufacture and use	CH_4	53.4	0.0	99.7
1A4	Other Sectors: all fuels	N_2O	49.0	0.0	99.7
1A4a	Commercial/Institutional: all fuels	CH_4	48.4	0.0	99.7
4B	Cropland	CH_4	45.9	0.0	99.8
2E	Electronic Industry	PFC	43.2	0.0	99.8
4B	Cropland	N_2O	41.3	0.0	99.8
4D	Wetlands	CO_2	41.2	0.0	99.8
1A2	Manufacturing Industries and Construction:all fuels	N_2O	39.3	0.0	99.9
2D3	Other	CO_2	34.3	0.0	99.9
1A3a	Domestic aviation	CO_2	26.8	0.0	99.9
3B2, 3B4	Other	CH_4	26.2	0.0	99.9
3G	Liming	CO_2	24.0	0.0	99.9
2B9	Fluorochemical production	PFC	21.7	0.0	99.9
4E	Settlements	N_2O	19.9	0.0	99.9
1B2a	Oil	CH_4	16.3	0.0	99.9
2H	Other industrial	CO_2	14.9	0.0	100.0
2C3	Aluminium production	PFC	14.5	0.0	100.0
3B1	Other mature cattle	CH_4	10.6	0.0	100.0
4F	Other Land	N_2O	8.9	0.0	100.0
4C	Grassland	N_2O	6.2	0.0	100.0
1A3 exl 1A3b	Other	N_2O	5.8	0.0	100.0
1B1b	Solid fuel transformation	CH_4	5.2	0.0	100.0
4A	Forest Land	N_2O	4.4	0.0	100.0
1A4	Solids	CO_2	4.2	0.0	100.0
4A	Forest Land	CH_4	3.9	0.0	100.0
1A3 exl 1A3b	Other	CH_4	3.3	0.0	100.0
3B1	Other mature cattle	N_2O	3.0	0.0	100.0
1A5b	Military use: liquids	N_2O	2.4	0.0	100.0
4D	Wetlands	N_2O	2.1	0.0	100.0

IPCC Category		Gas	2021 estimate (Gg CO_2 eq.)	Level assessment %	Cumulative total %
3B2	Sheep	N_2O	1.4	0.0	100.0
1A5b	Military use: liquids	CH_4	0.4	0.0	100.0
2D2	Non-energy products from fuels and solvent use: Paraffin wax use	CH_4	0.4	0.0	100.0
2G	Other product manufacture and use	CO_2	0.2	0.0	100.0
5C	Open burning of waste	CH_4	0.0	0.0	100.0
5C	Open burning of waste	N_2O	0.0	0.0	100.0
4H	Other	N_2O	0.0	0.0	100.0
2B7	Soda ash production	CO_2	0.0	0.0	100.0
2A1	Cement production	CO_2	0.0	0.0	100.0
		SUM	176,116		

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.)*

IPCC Category		Gas	1990 Estimate (Gg CO_2 eq.)	2021 Estimate (Gg CO_2 eq.)	Trend Assessment %	% Contribution to trend	Cumulative Total %
5A	Solid waste disposal	CH_4	15320.8	2356.3	6.9	14.3	14.3
1A1a	Public Electricity and Heat Production: gaseous	CO_2	13329.1	15334.4	4.0	8.3	22.6
2B2	Nitric acid production	N_2O	5410.9	179.5	2.9	6.1	28.7
1A3b	Road transportation: diesel oil	CO_2	13012.2	13118.4	2.5	5.2	33.9
2B	Fluorochemical production	HFC	4697.2	244.6	2.5	5.1	39.0
1A1a	Public Electricity and Heat Production: solids	CO_2	25862.2	16718.0	2.1	4.3	43.3
1A3b	Road transportation: gasoline	CO_2	10672.1	10660.1	2.0	4.1	47.4
1A1a	Public Electricity and Heat Production: other fuels: waste incineration	CO_2	601.5	2671.2	1.7	3.5	50.9
1A4b	Residential gaseous	CO_2	19894.1	16918.4	1.5	3.0	53.9
1A2	Manufacturing Industries and Construction: liquids	CO_2	9694.6	9212.9	1.4	3.0	56.9
1A4c	Agriculture/Forestry/Fisheries: gaseous	CO_2	7328.7	7425.7	1.4	3.0	59.9
2C3	Aluminium production	PFC	2373.9	14.5	1.3	2.8	62.6
1A1b	Petroleum Refining: gaseous	CO_2	1042.2	2524.4	1.3	2.7	65.4
1A3b	Road transportation: LPG	CO_2	2578.4	266.6	1.3	2.6	68.0
3A1	Mature dairy cattle	CH_4	5805.2	5966.2	1.2	2.5	70.5
1A4c	Agriculture/Forestry/Fisheries: all fuels	CH_4	84.2	1347.2	1.0	2.0	72.5
1B2c	Venting and flaring	CH_4	1669.8	132.8	0.8	1.8	74.2
3B3	Swine	CH_4	3772.8	1726.3	0.8	1.7	76.0
3Da	Direct emissions from agricultural soils	N_2O	6288.0	3650.8	0.8	1.7	77.6
1A2	Manufacturing Industries and Construction: solids	CO_2	6623.4	3957.8	0.8	1.6	79.3
2F1	Refrigeration and airconditioning	HFC	0.0	797.7	0.6	1.2	80.5
3B1	Mature dairy cattle	CH_4	1212.7	1665.2	0.6	1.2	81.7
1A1b	Petroleum Refining: liquids	CO_2	9968.2	6946.3	0.4	0.9	82.5
3Db	Indirect emissions from managed soils	N_2O	1423.0	520.7	0.4	0.9	83.4

IPCC Category		Gas	1990 Estimate (Gg CO_2 eq.)	2021 Estimate (Gg CO_2 eq.)	Trend Assessment %	% Contribution to trend	Cumulative Total %
1A4a	Commercial/Institutional: gaseous	CO_2	7757.8	6321.1	0.4	0.8	84.2
4B	Cropland	CO_2	3306.4	2017.0	0.4	0.7	84.9
1B2	Fugitive emissions from oil and gas operations	CO_2	774.6	1051.5	0.4	0.7	85.6
1A1c	Manufacture of Solid Fuels: solids	CO_2	916.3	1151.3	0.3	0.7	86.3
4E	Settlements	CO_2	1000.4	1175.6	0.3	0.7	87.0
1A1c	Manufacture of Solid Fuels: gaseous	CO_2	1184.2	1290.4	0.3	0.6	87.6
2B10	Other	CO_2	1037.6	1169.4	0.3	0.6	88.2
1A4	Liquids excl. 1A4c	CO_2	1330.5	627.8	0.3	0.6	88.8
4C	Grassland	CO_2	3946.4	2604.4	0.3	0.6	89.4
3A1	Young cattle	CH_4	3138.0	2000.4	0.3	0.6	90.0
2A1	Cement production	CO_2	415.8	0.0	0.2	0.5	90.4
2B8	Petrochemical and carbon black production	CO_2	335.6	556.5	0.2	0.5	90.9
3B4	Poultry	CH_4	481.7	73.1	0.2	0.5	91.4
2A4d	Other	CO_2	481.2	637.3	0.2	0.4	91.8
2C3	Aluminium production	CO_2	408.4	82.3	0.2	0.4	92.1
1A3d	Domestic navigation	CO_2	742.6	772.5	0.2	0.3	92.5
4A	Forest Land	CO_2	2452.8	2059.6	0.2	0.3	92.8
1A2	Manufacturing Industries and Construction: gaseous	CO_2	19044.2	14544.9	0.2	0.3	93.1
2B10	Other	N_2O	217.1	355.7	0.1	0.3	93.4
6	Indirect CO2	CO_2	917.2	502.7	0.1	0.3	93.7
1A3b	Road transportation: gaseous	CO_2	0.0	186.9	0.1	0.3	94.0
1A1	Energy Industries: all fuels	N_2O	131.8	264.9	0.1	0.3	94.3
1A3e	Other	CO_2	342.2	93.0	0.1	0.3	94.5
5D	Wastewater treatment and discharge	N_2O	726.7	711.3	0.1	0.3	94.8
1A1a	Public Electricity and Heat Production: liquids	CO_2	233.2	321.0	0.1	0.2	95.0
2D2	Paraffin wax use	CO_2	102.6	213.3	0.1	0.2	95.2

IPCC Category		Gas	1990 Estimate (Gg CO_2 eq.)	2021 Estimate (Gg CO_2 eq.)	Trend Assessment %	% Contribution to trend	Cumulative Total %
5B	Biological treatment of solid waste: composting	CH_4	4.8	137.0	0.1	0.2	95.4
2B8	Chemical industry: Petrochemical and carbon black production	CH_4	301.8	357.8	0.1	0.2	95.7
2F6	Other	HFC	0.0	130.2	0.1	0.2	95.9
2B4	Caprolactam production	N_2O	658.0	367.1	0.1	0.2	96.1
1A3b	Road transportation	N_2O	89.5	186.1	0.1	0.2	96.2
1A4	Solids	CO_2	162.7	4.2	0.1	0.2	96.4
3G	Liming	CO_2	183.2	24.0	0.1	0.2	96.6
1A1	Energy Industries: all fuels	CH_4	77.4	165.3	0.1	0.2	96.8
2B1	Ammonia production	CO_2	2695.0	2131.6	0.1	0.2	96.9
1A3b	Road transportation	CH_4	214.0	64.3	0.1	0.2	97.1
4F	Other Land	CO_2	89.9	163.9	0.1	0.2	97.2
5D	Wastewater treatment and discharge	CH_4	421.3	223.6	0.1	0.1	97.4
1B2b	Natural gas	CH_4	471.6	263.7	0.1	0.1	97.5
2G	Other product manufacture and use	N_2O	200.4	70.5	0.1	0.1	97.6
5B	Biological treatment of solid waste: composting	N_2O	5.8	82.0	0.1	0.1	97.8
1A4c	Agriculture/Forestry/Fisheries: liquids	CO_2	2521.2	1821.1	0.1	0.1	97.9
4G	Harvested wood products	CO_2	68.6	125.1	0.1	0.1	98.0
3A2, 3A4	Other	CH_4	576.4	506.0	0.1	0.1	98.1
1A5b	Military use: liquids	CO_2	314.0	164.5	0.1	0.1	98.2
2A4b	Other uses of soda ash	CO_2	68.6	120.4	0.1	0.1	98.3
2A2	Lime production	CO_2	162.7	180.8	0.0	0.1	98.4
3H	Ureum use	CO_2	1.5	59.1	0.0	0.1	98.5
3A1	Other mature cattle	CH_4	235.4	121.6	0.0	0.1	98.6
3B5	Indirect emissions	N_2O	345.1	204.8	0.0	0.1	98.7
3B1	Growing cattle	CH_4	563.3	476.9	0.0	0.1	98.8
2C1	Iron and steel production	CO_2	43.7	83.4	0.0	0.1	98.8
2B7	Soda ash production	CO_2	63.8	0.0	0.0	0.1	98.9

IPCC Category		Gas	1990 Estimate (Gg CO_2 eq.)	2021 Estimate (Gg CO_2 eq.)	Trend Assessment %	% Contribution to trend	Cumulative Total %
3B4	Other livestock	N_2O	53.9	87.5	0.0	0.1	99.0
2H	Other industrial	CO_2	72.5	14.9	0.0	0.1	99.1
2A3	Glass production	CO_2	142.4	68.0	0.0	0.1	99.1
3A3	Swine	CH_4	584.4	477.6	0.0	0.1	99.2
3B1	Mature dairy cattle	N_2O	169.1	164.9	0.0	0.1	99.2
1A3a	Domestic aviation	CO_2	84.2	26.8	0.0	0.1	99.3
2G2	SF6 use	SF6	213.1	123.9	0.0	0.1	99.4
1A4b	Residential:all fuels	CH_4	503.1	414.4	0.0	0.1	99.4
2D3	Other	CO_2	0.0	34.3	0.0	0.1	99.5
4D	Wetlands	CO_2	11.0	41.2	0.0	0.1	99.5
3B1	Growing cattle	N_2O	128.7	127.3	0.0	0.0	99.6
2D1	Lubricant use	CO_2	84.6	92.1	0.0	0.0	99.6
2E	Electronic Industry	PFC	23.5	43.2	0.0	0.0	99.6
4C	Grassland	CH_4	225.7	195.1	0.0	0.0	99.7
2B9	Fluorochemical production	PFC	0.0	21.7	0.0	0.0	99.7
2A4a	Ceramics	CO_2	140.1	126.6	0.0	0.0	99.8
1A2	Manufacturing Industries and Construction:all fuels	CH_4	77.6	75.5	0.0	0.0	99.8
1A4	Other Sectors: all fuels	N_2O	44.9	49.0	0.0	0.0	99.8
1A2	Manufacturing Industries and Construction:all fuels	N_2O	34.3	39.3	0.0	0.0	99.8
3B3	Swine	N_2O	124.7	81.1	0.0	0.0	99.8
1A3c	Railways	CO_2	90.8	55.8	0.0	0.0	99.9
4B	Cropland	CH_4	76.9	45.9	0.0	0.0	99.9
1B1b	Solid fuel transformation	CO_2	110.4	71.3	0.0	0.0	99.9
1A4a	Commercial/Institutional: all fuels	CH_4	50.9	48.4	0.0	0.0	99.9
2G	Other product manufacture and use	CH_4	57.8	53.4	0.0	0.0	99.9
3B1	Other mature cattle	CH_4	24.8	10.6	0.0	0.0	99.9
4F	Other Land	N_2O	5.1	8.9	0.0	0.0	100.0
4E	Settlements	N_2O	21.1	19.9	0.0	0.0	100.0

IPCC Category		Gas	1990 Estimate (Gg CO_2 eq.)	2021 Estimate (Gg CO_2 eq.)	Trend Assessment %	% Contribution to trend	Cumulative Total %
1B1b	Solid fuel transformation	CH_4	12.3	5.2	0.0	0.0	100.0
3B2	Sheep	N_2O	6.4	1.4	0.0	0.0	100.0
5C	Open burning of waste	CH_4	4.2	0.0	0.0	0.0	100.0
4B	Cropland	N_2O	57.9	41.3	0.0	0.0	100.0
3B2, 3B4	Other	CH_4	37.8	26.2	0.0	0.0	100.0
4C	Grassland	N_2O	5.5	6.2	0.0	0.0	100.0
3B1	Other mature cattle	N_2O	6.2	3.0	0.0	0.0	100.0
5C	Open burning of waste	N_2O	2.1	0.0	0.0	0.0	100.0
1A5b	Military use: liquids	N_2O	4.9	2.4	0.0	0.0	100.0
1A3 exl 1A3b	Other	N_2O	6.1	5.8	0.0	0.0	100.0
1A3 exl 1A3b	Other	CH_4	2.8	3.3	0.0	0.0	100.0
4A	Forest Land	CH_4	3.8	3.9	0.0	0.0	100.0
1B2a	Oil	CH_4	22.8	16.3	0.0	0.0	100.0
4D	Wetlands	N_2O	2.2	2.1	0.0	0.0	100.0
4A	Forest Land	N_2O	6.3	4.4	0.0	0.0	100.0
1A5b	Military use: liquids	CH_4	0.9	0.4	0.0	0.0	100.0
2D2	Non-energy products from fuels and solvent use: Paraffin wax use	CH_4	0.2	0.4	0.0	0.0	100.0
2G	Other product manufacture and use	CO_2	0.2	0.2	0.0	0.0	100.0
4H	Other	N_2O	0.0	0.0	0.0	0.0	100.0
	SUM		233,968	176,116			

A1.5 Approach 1 key category assessment including uncertainties

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 2021 annual emissions total) and A1.8 (contribution to the 1990-2021 trend).

Theinclusion 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 1 **level** assessment for 2021 emissions, including LULUCF (Gg CO_2 eq.)*

IPCC Category		Gas	Gg CO_2 eq. 2021	Share %	Uncertainty estimate%	Level * uncertainty%	Share L*U%	Cum. Share L*U%
1A2	Manufacturing Industries and Construction: liquids	CO_2	9212.9	5.2	24.3	1.3	7.9	7.9
4C	Grassland	CO_2	2604.4	1.5	75.0	1.1	6.9	14.7
1A1b	Petroleum Refining: liquids	CO_2	6946.3	3.9	25.7	1.0	6.3	21.0
3Da	Direct emissions from agricultural soils	N_2O	3650.8	2.1	35.4	0.7	4.6	25.6
5D	Wastewater treatment and discharge	N_2O	711.3	0.4	161.2	0.7	4.0	29.6
3Db	Indirect emissions from managed soils	N_2O	520.7	0.3	217.9	0.6	4.0	33.6
1A1a	Public Electricity and Heat Production: solids	CO_2	16718.0	9.5	6.1	0.6	3.6	37.2
1A2	Manufacturing Industries and Construction: solids	CO_2	3957.8	2.2	24.3	0.5	3.4	40.6
3A1	Mature dairy cattle	CH_4	5966.2	3.4	15.1	0.5	3.2	43.8
4B	Cropland	CO_2	2017.0	1.1	44.0	0.5	3.1	46.9
1A4b	Residential gaseous	CO_2	16918.4	9.6	5.0	0.5	3.0	49.9
3B5	Indirect emissions	N_2O	204.8	0.1	400.4	0.5	2.9	52.8
4E	Settlements	CO_2	1175.6	0.7	69.0	0.5	2.9	55.6
1A4c	Agriculture/Forestry/Fisheries: gaseous	CO_2	7425.7	4.2	10.0	0.4	2.6	58.2
1A4a	Commercial/Institutional: gaseous	CO_2	6321.1	3.6	10.9	0.4	2.4	60.7
1A4c	Agriculture/Forestry/Fisheries: all fuels	CH_4	1347.2	0.8	48.9	0.4	2.3	63.0
3B1	Mature dairy cattle	CH_4	1665.2	0.9	38.1	0.4	2.2	65.2
2B1	Ammonia production	CO_2	2131.6	1.2	28.6	0.3	2.1	67.4
5A	Solid waste disposal	CH_4	2356.3	1.3	23.7	0.3	2.0	69.3
1A1c	Manufacture of Solid Fuels: solids	CO_2	1151.3	0.7	43.5	0.3	1.8	71.1
3B3	Swine	CH_4	1726.3	1.0	24.6	0.2	1.5	72.6
2B8	Petrochemical and carbon black production	CO_2	556.5	0.3	70.7	0.2	1.4	74.0

IPCC Category		Gas	Gg CO_2 eq. 2021	Share %	Uncertainty estimate%	Level * uncertainty%	Share L*U%	Cum. Share L*U%
2A4d	**Other**	**CO_2**	**637.3**	**0.4**	**61.5**	**0.2**	**1.4**	**75.4**
1A3b	**Road transportation: diesel oil**	**CO_2**	**13118.4**	**7.4**	**2.8**	**0.2**	**1.3**	**76.7**
2F1	**Refrigeration and airconditioning**	**HFC**	**797.7**	**0.5**	**39.2**	**0.2**	**1.1**	**77.8**
1A3b	**Road transportation: gasoline**	**CO_2**	**10660.1**	**6.1**	**2.8**	**0.2**	**1.1**	**78.8**
1A2	**Manufacturing Industries and Construction: gaseous**	**CO_2**	**14544.9**	**8.3**	**2.0**	**0.2**	**1.0**	**79.9**
2B8	**Chemical industry: Petrochemical and carbon black production**	**CH_4**	**357.8**	**0.2**	**70.7**	**0.1**	**0.9**	**80.7**
2B10	**Other**	**N_2O**	**355.7**	**0.2**	**70.7**	**0.1**	**0.9**	**81.6**
4F	**Other Land**	**CO_2**	**163.9**	**0.1**	**152.0**	**0.1**	**0.9**	**82.5**
4A	**Forest Land**	**CO_2**	**2059.6**	**1.2**	**12.0**	**0.1**	**0.9**	**83.4**
1A4	**Liquids excl. 1A4c**	**CO_2**	**627.8**	**0.4**	**36.4**	**0.1**	**0.8**	**84.2**
2D2	**Paraffin wax use**	**CO_2**	**213.3**	**0.1**	**102.0**	**0.1**	**0.8**	**84.9**
1A4b	**Residential:all fuels**	**CH_4**	**414.4**	**0.2**	**52.1**	**0.1**	**0.8**	**85.7**
1A1c	**Manufacture of Solid Fuels: gaseous**	**CO_2**	**1290.4**	**0.7**	**15.8**	**0.1**	**0.7**	**86.4**
3A3	**Swine**	**CH_4**	**477.6**	**0.3**	**40.5**	**0.1**	**0.7**	**87.1**
1A1a	**Public Electricity and Heat Production: other fuels: waste incineration**	**CO_2**	**2671.2**	**1.5**	**7.1**	**0.1**	**0.7**	**87.8**
3A1	**Young cattle**	**CH_4**	**2000.4**	**1.1**	**9.3**	**0.1**	**0.7**	**88.4**
4B	**Cropland**	**N_2O**	**41.3**	**0.0**	**400.0**	**0.1**	**0.6**	**89.0**
4C	**Grassland**	**CH_4**	**195.1**	**0.1**	**79.0**	**0.1**	**0.5**	**89.6**
3A2, 3A4	**Other**	**CH_4**	**506.0**	**0.3**	**27.1**	**0.1**	**0.5**	**90.0**
2A2	**Lime production**	**CO_2**	**180.8**	**0.1**	**75.2**	**0.1**	**0.5**	**90.5**
6	Indirect CO2	CO_2	502.7	0.3	26.9	0.1	0.5	91.0
1A1	Energy Industries: all fuels	N_2O	264.9	0.2	45.1	0.1	0.4	91.4
3B1	Mature dairy cattle	N_2O	164.9	0.1	68.5	0.1	0.4	91.8
1A4c	Agriculture/Forestry/Fisheries: liquids	CO_2	1821.1	1.0	6.2	0.1	0.4	92.2
2B4	Caprolactam production	N_2O	367.1	0.2	30.5	0.1	0.4	92.6
1A3b	Road transportation	N_2O	186.1	0.1	50.0	0.1	0.3	92.9
5D	Wastewater treatment and discharge	CH_4	223.6	0.1	40.6	0.1	0.3	93.3

IPCC Category		Gas	Gg CO_2 eq. 2021	Share %	Uncertainty estimate%	Level * uncertainty%	Share L*U%	Cum. Share L*U%
2A4a	Ceramics	CO_2	126.6	0.1	70.7	0.1	0.3	93.6
1B2b	Natural gas	CH_4	263.7	0.1	33.3	0.0	0.3	93.9
1A1a	Public Electricity and Heat Production: gaseous	CO_2	15334.4	8.7	0.6	0.0	0.3	94.2
3B1	Growing cattle	CH_4	476.9	0.3	18.1	0.0	0.3	94.5
3B1	Growing cattle	N_2O	127.3	0.1	66.0	0.0	0.3	94.8
4E	Settlements	N_2O	19.9	0.0	400.0	0.0	0.3	95.1
5B	Biological treatment of solid waste: composting	CH_4	137.0	0.1	52.8	0.0	0.3	95.3
1A1a	Public Electricity and Heat Production: liquids	CO_2	321.0	0.2	22.1	0.0	0.2	95.6
1B2c	Venting and flaring	CH_4	132.8	0.1	53.0	0.0	0.2	95.8
2F6	Other	HFC	130.2	0.1	53.9	0.0	0.2	96.1
2D1	Lubricant use	CO_2	92.1	0.1	70.7	0.0	0.2	96.3
2A4b	Other uses of soda ash	CO_2	120.4	0.1	50.0	0.0	0.2	96.5
1B2	Fugitive emissions from oil and gas operations	CO_2	1051.5	0.6	5.0	0.0	0.2	96.7
1A4	Other Sectors: all fuels	N_2O	49.0	0.0	103.8	0.0	0.2	96.9
5B	Biological treatment of solid waste: composting	N_2O	82.0	0.0	60.5	0.0	0.2	97.0
3B4	Other livestock	N_2O	87.5	0.0	54.0	0.0	0.2	97.2
1A1	Energy Industries: all fuels	CH_4	165.3	0.1	27.9	0.0	0.2	97.4
3B3	Swine	N_2O	81.1	0.0	52.7	0.0	0.2	97.5
2G2	SF6 use	SF6	123.9	0.1	33.5	0.0	0.1	97.7
1A3d	Domestic navigation	CO_2	772.5	0.4	5.3	0.0	0.1	97.8
4B	Cropland	CH_4	45.9	0.0	79.0	0.0	0.1	97.9
4F	Other Land	N_2O	8.9	0.0	400.0	0.0	0.1	98.1
2A3	Glass production	CO_2	68.0	0.0	50.0	0.0	0.1	98.2
2B	Fluorochemical production	HFC	244.6	0.1	13.4	0.0	0.1	98.3
1A3b	Road transportation	CH_4	64.3	0.0	50.0	0.0	0.1	98.4
4D	Wetlands	CO_2	41.2	0.0	76.0	0.0	0.1	98.5
3B4	Poultry	CH_4	73.1	0.0	40.6	0.0	0.1	98.6
2B10	Other	CO_2	1169.4	0.7	2.4	0.0	0.1	98.7
2G	Other product manufacture and use	CH_4	53.4	0.0	50.2	0.0	0.1	98.8
3A1	Other mature cattle	CH_4	121.6	0.1	20.9	0.0	0.1	98.9

IPCC Category		Gas	Gg CO_2 eq. 2021	Share %	Uncertainty estimate%	Level * uncertainty%	Share L*U%	Cum. Share L*U%
4C	Grassland	N_2O	6.2	0.0	400.0	0.0	0.1	99.0
1A2	Manufacturing Industries and Construction:all fuels	CH_4	75.5	0.0	31.7	0.0	0.1	99.1
1A4a	Commercial/Institutional: all fuels	CH_4	48.4	0.0	39.4	0.0	0.1	99.2
4A	Forest Land	N_2O	4.4	0.0	400.0	0.0	0.1	99.2
1A2	Manufacturing Industries and Construction:all fuels	N_2O	39.3	0.0	38.8	0.0	0.1	99.3
3H	Ureum use	CO_2	59.1	0.0	25.0	0.0	0.1	99.3
1A3b	Road transportation: LPG	CO_2	266.6	0.2	5.4	0.0	0.1	99.4
1A1b	Petroleum Refining: gaseous	CO_2	2524.4	1.4	0.6	0.0	0.0	99.4
2B2	Nitric acid production	N_2O	179.5	0.1	7.8	0.0	0.0	99.5
3B2, 3B4	Other	CH_4	26.2	0.0	46.1	0.0	0.0	99.5
1B2a	Oil	CH_4	16.3	0.0	70.9	0.0	0.0	99.6
2E	Electronic Industry	PFC	43.2	0.0	25.5	0.0	0.0	99.6
1B1b	Solid fuel transformation	CO_2	71.3	0.0	15.0	0.0	0.0	99.6
1A5b	Military use: liquids	CO_2	164.5	0.1	6.4	0.0	0.0	99.7
1A3b	Road transportation: gaseous	CO_2	186.9	0.1	5.0	0.0	0.0	99.7
2D3	Other	CO_2	34.3	0.0	26.9	0.0	0.0	99.7
2G	Other product manufacture and use	N_2O	70.5	0.0	12.2	0.0	0.0	99.8
4D	Wetlands	N_2O	2.1	0.0	400.0	0.0	0.0	99.8
1A3 exl 1A3b	Other	N_2O	5.8	0.0	131.5	0.0	0.0	99.8
2C3	Aluminium production	PFC	14.5	0.0	42.7	0.0	0.0	99.8
3G	Liming	CO_2	24.0	0.0	24.2	0.0	0.0	99.9
2C1	Iron and steel production	CO_2	83.4	0.0	5.8	0.0	0.0	99.9
2C3	Aluminium production	CO_2	82.3	0.0	5.4	0.0	0.0	99.9
2B9	Fluorochemical production	PFC	21.7	0.0	20.0	0.0	0.0	99.9
3B1	Other mature cattle	CH_4	10.6	0.0	33.0	0.0	0.0	99.9
4A	Forest Land	CH_4	3.9	0.0	79.0	0.0	0.0	99.9
1A5b	Military use: liquids	N_2O	2.4	0.0	122.9	0.0	0.0	99.9

IPCC Category		Gas	Gg CO_2 eq. 2021	Share %	Uncertainty estimate%	Level * uncertainty%	Share L*U%	Cum. Share L*U%
1A3a	Domestic aviation	CO_2	26.8	0.0	9.4	0.0	0.0	100.0
3B1	Other mature cattle	N_2O	3.0	0.0	77.8	0.0	0.0	100.0
1A3e	Other	CO_2	93.0	0.1	2.0	0.0	0.0	100.0
1A3 exl 1A3b	Other	CH_4	3.3	0.0	51.1	0.0	0.0	100.0
1A4	Solids	CO_2	4.2	0.0	38.6	0.0	0.0	100.0
3B2	Sheep	N_2O	1.4	0.0	111.4	0.0	0.0	100.0
4G	Harvested wood products	CO_2	125.1	0.1	1.0	0.0	0.0	100.0
1A3c	Railways	CO_2	55.8	0.0	2.2	0.0	0.0	100.0
2H	Other industrial	CO_2	14.9	0.0	5.4	0.0	0.0	100.0
1B1b	Solid fuel transformation	CH_4	5.2	0.0	11.2	0.0	0.0	100.0
2D2	Non-energy products from fuels and solvent use: Paraffin wax use	CH_4	0.4	0.0	111.8	0.0	0.0	100.0
1A5b	Military use: liquids	CH_4	0.4	0.0	83.4	0.0	0.0	100.0
2G	Other product manufacture and use	CO_2	0.2	0.0	53.9	0.0	0.0	100.0
5C	Open burning of waste	CH_4	0.0	0.0	316.2	0.0	0.0	100.0
5C	Open burning of waste	N_2O	0.0	0.0	316.2	0.0	0.0	100.0
2B7	Soda ash production	CO_2	0.0	0.0	500.0	0.0	0.0	100.0
4H	Other	N_2O	0.0	0.0	25.0	0.0	0.0	100.0
2A1	Cement production	CO_2	0.0	0.0	11.0	0.0	0.0	100.0
	SUM		176,116					

Lines in bold represent the key sources.

With respect to Approach 1 level key sources, 1A4a Residential gaseous (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 quite uncertain sources are among the top five level key sources:

- 4C Grassland (CO_2)
- 3Da Direct emission from agricultural soils (N_2O)
- 5D Wastewater treatment and discharge (N_2O)

The uncertainty in these emissions is estimated in the range of 35-160%, an order of magnitude higher than the 1% uncertainty for CO_2 from 1A4a Residential gaseous .

Table A1.8 Source ranking using IPCC Approach 1 ***trend*** *assessment for 2021 emissions compared to the base year, including LULUCF ($Gg\ CO_2$ eq.)*

IPCC Category		Gas	Gg CO_2 eq 1990	Gg CO_2 eq 2021	trend assessment %	Uncertainty estimate %	Trend * uncertainty %	% Contr. to trend	Cumulative %
5A	**Solid waste disposal**	**CH_4**	**15320.8**	**2356.3**	**6.9**	**23.7**	**1.6**	**15.8**	**15.8**
3Db	**Indirect emissions from managed soils**	**N_2O**	**1423.0**	**520.7**	**0.4**	**217.9**	**0.9**	**8.7**	**24.6**
2C3	**Aluminium production**	**PFC**	**2373.9**	**14.5**	**1.3**	**42.7**	**0.6**	**5.5**	**30.1**
1A4c	**Agriculture/Forestry/Fisheries: all fuels**	**CH_4**	**84.2**	**1347.2**	**1.0**	**48.9**	**0.5**	**4.6**	**34.7**
1B2c	**Venting and flaring**	**CH_4**	**1669.8**	**132.8**	**0.8**	**53.0**	**0.4**	**4.3**	**39.0**
1A2	**Manufacturing Industries and Construction: liquids**	**CO_2**	**9694.6**	**9212.9**	**1.4**	**24.3**	**0.4**	**3.4**	**42.4**
2B	**Fluorochemical production**	**HFC**	**4697.2**	**244.6**	**2.5**	**13.4**	**0.3**	**3.2**	**45.6**
3Da	**Direct emissions from agricultural soils**	**N_2O**	**6288.0**	**3650.8**	**0.8**	**35.4**	**0.3**	**2.8**	**48.4**
2F1	**Refrigeration and airconditioning**	**HFC**	**0.0**	**797.7**	**0.6**	**39.2**	**0.2**	**2.3**	**50.7**
2B2	**Nitric acid production**	**N_2O**	**5410.9**	**179.5**	**2.9**	**7.8**	**0.2**	**2.2**	**52.9**
4E	**Settlements**	**CO_2**	**1000.4**	**1175.6**	**0.3**	**69.0**	**0.2**	**2.1**	**55.0**
3B1	**Mature dairy cattle**	**CH_4**	**1212.7**	**1665.2**	**0.6**	**38.1**	**0.2**	**2.1**	**57.1**
4C	**Grassland**	**CO_2**	**3946.4**	**2604.4**	**0.3**	**75.0**	**0.2**	**2.0**	**59.1**
3B3	**Swine**	**CH_4**	**3772.8**	**1726.3**	**0.8**	**24.6**	**0.2**	**2.0**	**61.1**
5D	**Wastewater treatment and discharge**	**N_2O**	**726.7**	**711.3**	**0.1**	**161.2**	**0.2**	**1.9**	**63.0**
1A2	**Manufacturing Industries and Construction: solids**	**CO_2**	**6623.4**	**3957.8**	**0.8**	**24.3**	**0.2**	**1.8**	**64.8**
3A1	**Mature dairy cattle**	**CH_4**	**5805.2**	**5966.2**	**1.2**	**15.1**	**0.2**	**1.8**	**66.6**
2B7	**Soda ash production**	**CO_2**	**63.8**	**0.0**	**0.0**	**500.0**	**0.2**	**1.7**	**68.3**
3B5	**Indirect emissions**	**N_2O**	**345.1**	**204.8**	**0.0**	**400.4**	**0.2**	**1.6**	**69.9**
2B8	**Petrochemical and carbon black production**	**CO_2**	**335.6**	**556.5**	**0.2**	**70.7**	**0.2**	**1.6**	**71.5**
4B	**Cropland**	**CO_2**	**3306.4**	**2017.0**	**0.4**	**44.0**	**0.2**	**1.5**	**73.0**
1A1c	**Manufacture of Solid Fuels: solids**	**CO_2**	**916.3**	**1151.3**	**0.3**	**43.5**	**0.2**	**1.5**	**74.5**
1A4c	**Agriculture/Forestry/Fisheries: gaseous**	**CO_2**	**7328.7**	**7425.7**	**1.4**	**10.0**	**0.1**	**1.4**	**75.9**

IPCC Category		Gas	Gg CO_2 eq 1990	Gg CO_2 eq 2021	trend assessment %	Uncertainty estimate %	Trend * uncertainty %	% Contr. to trend	Cumulative %
2A4d	**Other**	**CO_2**	**481.2**	**637.3**	**0.2**	**61.5**	**0.1**	**1.2**	**77.1**
1A1a	**Public Electricity and Heat Production: solids**	**CO_2**	**25862.2**	**16718.0**	**2.1**	**6.1**	**0.1**	**1.2**	**78.3**
1A1a	**Public Electricity and Heat Production: other fuels: waste incineration**	**CO_2**	**601.5**	**2671.2**	**1.7**	**7.1**	**0.1**	**1.1**	**79.5**
4F	**Other Land**	**CO_2**	**89.9**	**163.9**	**0.1**	**152.0**	**0.1**	**1.1**	**80.5**
1A1b	**Petroleum Refining: liquids**	**CO_2**	**9968.2**	**6946.3**	**0.4**	**25.7**	**0.1**	**1.0**	**81.6**
2D2	**Paraffin wax use**	**CO_2**	**102.6**	**213.3**	**0.1**	**102.0**	**0.1**	**1.0**	**82.6**
2B10	**Other**	**N_2O**	**217.1**	**355.7**	**0.1**	**70.7**	**0.1**	**1.0**	**83.6**
1A4	**Liquids excl. 1A4c**	**CO_2**	**1330.5**	**627.8**	**0.3**	**36.4**	**0.1**	**1.0**	**84.6**
3B4	**Poultry**	**CH_4**	**481.7**	**73.1**	**0.2**	**40.6**	**0.1**	**0.9**	**85.4**
1A4b	**Residential gaseous**	**CO_2**	**19894.1**	**16918.4**	**1.5**	**5.0**	**0.1**	**0.7**	**86.1**
1A3b	**Road transportation: diesel oil**	**CO_2**	**13012.2**	**13118.4**	**2.5**	**2.8**	**0.1**	**0.7**	**86.8**
2B8	**Chemical industry: Petrochemical and carbon black production**	**CH_4**	**301.8**	**357.8**	**0.1**	**70.7**	**0.1**	**0.7**	**87.5**
1A3b	**Road transportation: LPG**	**CO_2**	**2578.4**	**266.6**	**1.3**	**5.4**	**0.1**	**0.7**	**88.1**
1A1	**Energy Industries: all fuels**	**N_2O**	**131.8**	**264.9**	**0.1**	**45.1**	**0.1**	**0.5**	**88.7**
1A3b	**Road transportation: gasoline**	**CO_2**	**10672.1**	**10660.1**	**2.0**	**2.8**	**0.1**	**0.5**	**89.2**
5B	**Biological treatment of solid waste: composting**	**CH_4**	**4.8**	**137.0**	**0.1**	**52.8**	**0.1**	**0.5**	**89.7**
2F6	**Other**	**HFC**	**0.0**	**130.2**	**0.1**	**53.9**	**0.1**	**0.5**	**90.2**
1A1c	Manufacture of Solid Fuels: gaseous	CO_2	1184.2	1290.4	0.3	15.8	0.0	0.5	90.7
1A3b	Road transportation	N_2O	89.5	186.1	0.1	50.0	0.0	0.4	91.1
1A4a	Commercial/Institutional: gaseous	CO_2	7757.8	6321.1	0.4	10.9	0.0	0.4	91.5
6	Indirect CO2	CO_2	917.2	502.7	0.1	26.9	0.0	0.4	91.9
1A3b	Road transportation	CH_4	214.0	64.3	0.1	50.0	0.0	0.4	92.2
5B	Biological treatment of solid waste: composting	N_2O	5.8	82.0	0.1	60.5	0.0	0.3	92.6
1A4	Solids	CO_2	162.7	4.2	0.1	38.6	0.0	0.3	92.9
2A2	Lime production	CO_2	162.7	180.8	0.0	75.2	0.0	0.3	93.2

IPCC Category		Gas	Gg CO_2 eq 1990	Gg CO_2 eq 2021	trend assessment %	Uncertainty estimate %	Trend * uncertainty %	% Contr. to trend	Cumulative %
2B4	Caprolactam production	N_2O	658.0	367.1	0.1	30.5	0.0	0.3	93.5
5D	Wastewater treatment and discharge	CH_4	421.3	223.6	0.1	40.6	0.0	0.3	93.8
2A1	Cement production	CO_2	415.8	0.0	0.2	11.0	0.0	0.3	94.0
2A4b	Other uses of soda ash	CO_2	68.6	120.4	0.1	50.0	0.0	0.3	94.3
3A1	Young cattle	CH_4	3138.0	2000.4	0.3	9.3	0.0	0.2	94.5
1A1a	Public Electricity and Heat Production: liquids	CO_2	233.2	321.0	0.1	22.1	0.0	0.2	94.8
1B2b	Natural gas	CH_4	471.6	263.7	0.1	33.3	0.0	0.2	95.0
1A1a	Public Electricity and Heat Production: gaseous	CO_2	13329.1	15334.4	4.0	0.6	0.0	0.2	95.2
1A1	Energy Industries: all fuels	CH_4	77.4	165.3	0.1	27.9	0.0	0.2	95.4
2B1	Ammonia production	CO_2	2695.0	2131.6	0.1	28.6	0.0	0.2	95.6
3G	Liming	CO_2	183.2	24.0	0.1	24.2	0.0	0.2	95.9
3B1	Mature dairy cattle	N_2O	169.1	164.9	0.0	68.5	0.0	0.2	96.0
4A	Forest Land	CO_2	2452.8	2059.6	0.2	12.0	0.0	0.2	96.2
3B4	Other livestock	N_2O	53.9	87.5	0.0	54.0	0.0	0.2	96.4
4D	Wetlands	CO_2	11.0	41.2	0.0	76.0	0.0	0.2	96.6
1B2	Fugitive emissions from oil and gas operations	CO_2	774.6	1051.5	0.4	5.0	0.0	0.2	96.8
4F	Other Land	N_2O	5.1	8.9	0.0	400.0	0.0	0.1	96.9
2D1	Lubricant use	CO_2	84.6	92.1	0.0	70.7	0.0	0.1	97.1
3B1	Growing cattle	N_2O	128.7	127.3	0.0	66.0	0.0	0.1	97.2
4C	Grassland	CH_4	225.7	195.1	0.0	79.0	0.0	0.1	97.3
2A3	Glass production	CO_2	142.4	68.0	0.0	50.0	0.0	0.1	97.5
3A2, 3A4	Other	CH_4	576.4	506.0	0.1	27.1	0.0	0.1	97.6
1A4b	Residential:all fuels	CH_4	503.1	414.4	0.0	52.1	0.0	0.1	97.8
4E	Settlements	N_2O	21.1	19.9	0.0	400.0	0.0	0.1	97.9
1A4	Other Sectors: all fuels	N_2O	44.9	49.0	0.0	103.8	0.0	0.1	98.0
3A3	Swine	CH_4	584.4	477.6	0.0	40.5	0.0	0.1	98.1

IPCC Category		Gas	Gg CO_2 eq 1990	Gg CO_2 eq 2021	trend assessment %	Uncertainty estimate %	Trend * uncertainty %	% Contr. to trend	Cumulative %
2A4a	Ceramics	CO_2	140.1	126.6	0.0	70.7	0.0	0.1	98.2
3H	Ureum use	CO_2	1.5	59.1	0.0	25.0	0.0	0.1	98.3
2G2	SF6 use	SF6	213.1	123.9	0.0	33.5	0.0	0.1	98.4
2C3	Aluminium production	CO_2	408.4	82.3	0.2	5.4	0.0	0.1	98.5
3A1	Other mature cattle	CH_4	235.4	121.6	0.0	20.9	0.0	0.1	98.6
1A3d	Domestic navigation	CO_2	742.6	772.5	0.2	5.3	0.0	0.1	98.7
5C	Open burning of waste	CH_4	4.2	0.0	0.0	316.2	0.0	0.1	98.7
2G	Other product manufacture and use	N_2O	200.4	70.5	0.1	12.2	0.0	0.1	98.8
1A1b	Petroleum Refining: gaseous	CO_2	1042.2	2524.4	1.3	0.6	0.0	0.1	98.9
3B1	Growing cattle	CH_4	563.3	476.9	0.0	18.1	0.0	0.1	99.0
4B	Cropland	CH_4	76.9	45.9	0.0	79.0	0.0	0.1	99.0
2B10	Other	CO_2	1037.6	1169.4	0.3	2.4	0.0	0.1	99.1
1A3b	Road transportation: gaseous	CO_2	0.0	186.9	0.1	5.0	0.0	0.1	99.2
2D3	Other	CO_2	0.0	34.3	0.0	26.9	0.0	0.1	99.2
4B	Cropland	N_2O	57.9	41.3	0.0	400.0	0.0	0.1	99.3
4C	Grassland	N_2O	5.5	6.2	0.0	400.0	0.0	0.1	99.4
3B3	Swine	N_2O	124.7	81.1	0.0	52.7	0.0	0.0	99.4
2E	Electronic Industry	PFC	23.5	43.2	0.0	25.5	0.0	0.0	99.5
1A2	Manufacturing Industries and Construction:all fuels	CH_4	77.6	75.5	0.0	31.7	0.0	0.0	99.5
1A2	Manufacturing Industries and Construction:all fuels	N_2O	34.3	39.3	0.0	38.8	0.0	0.0	99.5
2G	Other product manufacture and use	CH_4	57.8	53.4	0.0	50.2	0.0	0.0	99.6
5C	Open burning of waste	N_2O	2.1	0.0	0.0	316.2	0.0	0.0	99.6
1A4c	Agriculture/Forestry/Fisheries: liquids	CO_2	2521.2	1821.1	0.1	6.2	0.0	0.0	99.6
1A5b	Military use: liquids	CO_2	314.0	164.5	0.1	6.4	0.0	0.0	99.7
2B9	Fluorochemical production	PFC	0.0	21.7	0.0	20.0	0.0	0.0	99.7
1A2	Manufacturing Industries and Construction: gaseous	CO_2	19044.2	14544.9	0.2	2.0	0.0	0.0	99.7

IPCC Category		Gas	Gg CO_2 eq 1990	Gg CO_2 eq 2021	trend assessment %	Uncertainty estimate %	Trend * uncertainty %	% Contr. to trend	Cumulative %
1A4a	Commercial/Institutional: all fuels	CH_4	50.9	48.4	0.0	39.4	0.0	0.0	99.8
3B2	Sheep	N_2O	6.4	1.4	0.0	111.4	0.0	0.0	99.8
1A3a	Domestic aviation	CO_2	84.2	26.8	0.0	9.4	0.0	0.0	99.8
1A3e	Other	CO_2	342.2	93.0	0.1	2.0	0.0	0.0	99.8
2C1	Iron and steel production	CO_2	43.7	83.4	0.0	5.8	0.0	0.0	99.9
3B1	Other mature cattle	CH_4	24.8	10.6	0.0	33.0	0.0	0.0	99.9
2H	Other industrial	CO_2	72.5	14.9	0.0	5.4	0.0	0.0	99.9
4D	Wetlands	N_2O	2.2	2.1	0.0	400.0	0.0	0.0	99.9
1B1b	Solid fuel transformation	CO_2	110.4	71.3	0.0	15.0	0.0	0.0	99.9
1A5b	Military use: liquids	N_2O	4.9	2.4	0.0	122.9	0.0	0.0	99.9
1A3 exl 1A3b	Other	N_2O	6.1	5.8	0.0	131.5	0.0	0.0	99.9
4A	Forest Land	N_2O	6.3	4.4	0.0	400.0	0.0	0.0	100.0
3B1	Other mature cattle	N_2O	6.2	3.0	0.0	77.8	0.0	0.0	100.0
3B2, 3B4	Other	CH_4	37.8	26.2	0.0	46.1	0.0	0.0	100.0
4A	Forest Land	CH_4	3.8	3.9	0.0	79.0	0.0	0.0	100.0
4G	Harvested wood products	CO_2	68.6	125.1	0.1	1.0	0.0	0.0	100.0
1B2a	Oil	CH_4	22.8	16.3	0.0	70.9	0.0	0.0	100.0
1A3 exl 1A3b	Other	CH_4	2.8	3.3	0.0	51.1	0.0	0.0	100.0
1B1b	Solid fuel transformation	CH_4	12.3	5.2	0.0	11.2	0.0	0.0	100.0
1A3c	Railways	CO_2	90.8	55.8	0.0	2.2	0.0	0.0	100.0
2D2	Non-energy products from fuels and solvent use: Paraffin wax use	CH_4	0.2	0.4	0.0	111.8	0.0	0.0	100.0
1A5b	Military use: liquids	CH_4	0.9	0.4	0.0	83.4	0.0	0.0	100.0

IPCC Category		Gas	Gg CO_2 eq 1990	Gg CO_2 eq 2021	trend assessment %	Uncertainty estimate %	Trend * uncertainty %	% Contr. to trend	Cumulative %
2G	Other product manufacture and use	CO_2	0.2	0.2	0.0	53.9	0.0	0.0	100.0
4H	Other	N_2O	0.0	0.0	0.0	25.0	0.0	0.0	100.0
	SUM		233,968	176,116					

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 1 uncertainty 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). For details of the Approach 1 uncertainty analysis the methodology reports (RIVM reports 2023-0035, 2023-0041, 2023-0046), Geilenkirchen et al., 2023 and Arets et al., 2023. Results of this analysis for both level and trend are presented in table A2.1.

Although the uncertainty estimates have been based on documented uncertainties uncertainty estimates are ultimately – and unavoidably – based on the judgement of the expert. On occasion, only limited reference to actual data for the Netherlands is possible in support of these estimates.
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 assessment of the NIR.

Table A2.1 Approach 1 level and trend uncertainty estimates related to 2021 emissions (trend: 1990 – 2021)

	Uncertainty in emissions level	**Uncertainty in emissions trend**
CO_2	±3%	±1.4% of 15% decrease
CH_4	±8%	±5% of 47% decrease
N_2O	±31%	±6% of 55% decrease
F-gases	±24%	±6% of 82% decrease
Total	±3%	±3% of 24.7% decrease

Details of the Approach 1 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 2021 emissions (based on the Approach 1 uncertainty assessment)

IPCC cat.	Category	Gas	Uncertainty introduced into the trend in total national emissions (%)
5A	Solid waste disposal	CH_4	15.8
3Db	Indirect emissions from managed soils	N_2O	8.7
2C3	Aluminium production	PFC	5.5
1A4c	Agriculture/Forestry/Fisheries: all fuels	CH_4	4.6
1B2c	Venting and flaring	CH_4	4.3
1A2	Manufacturing Industries and Construction: liquids	CO_2	3.4
2B	Fluorochemical production	HFC	3.2
3Da	Direct emissions from agricultural soils	N_2O	2.8
2F1	Refrigeration and airconditioning	HFC	2.3
2B2	Nitric acid production	N_2O	2.2

Table A2.3 Detailed 2 level and trend uncertainty assessment 1990–2021 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 2021.

IPCC 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 (+)
1A2	Manufacturing Industries and Construction: liquids	CO_2	9694.6	9212.9	0.01	0.01	0.24	0.24	0.24	0.24	0.19	-5	0.21
4C	Grassland	CO_2	3946.4	2604.4	0.00	0.00	0.75	0.75	0.75	0.75	0.14	-34	0.12
1A1b	Petroleum Refining: liquids	CO_2	9968.2	6946.3	0.05	0.05	0.25	0.25	0.26	0.26	0.12	-30	0.22
3Da	Direct emissions from agricultural soils	N_2O	6288.0	3650.8	0.09	0.09	0.34	0.34	0.35	0.35	0.06	-42	0.25
5D	Wastewater treatment and discharge	N_2O	726.7	711.3	0.27	0.27	1.59	1.59	1.61	1.61	0.05	-2	0.16
3Db	Indirect emissions from managed soils	N_2O	1423.0	520.7	0.32	0.32	2.16	2.16	2.18	2.18	0.05	-63	0.52
1A1a	Public Electricity and Heat Production: solids	CO_2	25862.2	16718.0	0.01	0.01	0.06	0.06	0.06	0.06	0.04	-35	0.12
1A2	Manufacturing Industries and Construction: solids	CO_2	6623.4	3957.8	0.02	0.02	0.24	0.24	0.24	0.24	0.04	-40	0.12
3A1	Mature dairy cattle	CH_4	5805.2	5966.2	0.02	0.02	0.15	0.15	0.15	0.15	0.03	3	0.13
4B	Cropland	CO_2	3306.4	2017.0	0.00	0.00	0.44	0.44	0.44	0.44	0.03	-39	0.09
1A4b	Residential gaseous	CO_2	19894.1	16918.4	0.05	0.05	0.00	0.00	0.05	0.05	0.03	-15	0.51
3B5	Indirect emissions	N_2O	345.1	204.8	0.18	0.18	4.00	4.00	4.00	4.00	0.03	-41	0.10
4E	Settlements	CO_2	1000.4	1175.6	0.00	0.00	0.69	0.69	0.69	0.69	0.02	18	0.12
1A4c	Agriculture/Forestry/Fisheries: gaseous	CO_2	7328.7	7425.7	0.10	0.10	0.00	0.00	0.10	0.10	0.02	1	0.45
1A4a	Commercial/Institutional: gaseous	CO_2	7757.8	6321.1	0.11	0.11	0.00	0.00	0.11	0.11	0.02	-19	0.42
1A4c	Agriculture/Forestry/Fisheries: all fuels	CH_4	84.2	1347.2	0.10	0.10	0.48	0.48	0.49	0.49	0.02	1500	0.27

IPCC 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
3B1	Mature dairy cattle	CH_4	1212.7	1665.2	0.02	0.02	0.38	0.38	0.38	0.38	0.02	37	0.12
2B1	Ammonia production	CO_2	2695.0	2131.6	0.06	0.06	0.28	0.28	0.29	0.29	0.01	-21	0.07
5A	Solid waste disposal	CH_4	15320.8	2356.3	0.00	0.00	0.24	0.24	0.24	0.24	0.01	-85	0.93
1A1c	Manufacture of Solid Fuels: solids	CO_2	916.3	1151.3	0.16	0.16	0.40	0.40	0.43	0.43	0.01	26	0.14
3B3	Swine	CH_4	3772.8	1726.3	0.08	0.08	0.23	0.23	0.25	0.25	0.01	-54	0.14
2B8	Petrochemical and carbon black production	CO_2	335.6	556.5	0.50	0.50	0.50	0.50	0.71	0.71	0.01	66	0.18
2A4d	Other	CO_2	481.2	637.3	0.25	0.25	0.56	0.56	0.62	0.62	0.01	32	0.12
1A3b	Road transportation: diesel oil	CO_2	13012.2	13118.4	0.02	0.02	0.02	0.02	0.03	0.03	0.01	1	0.16
2F1	Refrigeration and airconditioning	HFC	0.0	797.7	0.15	0.15	0.36	0.36	0.39	0.39	0.00		0.14
1A3b	Road transportation: gasoline	CO_2	10672.1	10660.1	0.02	0.02	0.02	0.02	0.03	0.03	0.00	0	0.13
1A2	Manufacturing Industries and Construction: gaseous	CO_2	19044.2	14544.9	0.02	0.02	0.00	0.00	0.02	0.02	0.00	-24	0.18
2B8	Chemical industry: Petrochemical and carbon black production	CH_4	301.8	357.8	0.50	0.50	0.50	0.50	0.71	0.71	0.00	19	0.11
2B10	Other	N_2O	217.1	355.7	0.50	0.50	0.50	0.50	0.71	0.71	0.00	64	0.12
4F	Other Land	CO_2	89.9	163.9	0.00	0.00	1.52	1.52	1.52	1.52	0.00	82	0.06
4A	Forest Land	CO_2	2452.8	2059.6	0.00	0.00	0.12	0.12	0.12	0.12	0.00	-16	0.01
1A4	Liquids excl. 1A4c	CO_2	1330.5	627.8	0.36	0.36	0.01	0.01	0.36	0.36	0.00	-53	0.14
2D2	Paraffin wax use	CO_2	102.6	213.3	1.00	1.00	0.20	0.20	1.02	1.02	0.00	108	0.13
1A4b	Residential:all fuels	CH_4	503.1	414.4	0.08	0.08	0.52	0.52	0.52	0.52	0.00	-18	0.02
1A1c	Manufacture of Solid Fuels: gaseous	CO_2	1184.2	1290.4	0.15	0.15	0.05	0.05	0.16	0.16	0.00	9	0.12
3A3	Swine	CH_4	584.4	477.6	0.06	0.06	0.40	0.40	0.41	0.41	0.00	-18	0.02

IPCC 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: other fuels: waste incineration	CO_2	601.5	2671.2	0.03	0.03	0.06	0.06	0.07	0.07	0.00	344	0.08
3A1	Young cattle	CH_4	3138.0	2000.4	0.01	0.01	0.09	0.09	0.09	0.09	0.00	-36	0.02
4B	Cropland	N_2O	57.9	41.3	0.00	0.00	4.00	4.00	4.00	4.00	0.00	-29	0.00
4C	Grassland	CH_4	225.7	195.1	0.00	0.00	0.79	0.79	0.79	0.79	0.00	-14	0.01
3A2, 3A4	Other	CH_4	576.4	506.0	0.17	0.17	0.21	0.21	0.27	0.27	0.00	-12	0.05
2A2	Lime production	CO_2	162.7	180.8	0.75	0.75	0.05	0.05	0.75	0.75	0.00	11	0.08
6	Indirect CO2	CO_2	917.2	502.7	0.25	0.25	0.10	0.10	0.27	0.27	0.00	-45	0.08
1A1	Energy Industries: all fuels	N_2O	131.8	264.9	0.01	0.01	0.45	0.45	0.45	0.45	0.00	101	0.03
3B1	Mature dairy cattle	N_2O	169.1	164.9	0.02	0.02	0.68	0.68	0.69	0.69	0.00	-2	0.01
1A4c	Agriculture/Forestry/Fisheries: liquids	CO_2	2521.2	1821.1	0.06	0.06	0.02	0.02	0.06	0.06	0.00	-28	0.07
2B4	Caprolactam production	N_2O	658.0	367.1	0.20	0.20	0.23	0.23	0.30	0.30	0.00	-44	0.05
1A3b	Road transportation	N_2O	89.5	186.1	0.02	0.02	0.50	0.50	0.50	0.50	0.00	108	0.03
5D	Wastewater treatment and discharge	CH_4	421.3	223.6	0.13	0.13	0.38	0.38	0.41	0.41	0.00	-47	0.02
2A4a	Ceramics	CO_2	140.1	126.6	0.50	0.50	0.50	0.50	0.71	0.71	0.00	-10	0.04
1B2b	Natural gas	CH_4	471.6	263.7	0.01	0.01	0.33	0.33	0.33	0.33	0.00	-44	0.01
1A1a	Public Electricity and Heat Production: gaseous	CO_2	13329.1	15334.4	0.01	0.01	0.00	0.00	0.01	0.01	0.00	15	0.05
3B1	Growing cattle	CH_4	563.3	476.9	0.01	0.01	0.18	0.18	0.18	0.18	0.00	-15	0.01
3B1	Growing cattle	N_2O	128.7	127.3	0.29	0.29	0.59	0.59	0.66	0.66	0.00	-1	0.02
4E	Settlements	N_2O	21.1	19.9	0.00	0.00	4.00	4.00	4.00	4.00	0.00	-5	0.01
5B	Biological treatment of solid waste: composting	CH_4	4.8	137.0	0.12	0.12	0.52	0.52	0.53	0.53	0.00	2762	0.03

IPCC 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: liquids	CO_2	233.2	321.0	0.02	0.02	0.22	0.22	0.22	0.22	0.00	38	0.01
1B2c	Venting and flaring	CH_4	1669.8	132.8	0.49	0.49	0.20	0.20	0.53	0.53	0.00	-92	0.10
2F6	Other	HFC	0.0	130.2	0.20	0.20	0.50	0.50	0.54	0.54	0.00		0.03
2D1	Lubricant use	CO_2	84.6	92.1	0.50	0.50	0.50	0.50	0.71	0.71	0.00	9	0.03
2A4b	Other uses of soda ash	CO_2	68.6	120.4	0.00	0.00	0.50	0.50	0.50	0.50	0.00	76	0.01
1B2	Fugitive emissions from oil and gas operations	CO_2	774.6	1051.5	0.01	0.01	0.05	0.05	0.05	0.05	0.00	36	0.01
1A4	Other Sectors: all fuels	N_2O	44.9	49.0	0.12	0.12	1.03	1.03	1.04	1.04	0.00	9	0.01
5B	Biological treatment of solid waste: composting	N_2O	5.8	82.0	0.11	0.11	0.60	0.60	0.61	0.61	0.00	1314	0.02
3B4	Other livestock	N_2O	53.9	87.5	0.12	0.12	0.53	0.53	0.54	0.54	0.00	62	0.01
1A1	Energy Industries: all fuels	CH_4	77.4	165.3	0.02	0.02	0.28	0.28	0.28	0.28	0.00	114	0.01
3B3	Swine	N_2O	124.7	81.1	0.18	0.18	0.49	0.49	0.53	0.53	0.00	-35	0.01
2G2	SF6 use	SF6	213.1	123.9	0.30	0.30	0.15	0.15	0.34	0.34	0.00	-42	0.02
1A3d	Domestic navigation	CO_2	742.6	772.5	0.05	0.05	0.02	0.02	0.05	0.05	0.00	4	0.02
4B	Cropland	CH_4	76.9	45.9	0.00	0.00	0.79	0.79	0.79	0.79	0.00	-40	0.00
4F	Other Land	N_2O	5.1	8.9	0.00	0.00	4.00	4.00	4.00	4.00	0.00	76	0.01
2A3	Glass production	CO_2	142.4	68.0	0.00	0.00	0.50	0.50	0.50	0.50	0.00	-52	0.01
2B	Fluorochemical production	HFC	4697.2	244.6	0.00	0.00	0.13	0.13	0.13	0.13	0.00	-95	0.19
1A3b	Road transportation	CH_4	214.0	64.3	0.02	0.02	0.50	0.50	0.50	0.50	0.00	-70	0.02
4D	Wetlands	CO_2	11.0	41.2	0.00	0.00	0.76	0.76	0.76	0.76	0.00	275	0.01
3B4	Poultry	CH_4	481.7	73.1	0.02	0.02	0.40	0.40	0.41	0.41	0.00	-85	0.05
2B10	Other	CO_2	1037.6	1169.4	0.02	0.02	0.02	0.02	0.02	0.02	0.00	13	0.01
2G	Other product manufacture and use	CH_4	57.8	53.4	0.10	0.10	0.49	0.49	0.50	0.50	0.00	-8	0.00
3A1	Other mature cattle	CH_4	235.4	121.6	0.02	0.02	0.21	0.21	0.21	0.21	0.00	-48	0.01

IPCC 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
4C	Grassland	N_2O	5.5	6.2	0.00	0.00	4.00	4.00	4.00	4.00	0.00	12	0.00
1A2	Manufacturing Industries and Construction:all fuels	CH_4	77.6	75.5	0.02	0.02	0.32	0.32	0.32	0.32	0.00	-3	0.00
1A4a	Commercial/Institutional: all fuels	CH_4	50.9	48.4	0.09	0.09	0.38	0.38	0.39	0.39	0.00	-5	0.00
4A	Forest Land	N_2O	6.3	4.4	0.00	0.00	4.00	4.00	4.00	4.00	0.00	-30	0.00
1A2	Manufacturing Industries and Construction:all fuels	N_2O	34.3	39.3	0.05	0.05	0.38	0.38	0.39	0.39	0.00	15	0.00
3H	Ureum use	CO_2	1.5	59.1	0.25	0.25	0.01	0.01	0.25	0.25	0.00	3804	0.01
1A3b	Road transportation: LPG	CO_2	2578.4	266.6	0.05	0.05	0.02	0.02	0.05	0.05	0.00	-90	0.02
1A1b	Petroleum Refining: gaseous	CO_2	1042.2	2524.4	0.01	0.01	0.00	0.00	0.01	0.01	0.00	142	0.01
2B2	Nitric acid production	N_2O	5410.9	179.5	0.05	0.05	0.06	0.06	0.08	0.08	0.00	-97	0.10
3B2, 3B4	Other	CH_4	37.8	26.2	0.27	0.27	0.38	0.38	0.46	0.46	0.00	-31	0.00
1B2a	Oil	CH_4	22.8	16.3	0.02	0.02	0.71	0.71	0.71	0.71	0.00	-29	0.00
2E	Electronic Industry	PFC	23.5	43.2	0.05	0.05	0.25	0.25	0.25	0.25	0.00	84	0.00
1B1b	Solid fuel transformation	CO_2	110.4	71.3	0.00	0.00	0.15	0.15	0.15	0.15	0.00	-35	0.00
1A5b	Military use: liquids	CO_2	314.0	164.5	0.06	0.06	0.02	0.02	0.06	0.06	0.00	-48	0.01
1A3b	Road transportation: gaseous	CO_2	0.0	186.9	0.05	0.05	0.00	0.00	0.05	0.05	0.00		0.01
2D3	Other	CO_2	0.0	34.3	0.25	0.25	0.10	0.10	0.27	0.27	0.00		0.01
2G	Other product manufacture and use	N_2O	200.4	70.5	0.09	0.09	0.09	0.09	0.12	0.12	0.00	-65	0.00
4D	Wetlands	N_2O	2.2	2.1	0.00	0.00	4.00	4.00	4.00	4.00	0.00	-3	0.00
1A3 exl 1A3b	Other	N_2O	6.1	5.8	0.07	0.07	1.31	1.31	1.31	1.31	0.00	-5	0.00
2C3	Aluminium production	PFC	2373.9	14.5	0.02	0.02	0.43	0.43	0.43	0.43	0.00	-99	0.32
3G	Liming	CO_2	183.2	24.0	0.24	0.24	0.01	0.01	0.24	0.24	0.00	-87	0.00
2C1	Iron and steel production	CO_2	43.7	83.4	0.03	0.03	0.05	0.05	0.06	0.06	0.00	91	0.00

IPCC 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
2C3	Aluminium production	CO_2	408.4	82.3	0.02	0.02	0.05	0.05	0.05	0.05	0.00	-80	0.00
2B9	Fluorochemical production	PFC	0.0	21.7	0.00	0.00	0.20	0.20	0.20	0.20	0.00		0.00
3B1	Other mature cattle	CH_4	24.8	10.6	0.02	0.02	0.33	0.33	0.33	0.33	0.00	-57	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	0.00
1A5b	Military use: liquids	N_2O	4.9	2.4	0.08	0.08	1.23	1.23	1.23	1.23	0.00	-52	0.00
1A3a	Domestic aviation	CO_2	84.2	26.8	0.09	0.09	0.03	0.03	0.09	0.09	0.00	-68	0.00
3B1	Other mature cattle	N_2O	6.2	3.0	0.02	0.02	0.78	0.78	0.78	0.78	0.00	-51	0.00
1A3e	Other	CO_2	342.2	93.0	0.02	0.02	0.00	0.00	0.02	0.02	0.00	-73	0.00
1A3 exl 1A3b	Other	CH_4	2.8	3.3	0.16	0.16	0.48	0.48	0.51	0.51	0.00	16	0.00
1A4	Solids	CO_2	162.7	4.2	0.36	0.36	0.13	0.13	0.39	0.39	0.00	-97	0.01
3B2	Sheep	N_2O	6.4	1.4	0.06	0.06	1.11	1.11	1.11	1.11	0.00	-78	0.00
4G	Harvested wood products	CO_2	68.6	125.1	0.00	0.00	0.01	0.01	0.01	0.01	0.00	82	0.00
1A3c	Railways	CO_2	90.8	55.8	0.01	0.01	0.02	0.02	0.02	0.02	0.00	-39	0.00
2H	Other industrial	CO_2	72.5	14.9	0.02	0.02	0.05	0.05	0.05	0.05	0.00	-79	0.00
1B1b	Solid fuel transformation	CH_4	12.3	5.2	0.02	0.02	0.11	0.11	0.11	0.11	0.00	-57	0.00
2D2	Non-energy products from fuels and solvent use: Paraffin wax use	CH_4	0.2	0.4	1.00	1.00	0.50	0.50	1.12	1.12	0.00	108	0.00
1A5b	Military use: liquids	CH_4	0.9	0.4	0.08	0.08	0.83	0.83	0.83	0.83	0.00	-52	0.00
2G	Other product manufacture and use	CO_2	0.2	0.2	0.50	0.50	0.20	0.20	0.54	0.54	0.00	-26	0.00
5C	Open burning of waste	CH_4	4.2	0.0	1.00	1.00	3.00	3.00	3.16	3.16	0.00	-100	0.00
5C	Open burning of waste	N_2O	2.1	0.0	1.00	1.00	3.00	3.00	3.16	3.16	0.00	-100	0.00
2B7	Soda ash production	CO_2	63.8	0.0	0.00	0.00	0.05	0.05	5.00	5.00	0.00	-100	0.00
4H	Other	N_2O	0.0	0.0	0.25	0.25	0.01	0.01	0.25	0.25	0.00	0	0.00
2A1	Cement production	CO_2	415.8	0.0	0.05	0.05	0.10	0.10	0.11	0.11	0.00	-100	0.01

2.2 Uncertainties 1990 emissions

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 with all 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, based on expert judgement. To enable a comparison with the current Approach 1 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 (%) 2022(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 a bit smaller in the 2022 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 2021 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 2021, part 1-2

Energy balance sheet the Netherlands 2021	Anthracite	Coking coal	Steam coal	Lignite	Coke-oven cokes	BKB (Braunkohlenbrikett	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)	**0.2**	**116.3**	**118.7**	**0.2**	**-0.2**	**0.3**		**-1.3**				**2296.8**	**214.8**	**35.0**		**11.5**	**38.2**
Indigenous production												**32.0**	**4.3**	**11.8**		**11.5**	
Imports	**0.2**	**115.6**	**116.2**	**0.2**	**2.2**	**0.3**						**4016.1**	**211.0**	**54.3**			**141.8**
Exports					**0.3**			**1.1**				**1882.3**	**15.0**	**39.5**			**103.1**
Bunkers																	
Stock change		**0.8**	**2.5**		**-2.1**			**-0.2**				**131.1**	**14.5**	**8.3**			**-0.4**
Energy consumption																	
Net energy consumption	**0.2**	**116.3**	**118.7**	**0.2**	**-0.2**	**0.3**		**-1.3**				**2296.8**	**214.8**	**35.0**		**11.5**	**38.2**
Energy transformation																	
Total energy transformation input		**115.9**	**118.0**		**48.8**					**1.6**	**24.5**	**2296.8**	**154.7**	**33.1**		**21.4**	**41.8**
Electricity and CHP transformation input			**118.0**							**1.6**	**24.5**					**16.2**	
Other transformation input		**115.9**			**48.8**							**2296.8**	**154.7**	**33.1**		**5.2**	**41.8**
Total energy transformation output					**53.7**			**3.0**		**15.1**	**36.5**					**203.4**	**78.8**
Electricity/CHP transformation output																	
Other transformation output					**53.7**			**3.0**		**15.1**	**36.5**					**203.4**	**78.8**
Total net energy transformation		**115.9**	**118.0**		**-4.9**			**-3.0**		**-13.5**	**-12.0**	**2296.8**	**154.7**	**33.1**		**-182.0**	**-37.0**
Net electricity/CHP transformation			**118.0**							**1.6**	**24.5**					**16.2**	
Net other transformation		**115.9**			**-4.9**			**-3.0**		**-15.1**	**-36.5**	**2296.8**	**154.7**	**33.1**		**-198.2**	**-37.0**
Energy sector own use																	
Total energy sector own use										**8.1**	**10.3**					**86.3**	**1.2**
Production of heat and power																	
Extraction of crude petroleum and gas																	
Coke-oven plants										**5.7**	**1.7**						
Blast furnaces										**2.4**	**8.7**						
Oil refineries																**86.3**	**1.2**
Electricity and gas supply																	
Distribution losses																	
Distribution losses																	
Final consumption																	
Total final consumption	**0.2**	**0.4**	**0.7**	**0.2**	**4.7**	**0.3**		**1.7**		**5.5**	**1.7**		**60.0**	**1.9**		**107.2**	**74.0**
Total final energy consumption	**0.0**	**0.4**	**0.7**	**0.2**	**4.5**	**0.3**				**5.5**	**1.7**					**107.2**	**11.2**
Total industry	**0.0**	**0.4**	**0.7**	**0.1**	**4.5**	**0.2**				**5.5**	**1.7**					**107.2**	**0.3**
Iron and steel		**0.4**			**3.5**					**5.5**	**1.7**						**0.0**
Chemical and petrochemical																**107.2**	**0.0**
Non-ferrous metals																	**0.0**
Non-metallic minerals		**0.0**		**0.0**	**1.0**												**0.0**
Transport equipment																	**0.0**
Machinery																	**0.1**

Mining and quarrying				**0.1**													**0.0**
Food and tobacco	**0.0**		**0.7**														**0.0**
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						**0.2**										**0.0**	**0.1**
Total transport																	**4.9**
Domestic aviation																	
Road transport																	**4.9**
Rail transport																	
Pipeline transport																	
Domestic navigation																	
Non-specified																	
Total other sectors	**0.0**			**0.1**		**0.0**											**6.0**
Services, waste, water and repair				**0.1**		**0.0**											**3.6**
Households	**0.0**					**0.0**											**1.0**
Agriculture																	**1.4**
Fishing																	
Non-specified																	
Total non-energy use	**0.2**	**0.0**			**0.1**			**1.7**					**60.0**	**1.9**			**62.9**
Industry (excluding the energy sector)	**0.2**	**0.0**			**0.1**			**1.7**					**60.0**	**1.9**			**62.9**
Of which chemistry and pharmaceuticals													**60.0**	**1.9**			**62.9**
Transport																	
Other sectors																	
Statistical difference																	
Statistical differences					**0.0**								**0.0**			**0.0**	

Energy Balance the Netherlands 2021, part 2-2

Energy balance sheet the Netherlands 2021	Naphtha	Motor gasoline	Gasoline type jet	Aviation gasoline	Kerosene type jet fuel	Other kerosene	Heating and other gasoil	Fuel oil	White spirit and industrial spirit	Lubricants	Bitumen	Paraffin waxes	Petroleum coke	Other petroleum products	Natural gas	Municipal waste; renewable fraction	Solid and liquid biomass	Biogas	Non-rene.municipal
Energy supply																			
Total Primary Energy Supply (TPES)	**440.1**	**-663.8**		**-2.7**	**-136.2**	**-1.7**	**-806.6**	**-235.4**	**18.5**	**-38.2**	**-27.1**	**0.9**	**14.6**	**-55.9**	**1261.9**	**40.9**	**155.3**	**17.9**	**45.8**
Indigenous production														**5.8**	**649.6**	**36.2**	**148.7**	**17.9**	**41.9**
Imports	**1015.6**	**348.7**		**0.0**	**193.9**	**13.3**	**379.9**	**1139.8**	**78.5**	**77.6**	**12.7**	**9.0**	**61.8**	**32.9**	**1724.5**	**5.7**	**68.9**		**4.8**
Exports	**604.2**	**1027.0**		**2.9**	**238.0**	**17.6**	**1167.0**	**996.3**	**60.9**	**109.1**	**39.7**	**8.2**	**47.3**	**91.0**	**1298.6**	**1.0**	**59.2**		**0.9**
Bunkers					**102.0**		**90.3**	**378.5**		**4.7**					**5.0**				
Stock change	**28.7**	**14.5**		**0.1**	**9.9**	**2.5**	**70.9**	**-0.5**	**0.9**	**-2.0**	**0.0**	**0.0**	**0.0**	**-3.6**	**191.4**		**-3.1**		
Energy consumption																			
Net energy consumption	**440.1**	**-663.8**		**-2.7**	**-136.2**	**-1.7**	**-806.6**	**-235.4**	**18.5**	**-38.2**	**-27.1**	**0.9**	**14.6**	**-55.9**	**1256.1**	**40.9**	**155.3**	**17.7**	**45.8**
Energy transformation																			
Total energy transformation input	**715.3**	**30.3**		**0.0**	**50.1**	**21.8**	**163.4**	**262.2**	**55.0**	**8.3**	**0.0**	**2.8**		**26.4**	**489.8**	**40.9**	**128.3**	**15.7**	**45.8**
Electricity and CHP transformation input							**0.5**							**0.1**	**463.4**	**40.9**	**82.9**	**8.7**	**34.9**
Other transformation input	**715.3**	**30.3**		**0.0**	**50.1**	**21.8**	**162.8**	**262.2**	**55.0**	**8.3**	**0.0**	**2.8**		**26.2**	**26.4**		**45.4**	**7.0**	**11.0**
Total energy transformation output	**524.7**	**854.1**		**2.8**	**187.8**	**25.1**	**1231.8**	**497.6**	**39.7**	**52.9**	**30.9**	**10.0**	**15.1**	**90.5**	**8.3**				
Electricity/CHP transformation output																			
Other transformation output	**524.7**	**854.1**		**2.8**	**187.8**	**25.1**	**1231.8**	**497.6**	**39.7**	**52.9**	**30.9**	**10.0**	**15.1**	**90.5**	**8.3**				
Total net energy transformation	**190.6**	**-823.9**		**-2.8**	**-137.8**	**-3.3**	**-1068.4**	**-235.4**	**15.4**	**-44.6**	**-30.9**	**-7.3**	**-15.1**	**-64.1**	**481.5**	**40.9**	**128.3**	**15.7**	**45.8**
Net electricity/CHP transformation							**0.5**							**0.1**	**463.4**	**40.9**	**82.9**	**8.7**	**34.9**
Net other transformation	**190.6**	**-823.9**		**-2.8**	**-137.8**	**-3.3**	**-1068.9**	**-235.4**	**15.4**	**-44.6**	**-30.9**	**-7.3**	**-15.1**	**-64.3**	**18.1**		**45.4**	**7.0**	**11.0**
Energy sector own use																			
Total energy sector own use							**0.1**						**10.8**	**0.0**	**41.4**				
Production of heat and power																			
Extraction of crude petroleum and gas							**0.0**								**21.8**				
Coke-oven plants																			
Blast furnaces															**0.6**				
Oil refineries							**0.0**						**10.8**		**17.2**				
Electricity and gas supply														**0.0**	**1.9**				
Distribution losses																			
Distribution losses																			
Final consumption																			

Total final consumption	**249.5**	**160.0**		**0.1**	**1.6**	**1.5**	**261.8**		**3.1**	**6.4**	**3.8**	**8.2**	**18.9**	**8.2**	**733.2**		**27.0**	**2.0**	
Total final energy consumption		**160.0**		**0.1**	**1.6**	**0.2**	**261.0**						**0.1**	**1.8**	**622.0**		**27.0**	**2.0**	
Total industry						**0.0**	**21.4**						**0.1**	**1.8**	**172.8**		**2.8**	**1.6**	
Iron and steel							**0.1**						**0.1**	**0.0**	**10.2**				
Chemical and petrochemical						**0.0**	**0.1**							**1.8**	**66.5**				
Non-ferrous metals							**0.0**								**2.7**				
Non-metallic minerals						**0.0**	**0.2**								**19.2**				
Transport equipment							**0.0**							**0.0**	**2.0**				
Machinery						**0.0**	**0.1**							**0.0**	**10.5**				
Mining and quarrying							**0.2**								**2.0**				
Food and tobacco							**0.0**							**0.0**	**41.6**				
Paper, pulp and printing							**0.0**								**7.3**				
Wood and wood products							**0.0**								**0.6**				
Construction							**20.8**								**3.2**		**0.2**		
Textile and leather															**2.3**				
Other industry and non-specified							**0.0**							**0.0**	**4.9**				
Total transport		**160.0**		**0.1**	**0.3**		**206.6**								**3.3**				
Domestic aviation				**0.1**	**0.3**														
Road transport		**160.0**					**195.9**								**3.3**				
Rail transport							**0.8**												
Pipeline transport																			
Domestic navigation							**9.9**								**0.0**				
Non-specified																			
Total other sectors		**0.0**			**1.2**	**0.2**	**33.0**							**0.0**	**445.8**		**24.2**	**0.4**	
Services, waste, water and repair		**0.0**				**0.0**	**6.0**							**0.0**	**111.4**		**1.7**	**0.4**	
Households						**0.2**	**0.3**								**301.7**		**16.2**		
Agriculture							**19.4**								**32.6**		**6.4**		
Fishing							**5.8**												
Non-specified					**1.2**		**1.5**								**0.2**				
Total non-energy use	**249.5**					**1.3**	**0.8**		**3.1**	**6.4**	**3.8**	**8.2**	**18.8**	**6.4**	**111.2**				
Industry (excluding the energy sector)	**249.5**					**1.3**	**0.8**		**3.1**	**2.2**	**3.8**	**8.2**	**18.8**	**6.4**	**97.3**				
Of which chemistry and pharmaceuticals	**249.5**					**1.3**	**0.8**		**2.5**	**0.1**		**7.5**	**11.8**	**6.4**	**97.3**				
Transport										**2.7**									
Other sectors	**0.0**					**0.0**				**1.5**				**0.0**	**13.9**				
Statistical difference																			
Statistical differences	**0.0**							**0.0**	**0.0**		**0.0**				**5.8**		**0.0**	**0.2**	

Annex 5 The Netherlands' fuel list and standard CO_2 emission factors. Version January 2023

Colophon

Project name	Annual update of fuel list for the Netherlands
Project number	113569/BL2023
Version number	January 2023
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 2023) is approved by WEM, after detailed discussions with the Dutch Emission 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 organization for Applied Scientific Research (TNO).

Fuel list, version of January 2023

Name (Dutch)	Name (English)	Unit	Net Calorific Value (MJ/unit)				CO_2 EF (kg/GJ)			
			2021	2022	2023	Ref [1)]	2021	2022	2023	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

Name (Dutch)	Name (English)	Unit	Net Calorific Value (MJ/unit)				CO_2 EF (kg/GJ)			
			2021	2022	2023	Ref 1)	2021	2022	2023	Ref 1)
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
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	24.9	24.9 3)	24.9 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

Name (Dutch)	Name (English)	Unit	Net Calorific Value (MJ/unit)				CO_2 EF (kg/GJ)			
			2021	2022	2023	Ref [1]	2021	2022	2023	Ref [1]
	C. Gaseous Fossil Fuels									
Aardgas [4]	Natural Gas (dry) [4]	Nm3 ae	31.65	31.65	31.65	CS	56.4[4]	56.5[4]	56.3[4]	CS
Compressed natural gas (CNG) [4]	Compressed natural gas (CNG) [4]	Nm3 ae	31.65	31.65	31.65	CS	56.4[4]	56.5[4]	56.3[4]	CS
Liquified natural gas (LNG) [4]	Liquified natural gas (LNG) [4]	Nm3 ae	31.65	31.65	31.65	CS	56.4[4]	56.5[4]	56.3[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
Houtskool	Charcoal	kg	30.0	30.0	30.0	CS	112.0	112.0	112.0	IPCC
Biobenzine [3]	Biogasoline [3]	Kg	27.8	27.8[3]	27.8[3]	CS	70.8	70.8[3]	70.8[3]	CS
Biodiesel [3]	Biodiesels [3]	Kg	38.3	38.3[3]	38.3[3]	CS	74.4	74.4[3]	74.4[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	107.0	107.0[3]	107.0 [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 2022 and 2023 are not yet known, they are set equal to the value for 2021. 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 65%.

Notes on the fuel list

Netherlands Enterprise Agency (RVO.nl) 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 2023) 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 2023), the years in question are 2021, 2022 and 2023. The values in these columns are used for the following purposes:

1. **2021**: these values are used in 2023 for calculations concerning the calendar year 2021, 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 2023 (NIR 2023) gives full details of greenhouse gas emissions in the Netherlands up to and including 2021. The fuel list forms an integral part of the NIR 2023.
2. **2022**: these values are used in 2023 for reports on energy consumption and CO_2 emission for the calendar year 2022 in the Electronic Environmental Annual Report (e-MJV).
3. **2023**: these values will be used in 2023 in emission reports for the calendar year 2023 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 2023.

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.
- In LULUCF category 4.A2 Land converted to forest Land, the accumulation of dead wood and litter in newly established forest plots is an uncertain carbon sink of unknown magnitude (see Arets et al., 2021). Therefore in order to be conservative this sink is reported as ‘NE’. However, when ‘Land converted to forest land’ transitions to ‘Forest land remaining forest land’, a litter layer will have formed in the 20 years of that forest area’s existence. Therefore in units of Forest land that newly enter the category Forest land remaining Forest land in the reporting year, carbon stocks will increase to the average carbon stock/ha in litter in ‘Forest land remaining forest land’.

A number of recommendations by DNV GL, related 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 2023. These reports are to be considered as an integrated part of this NIR2023.

A7.1 List of methodology reports

ENINA: (Energy, IP, Waste)
Methodology report on the calculations of emissions to air from the sectors Energy, Industry and Waste
RIVM Report 2023-0035
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 - 2023
G. Geilenkirchen, M. Bolech, J. Hulskotte, S. Dellaert, N. Ligterink, M. Sijstermans, K. Geertjes, K. Felter, M. ’t Hoen.

IPPU
Methods used for the Dutch Emission Inventory. Product usage by consumers, construction and services
RIVM Report 2023-0046
A.J.H. Visschedijk, J.A.J. Meesters, M.M. Nijkamp, W.W.R Koch, B.I. Jansen, R. Dröge.

Agriculture:
Methodology for estimating emissions from agriculture in the Netherlands
RIVM Report 2023-0041 .
Calculations of CH_4, NH_3, N_2O, NO_x, NMVOC, PM10, PM2.5 and CO_2 using the National Emission Model for Agriculture (NEMA)
T.C. van der Zee, A. Bleeker, C. van Bruggen, W. Bussink, 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 2023, WOt-technical report 238
E.J.M.M. Arets, S.A. van Baren, 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 with 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	
$C \rightarrow CO_2$:	x 44/12 = 3.67	$CO_2 \rightarrow C$:	x 12/44 = 0.27
$C \rightarrow CH_4$:	x 16/12 = 1.33	$CH_4 \rightarrow C$:	x 12/16 = 0.75
$C \rightarrow CO$:	x 28/12 = 2.33	$CO \rightarrow C$:	x 12/28 = 0.43
$N \rightarrow N_2O$:	x 44/28 = 1.57	$N_2O \rightarrow N$:	x 28/44 = 0.64
$N \rightarrow NO$:	x 30/14 = 2.14	$NO \rightarrow N$:	x 14/30 = 0.47
$N \rightarrow NO_2$:	x 46/14 = 3.29	$NO_2 \rightarrow N$:	x 14/46 = 0.30
$N \rightarrow NH_3$:	x 17/14 = 1.21	$NH_3 \rightarrow N$:	x 14/17 = 0.82
$N \rightarrow HNO_3$:	x 63/14 = 4.50	$HNO_3 \rightarrow N$:	x 14/63 = 0.22
$S \rightarrow SO_2$:	x 64/32 = 2.00	$SO_2 \rightarrow S$:	x 32/64 = 0.50

Annex 9 List of abbreviations

AD	Activity Data
AGB	Above-Ground Biomass
AR	Afforestation andFreforestation
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	Minisery 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 Desulphurization
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 wWastewater 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
NEa	Dutch Emissions Authority
NE	Not Estimated (notation code in CRF)
NEa	Netherlands Emission authority (Dutch Emission 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 Organization 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

Sector	**General**
ID# PMF 2022	G.1
Table PMF 2022	1
Adressing/Not resolved/ New from 2022 review	-
Issue and/or problem classification[a[, b]]	QA/QC and verification (G.4, 2021) Convention reporting adherence
Is finding an issue/problem	-
Recommendation made in previous review report	The ERT recommends that the Party review the QC procedures used to verify the input inventory data collected under directive EC/2009/29 and report the results of this verification in future annual submissions.
ERT assessment and rationale	The Party reported in its NIR (chapter 2.1, p.30-34) about enhanced QA/QC processes which helped the sectoral experts detect and correct erroneous inputs in the CRF (including links between inventory sources and CRF categories, missing notation keys, fluctuations in IEFs) in an early stage of the compilation process.
NLD Response in NIR /CRF 2023	No action required.
Paragraph or table number in: NIR, CRF and or Methodology report (MR)	-

Sector	General
ID# PMF 2022	G.2
Table PMF 2022	1
Adressing/Not resolved/ New from 2022 review	-
Issue and/or problem classification[a[, b]]	Uncertainty analysis (G.5, 2021) Convention reporting adherence
Is finding an issue/problem	-
Recommendation made in previous review report	The ERT recommends that the Party report the correct information in NIR table A2.3 for AD and EF uncertainties for category 1.B.2.b in future annual submissions.
ERT assessment and rationale	The Party reported in its NIR (Annex 2, p.368, table A2.3) with correct information on AD and EF uncertainties for category 1.B.2.b.
NLD Response in NIR /CRF 2023	No action required.
Paragraph or table number in: NIR, CRF and or Methodology report (MR)	-

Sector	Energy
ID# PMF 2022	E.1
Table PMF 2022	1
Adressing/Not resolved/ New from 2022 review	-

Sector	Energy
Issue and/or problem classification[a[, b]]	1.A.1.c Manufacture of solid fuels and other energy industries – liquid fuels – CO2, CH4 and N2O (E.3, 2021) (E.9, 2019) (E.16, 2017) Completeness
Is finding an issue/problem	-
Recommendation made in previous review report	Include in the NIR the reason why emissions from liquid fuels are reported for 1990 only.
ERT assessment and rationale	The Party reported the missing CH4 and N2O emissions from liquid fuels for 1991-2013 in CRF table 1.A(a)s1, indicating this activity in the NIR (chapter 3.2.4.5, p.89). Starting with 2014 the liquid fuels are reported as not occurring by using the notation key" NO" in the category 1.A.1.c in the CRF table1.A(a)s1.
NLD Response in NIR /CRF 2023	This issue is resolved (all emissions are now calculated for the years that liquid fuels are used in 1A1c)
Paragraph or table number in: NIR, CRF and or Methodology report (MR)	-

Sector	Energy
ID# PMF 2022	E.2
Table PMF 2022	1
Adressing/Not resolved/ New from 2022 review	-
Issue and/or problem classification[a[, b]]	1.A.2.c Chemicals – all fuels – CO2 (E.6, 2021) (E.27, 2019) Comparability
Is finding an issue/problem	-

Sector	Energy
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	The Party reported in the CRF tables1.A(a)s2 under the category 1.A.2.c (chemicals) the emissions resulting from the use of fossil fuels as feedstocks for the production of silicon carbide, carbon black, ethylene and methanol. As per the explanation provided in the NIR (chap. 3.2.5.2, p.98 and chap. 4.3, p.138), the activity data provided by the energy balance do not allow the separation of the activities between combustion and processes. During the review the Party confirmed that it will keep to report the GHG emissions from production of silicon carbide, carbon black, ethylene and methanol in the energy sector in the 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, 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.
NLD Response in NIR /CRF 2023	Emissions from the combustion of waste gases are reported in the energy sector, because the fuel consumption of waste gases is included in the energy statistics. Reallocation of these emissions has not been prioritized in the 2023 submission.
Paragraph or table number in: NIR, CRF and or Methodology report (MR)	-

Sector	**Energy**
ID# PMF 2022	E.3
Table PMF 2022	1
Adressing/Not resolved/ New from 2022 review	-
Issue and/or problem classification[a[, b]]	1.A.2.c Chemicals – all fuels – CO2 (E.13, 2021) Transparency
Is finding an issue/problem	-
Recommendation made in previous review report	The ERT recommends that the Party 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	The Party included in its NIR (chap. 3.2.5.5, p.100) information related to the impact of recalculations on the CO2 emissions of the 1.A.2. subsector categories, including in the category 1.A.2.c (chemicals), as result of the activity data changes in the energy balance for 2015–2019 period. For example, the impact of recalculations in the category 1.A.2.c is the decreasing of the CO2 emissions with 104.61 ktCO2 in 2019. The Party also reported that CH4 and N2O emissions were recalculated (NIR, p.101), but it did not report the impact of recalculations at the aggregated level. Also, it did not specify what kind of changes the energy balance reported (e.g. the changed energy consumption by type of fuel). The ERT noted that the impact of recalculations in 2019 for all fuels at the category 1.A.2.c aggregated level is the decreasing of the emissions with 104.61 CO2eq.
NLD Response in NIR /CRF 2023	In the NIR 2023, also the impact of recalculations on CH4 and N2O is described.
Paragraph or table number in: NIR, CRF and or Methodology report (MR)	-
ID# PMF 2022	E.4

Sector	**Energy**
Table PMF 2022	1
Adressing/Not resolved/ New from 2022 review	-
Issue and/or problem classification[a[, b]]	1.A.3.e.i Pipeline transport – gaseous fuels – CH_4 (E.7, 2021]) (E.15, 2019) (E.21, 2017) Comparability
Is finding an issue/problem	-
Recommendation made in previous review report	Allocate combustion emissions of CH_4 from the natural gas transport network to subcategory 1.A.3.e.i (pipeline transport).
ERT assessment and rationale	The Party reported in its NIR (chap. 3.2.6.1, p.107 and chap. 3.3.2.1, p.125) that the energy consumption for pipeline transport (CRF category 1.A.3.e.i other transportation) is not recorded separately in the national energy statistics and, as consequence, CO_2 and N_2O combustion emissions resulted from natural gas transport are included in category 1.A.3.e. At the same time, the corresponding CH_4 combustion emissions are reported in category 1.B.2.b Natural gas transmission and storage aggregated with the fugitive emissions resulted from this activity. During the review the Party clarified that it has no plan to investigate the allocation of the CH_4 emissions from fossil fuel combustion from natural gas transport network to 1.A.3.e.i Pipeline transport. The ERT noted that the approach of the Party is not in accordance with the 2006 IPCC Guidelines (vol. 2, table 3.1.1) related with the comparability of the report.
NLD Response in NIR /CRF 2023	The NIR and Methodology report Honig et al 2022 and 2023 mention that total emissions of CH_4 from gas transmission are included in 1B2b. Also the Methodology report mentiones 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).
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 2022, Honig et al 2023).

Sector	Energy
ID# PMF 2022	E.5
Table PMF 2022	1
Adressing/Not resolved/ New from 2022 review	-
Issue and/or problem classification[a[, b]]	1.A.4.a Commercial/institutional – biomass – CO2 and CH4 (E.14, 2021) Transparency
Is finding an issue/problem	-
Recommendation made in previous review report	The ERT recommends that the Party 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 in future annual submissions.

Sector	**Energy**
ERT assessment and rationale	The Party explains in its NIR (chap. 3.2.7.5, p.121) that it took into considerations the recalculations provided by the energy balance for the period 2015 onward for natural gas, but it did not provide transparently information on the AD for landfill gas or related to the biomass recalculations. Regarding the GHG emissions from landfill gas flaring, during the review the Party clarified the followings: 1) the CH4 emissions have been reallocated from 1.A.4.a.i (commercial/institutional stationary combustion) to the 5.A.1.a category (managed waste disposal sites, anaerobic) (9.7 tonnes CH4 in 2018 and 9.1 tonnes CH4 in 2019); 2) the CO2 emissions have been removed from 1.A.4.a.i but not reported elsewhere, since these emissions are generated by a biofuel (48.7 kt CO2 in 1998, 104.4 kt CO2 in 2003, 47.5 kt CO2 in 2018 and 44.7 kt CO2 in 2019); 3) the N2O emissions were not calculated because they are very small. At the same time, the Party mentioned that it is not required to report N2O and CH4 emissions from landfill gas flaring. It also specified that the small changes of the N2O emissions in 1.A.4.a.i are the result of the energy statistics corrections on biofuels, but it did not specify what type of biofuels and at what level are corrected by the energy balance. Regarding the biomass, the Party reported recalculations in the CRF tables1.A(a)s4 on the entire time series for CO2 and CH4 emissions and on 2015–2019 period for biomass consumption and N2O emissions, but it did not provide any related information in its NIR or during the review. The ERT noted that in the 1.A.4.a.i category the biomass consumption decreased with 10.93 TJ in 2019, and smaller differences occur for the period 2015–2018 in comparison with the previous submission. As consequence, the corresponding recalculations are noted for the CO2, CH4 and N2O emissions in 2019, the overall impact being the decreasing of emissions with 0.26 ktCO2eq (0.26 per cent) in comparison with the previous submission, excluding CO2 emissions.
NLD Response in NIR /CRF 2023	The notations key NA for the category 1.B.2.b.6 AD will be changed to NO in the april 2023 submission of the CRF
Paragraph or table number in: NIR, CRF and or Methodology report (MR)	CRF category 1.B.2.b.6

Sector	Energy
ID# PMF 2022	E.6
Table PMF 2022	1
Adressing/Not resolved/ New from 2022 review	-
Issue and/or problem classification[a[, b]]	1.A.4.b Residential – biomass – CO2, CH4 and N2O (E.15, 2021) Transparency
Is finding an issue/problem	-
Recommendation made in previous review report	The ERT recommends that the Party 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	The Party explains in its NIR (chap. 3.2.7.5, p.121) that it took into considerations the recalculations provided by the energy balance on the period 2015-2019 for natural gas, but it not provided transparently information related to the biomass recalculations that are reported in the CRF tables1.A(a)s4 for biomass consumption and the corresponding CO2, CH4 and N2O emissions in 1.A.4.b.i – Residential Stationary combustion. The Party did not provide additional information during the review. The ERT noted that in the 1.A.4.b.i category the biomass consumption increased with 21.28 TJ in 2019, and smaller differences occur for the period 2015–2018 in comparison with the previous submission. As consequence, the corresponding recalculations are noted for the CO2, CH4 and N2O emissions in 2019, the overall impact being the increasing of emissions with 0.022 ktCO2eq in comparison with the previous submission, excluding the CO2 emissions.
NLD Response in NIR /CRF 2023	Information on the methods, EF's 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 2023).

Sector	**Energy**
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 2023).

Sector	**Energy**
ID# PMF 2022	E.7
Table PMF 2022	1
Adressing/Not resolved/ New from 2022 review	-
Issue and/or problem classification[a[, b]]	1.B.2.b Natural gas – gaseous fuels – CO_2 and CH_4 (E.12, 2021) (E.21, 2019) (E.27, 2017) Comparability
Is finding an issue/problem	-
Recommendation made in previous review report	Report the appropriate notation keys in CRF table 1.B.2 for AD and CO_2 and CH_4 emissions, ensuring time-series consistency.

Sector	Energy
ERT assessment and rationale	In its current submission the Party reported on the entire time series in the CRF tables 1.B.2, for the category 1.B.2.b.6, the notation keys "NA" for the AD and "NO" for the CH_4 and CO_2 emissions by changing the previous notation keys that were "IE" for AD and "NO" for CH_4 and CO_2 emissions. During the review the Party informed ERT that it used the notation key "NA" for AD because there are no emissions in this category. According to the 2006 IPCC Guidelines (Vol 1_Ch. 8 Reporting Guidance), the notation key "NA" is 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 and the 2006 IPCC Guidelines provide a method and an EF for the particular category–gas combination, then the "NE" notation key should be used for the CH_4 and CO_2 emissions. According to the same 2006 IPCC Guidelines, the activities under 1.B.2.b.6 – Natural gas, Other could be represented by the fugitive emissions from natural gas systems (excluding venting and flaring) not otherwise accounted for in the other categories (exploration, production, processing, transmission & storage, distribution) and may include emissions from well blowouts and pipeline ruptures or dig-ins. Considering the above information, the Party informed ERT during the review that the appropriate notation key for the AD in the category 1.B.2.b.6 would be "NO.
NLD Response in NIR /CRF 2023	The notations key NA for the category 1.B.2.b.6 AD will be changed to NO in the april 2023 submission of the CRF
Paragraph or table number in: NIR, CRF and or Methodology report (MR)	CRF category 1.B.2.b.6

Sector	Energy
ID# PMF 2022	E.8
Table PMF 2022	1
Adressing/Not resolved/ New from 2022 review	-
Issue and/or problem classification[a[, b]]	1.B.2.b Natural gas – gaseous fuels – CH4 (E.17, 2021) Comparability
Is finding an issue/problem	-
Recommendation made in previous review report	The ERT recommends that the Party 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, and 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.

Sector	Energy
ERT assessment and rationale	The Party continued to report in its CRF tables 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 for the corresponding CO2 and CH4 emissions the notation key "IE" and it did not introduce in the NIR information on the used methods and EFs and information on the verification processes for estimation of CH4 emissions from natural gas (category 1.B.2.b). During the review, the Party indicated that the companies did not provide consistently separated reports and the separation of the AD and the GHG emissions by the activities is not planned for the future. In response to the ERT question the Party provided CO2 and CH4 emissions separated by activities, that are reported by three from a total of eleven companies developing natural gas activities in the Netherlands. According to the CRF tables 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 the natural gas activities. Thus, the emissions from oil exploration and production and from natural gas exploration and production are included in 1.A.1.c.ii (oil and gas extraction). The fugitive emissions from natural gas processing are reported under 1B2c.iii (venting combined) and 1B2c.iii (flaring combined). At the same time, the venting emissions from gas and oil are included under venting 1.B.2.c.1.iii (combined), and the flaring emissions from gas and oil are included under flaring 1.B.2.c.2.iii (combined). The ERT noted that it is good practice under the 2006 IPCC Guidelines (vol. 2, p.4.36; 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 sense, the Party can explore a modality to use the detailed reports provided by the three companies and extend the separation of the GHG emissions by CRF categories of the total emissions reported from natural gas activities.

Sector	Energy
NLD Response in NIR /CRF 2023	Information on the methods, EF's and verification of the estimation of CH_4 emissions from natural gas can be found in the NIR and in more detail in the Methodology report (Honig et al 2023). 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 2023).

Sector	IPPU
ID# PMF 2022	I.1
Table PMF 2022	1
Adressing/Not resolved/ New from 2022 review	-
Issue and/or problem classification[a[, b]]	2.A.1 Cement production – CO_2 (I.17, 2021) Consistency
Is finding an issue/problem	-
Recommendation made in previous review report	The ERT recommends that the Netherlands 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. The ERT also recommends that the Netherlands 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	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.

Sector	IPPU
NLD Response in NIR /CRF 2023	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# PMF 2022	I.2
Table PMF 2022	1
Adressing/Not resolved/ New from 2022 review	-
Issue and/or problem classification[a[, b]]	2.A.2 Lime production – CO2 (I.18, 2021) Transparency
Is finding an issue/problem	-
Recommendation made in previous review report	The ERT recommends that the Netherlands provide information on the source of the AD in the NIR, including a discussion on time-series consistency in its NIR.
ERT assessment and rationale	The Party reported in its NIR (chap. 4.2.2, p.134) the activity data used and the development of it over the time series.
NLD Response in NIR /CRF 2023	Activity data is obtained from the sugar company’s annual reports.
Paragraph or table number in: NIR, CRF and or Methodology report (MR)	NIR 4.2.2

Sector	IPPU
ID# PMF 2022	I.3
Table PMF 2022	1
Adressing/Not resolved/ New from 2022 review	-
Issue and/or problem classification[a[, b]]	2.A.3 Glass production – CO2 (I.19, 2021) Consistency
Is finding an issue/problem	-
Recommendation made in previous review report	The ERT recommends that the Netherlands 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	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.
NLD Response in NIR /CRF 2023	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)	-

Sector	IPPU
ID# PMF 2022	I.4
Table PMF 2022	1
Adressing/Not resolved/ New from 2022 review	-
Issue and/or problem classification[a[, b]]	2.A.4 Other process uses of carbonates – CO2 (I.20, 2021) Comparability
Is finding an issue/problem	-
Recommendation made in previous review report	The ERT recommends that the Netherlands 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	The Party did not implement in its NIR the recommendation made in the previous review report. During the review, the Party clarified that it plans to implement this in the next submission.
NLD Response in NIR /CRF 2023	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# PMF 2022	I.5
Table PMF 2022	1
Adressing/Not resolved/ New from 2022 review	-
Issue and/or problem classification[a[, b]]	2.A.4 Other process uses of carbonates – CO2 (I.21, 2021) Accuracy
Is finding an issue/problem	-
Recommendation made in previous review report	The ERT recommends that the Netherlands investigate the reporting for 2017 and explain the slightly higher IEF for this year compared with all other years of the time series. It also recommends that the Netherlands 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	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.
NLD Response in NIR /CRF 2023	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# PMF 2022	I.6
Table PMF 2022	1
Adressing/Not resolved/ New from 2022 review	-
Issue and/or problem classification[a[, 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
Is finding an issue/problem	-
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	The Party reported in its additional report (Honig et al) (chapter 2.2.3.2, p.52) that a new methodology was developed. However, owing to the lack of data, the methodology could not be implemented.
NLD Response in NIR /CRF 2023	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# PMF 2022	I.7
Table PMF 2022	1
Adressing/Not resolved/ New from 2022 review	-
Issue and/or problem classification[a[, b]]	2.B Chemical industry – CO2, CH4 and N2O (I.22, 2021) Transparency
Is finding an issue/problem	-
Recommendation made in previous review report	The ERT recommends that the Netherlands 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). Additionally, the ERT recommends that the Netherlands 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	The Party reported in its NIR (chap. 4.3.1, p.137) the number of plants for the different sectors. Furthermore, the Party used in the CRF table 2(I)A-Hs1 “C” notation key for AD in chemical industries, where emissions occur. During the review, the Party provided further information on the AD, EFs and emissions for chemical industry, containing some confidential data from the plants.
NLD Response in NIR /CRF 2023	The number of plants is mentioned in section 4.3.1
Paragraph or table number in: NIR, CRF and or Methodology report (MR)	NIR 4.3.1

Sector	IPPU
ID# PMF 2022	I.8
Table PMF 2022	1
Adressing/Not resolved/ New from 2022 review	-
Issue and/or problem classification[a[, b]]	2.B.8 Petrochemical and carbon black production – CO2 and CH4 (I.23, 2021) Comparability
Is finding an issue/problem	-
Recommendation made in previous review report	The ERT recommends that the Netherlands either report AD and emissions under category 2.B.8.c or, if this is not possible for confidentiality reasons, change the notation key used from “NO” to “IE”.
ERT assessment and rationale	The Party neither reported AD and emissions under category 2.B.8.c nor changed the notation key used from “NO” to “IE”.
NLD Response in NIR /CRF 2023	Not all AD data is available, therefore notoations keys are changed tot IE
Paragraph or table number in: NIR, CRF and or Methodology report (MR)	NIR 4.3.2

Sector	IPPU
ID# PMF 2022	I.9
Table PMF 2022	1
Adressing/Not resolved/ New from 2022 review	-
Issue and/or problem classification[a[, 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
Is finding an issue/problem	-
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	The Party did report in its NIR (chap. 4.3.4, p.146) the information about the QA/QC activities and outcomes for the chemical and petrochemical sources. During the review, the Party clarified that the information on QA/QC activities could not be reported in the NIR 2022 as EU-ETS reports for these companies were not available on time and it received them only during the review week.
NLD Response in NIR /CRF 2023	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# PMF 2022	I.10
Table PMF 2022	1
Adressing/Not resolved/ New from 2022 review	-
Issue and/or problem classification[a[, b]]	2.B.9 Fluorochemical production – HFCs (I.6, 2021) (I.15, 2019) (I.21, 2017) Transparency
Is finding an issue/problem	-
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	The Party did not report the flow meter results as AD in the CRF tables. During the review, the Party clarified that the flow meter results were not available. The emissions data is obtained from the Annual Emission Report of the only company in the Netherlands. The Party further clarified that the Annual Emissions Report is annually checked by the competent authority, hence these data are considered of the highest quality.
NLD Response in NIR /CRF 2023	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**
Sector	IPPU
ID# PMF 2022	I.11
Table PMF 2022	1
Adressing/Not resolved/ New from 2022 review	-
Issue and/or problem classification[a[, b]]	2.C.1 Iron and steel production – CO2 (I.8, 2021) (I.17, 2019) (I.23, 2017) Transparency
Is finding an issue/problem	-
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; (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).

Sector	**IPPU**
ERT assessment and rationale	The Party did not provide in its NIR an assessment of the carbon flow and carbon balance in each process in the iron and steel industry. The Party reported in its NIR (chap. 4.4.4, p.150) that besides the general QA/QC procedure for the category 2.C.1, the activity and emissions data of the AERs were compared with the EU-ETS monitoring reports and that no differences were found. During the review, the Party clarified that the answer was provided in the NIR (chap. 4.4.2). The ERT noted that the NIR (chap. 4.4.2) did not contain any additional information compared to the previous NIR. The Party also did not report in its NIR an 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 (chap. 4.4.2). The ERT noted that the NIR (chap. 4.4.2) did not contain any additional information compared to the previous NIR.
NLD Response in NIR /CRF 2023	The Netherlands need 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)	-

Sector	IPPU
ID# PMF 2022	I.12
Table PMF 2022	1
Adressing/Not resolved/ New from 2022 review	-
Issue and/or problem classification[a[, b]]	2.C.1 Iron and steel production – CO_2 and CH_4 (I.9, 2021) (I.18, 2019) (I.24, 2017) Comparability
Is finding an issue/problem	-
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	The Party was requested to report all emissions under iron and steel production subcategories in the IPPU sector, in accordance with the 2006 IPCC Guidelines. The Party uses in its CRF table 2(I)A- Hs2 for CO2 the notation key IE for the emissions from pig iron, sinter and pellet production. During the review, Netherlands was asked to provide the ERT with (i) a clear presentation of the iron and steel production processes used in 2020 (i.e. BOF steel, EAF steel, direct reduction); (ii) the calculation datasheets for the total GHG emissions associated with the iron and steel production (included in 2C1, 2A4d, 1A1c (flaring), 1A2a, 1B1b) for the year 2020; (iii) the comparison with the EU-ETS data (year 2020). The Netherlands provided 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, the CO2 emissions and allocation on CRF categories for the year 2015. The Party informed that this schema 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 BOF steel, EAF steel, direct reduction. The Party provided ERT with the confidential calculation datasheet ("Confidential review data calculation 2A4d 2C1.xls") for the processes in one of the iron and steel plants for the year 2021 (including calculations for 2A4d and 2C1). The ERT commends the Party for the information, but from the data provided the ERT was not able to verify the 2020 CO2 emissions, as the data were from 2021 and 2015. Concerning the comparison with EU-ETS data, the Party informed ERT that the Dutch Emission Authority is the independent national authority which is the appointed organization to implement and monitor the EU ETS, and the necessary confidential data would have to be requested from them. The Party also stated that, the previous ERT (ARR2021; ARR2019) 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 with the EU-ETS data. ERT could not check if all emissions are reported under iron and steel production subcategories in the IPPU sector, as the data provided were from 2015 and 2021, instead from 2020 and as the ETS data for comparison could not be provided.

Sector	IPPU
NLD Response in NIR /CRF 2023	Confidential data sheet was provided.
Paragraph or table number in: NIR, CRF and or Methodology report (MR)	-

Sector	IPPU
ID# PMF 2022	I.13
Table PMF 2022	1
Adressing/Not resolved/ New from 2022 review	-
Issue and/or problem classification[a[, b]]	2.C.1 Iron and steel production – CO2 and CH4 (I.24, 2021) Completeness
Is finding an issue/problem	-
Recommendation made in previous review report	The ERT recommends that the Netherlands either justify why CH4 emissions from sinter production do not occur or estimate and report these emissions or change the notation key used 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. It also recommends that the Netherlands explain the reporting of “NO” for CO2 emissions for category 2.C.1.f, given that sinter and pellet production are reported as “IE”. The ERT further recommends that the Netherlands check and correct the use of notation keys for all subcategories of category 2.C.1.
ERT assessment and rationale	The Party reported in its NIR (section 4.4.6, p.150) that CH4 process emission calculations from sinter production will be implemented in the next submission. During review the Party clarified that a preliminary assessment is 0.02 kt CH4 emissions (0.5 kt CO2 eq). This value is below the threshold of significance.

Sector	IPPU
NLD Response in NIR /CRF 2023	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# PMF 2022	I.14
Table PMF 2022	1
Adressing/Not resolved/ New from 2022 review	-
Issue and/or problem classification[a[, b]]	2.C.3 Aluminium production – CO2 (I.25, 2021) Convention reporting adherence
Is finding an issue/problem	-
Recommendation made in previous review report	The ERT recommends that the Netherlands include a check of the IEFs as part of its QC procedures prior to reporting.
ERT assessment and rationale	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 CO2 and PFCs figures are taken directly from both AERs and EU-ETS reports, which are themselves subject to stringent QA/QC procedures (e.g. a description of the verification process for EU ETS reports: https://www.emissionsauthority.nl/topics/year-end-closing-ets/emissions-report-verification). The ERT agrees with the Party that these processes have already a good QA/QC system implemented.

Sector	IPPU
NLD Response in NIR /CRF 2023	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.
Paragraph or table number in: NIR, CRF and or Methodology report (MR)	-

Sector	IPPU
ID# PMF 2022	I.15
Table PMF 2022	1
Adressing/Not resolved/ New from 2022 review	-
Issue and/or problem classification[a[, b]]	2.C.3 Aluminium production – CO_2 (I.26, 2021) Transparency
Is finding an issue/problem	-
Recommendation made in previous review report	The ERT recommends that the Netherlands correct the information provided in the NIR to reflect the current methodology used (i.e. the estimation of CO_2 emissions on the basis of data reported under the EU ETS) and also provide information on the methodology used for the years before EU ETS data became available.
ERT assessment and rationale	The Party reported in its NIR (chap. 4.4.2, p.149) a description of the methodology used for the estimation of CO_2 emissions on the basis of data reported under the EU ETS. The Party also explained that tier 1 method was used for the years before EU ETS data became available.

Sector	IPPU
NLD Response in NIR /CRF 2023	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.
Paragraph or table number in: NIR, CRF and or Methodology report (MR)	NIR 4.4.2

Sector	IPPU
ID# PMF 2022	I.16
Table PMF 2022	1
Adressing/Not resolved/ New from 2022 review	-
Issue and/or problem classification[a[, b]]	2.C.6 Zinc production – CO2 (I.10, 2021) (I.25, 2019) Convention reporting adherence
Is finding an issue/problem	-
Recommendation made in previous review report	Use notation keys in a consistent manner and use “NO” for reporting AD and IEFs for this category in CRF table 2(I).A-Hs2.
ERT assessment and rationale	The Party changed in its CRF table 2(I).A-Hs2 the notation key from NA to NO for the zinc production.
NLD Response in NIR /CRF 2023	Notation keys are changed to NO
Paragraph or table number in: NIR, CRF and or Methodology report (MR)	-

Sector	**IPPU**
ID# PMF 2022	I.17
Table PMF 2022	1
Adressing/Not resolved/ New from 2022 review	-
Issue and/or problem classification[a[, b]]	2.D.1 Lubricant use – CO_2 (I.27, 2021) Transparency
Is finding an issue/problem	-
Recommendation made in previous review report	The ERT recommends that the Netherlands report the AD in CRF table 2(I).A-Hs2 in the annual submission.
ERT assessment and rationale	The Party reported in table 2(I)A-Hs2 the AD as "C". However, the Party did not explain in its NIR (chap. 4.5.2, p.151) why the AD is reported as confidential. During the review, the Party clarified that the AD is now not anymore confidential and delivered the table with the data and that it plans to include the AD in the next submission.
NLD Response in NIR /CRF 2023	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# PMF 2022	I.18
Table PMF 2022	1
Adressing/Not resolved/ New from 2022 review	-
Issue and/or problem classification[a[, b]]	2.D.2 Paraffin wax use – CO2 (I.28, 2021) Transparency
Is finding an issue/problem	-
Recommendation made in previous review report	The ERT recommends that the Netherlands include in its NIR the AD for the use of paraffin wax and a description of the methodology and data used to derive them.
ERT assessment and rationale	The Party reported in its NIR (chap. 4.5.2, p.151) a short overview on the methodology and data sources for the AD and EFs used for estimating emissions.
NLD Response in NIR /CRF 2023	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)	NIR 4.5.2

Sector	IPPU
ID# PMF 2022	I.19
Table PMF 2022	1
Adressing/Not resolved/ New from 2022 review	-
Issue and/or problem classification[a[, b]]	2.F.1 Refrigeration and air conditioning – HFCs (I.14, 2021) (I.27, 2019) Consistency
Is finding an issue/problem	-
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	The Party provided in its NIR (chap. 4.7.2, p.155) and the methodology document (Honig et. al., 2022) (chap. 2.2.3.9, p.65) a description of the data collection methods. However, the ERT noted that the data reported continued to be aggregated for 2.F.1.a, 2.F.1.d and 2.F.1.f for 1990–2012. During the review, the Party clarified that it was not possible to disaggregate data for the years prior to 2013 owing to unavailability of data.
NLD Response in NIR /CRF 2023	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# PMF 2022	I.20
Table PMF 2022	1
Adressing/Not resolved/ New from 2022 review	-
Issue and/or problem classification[a[, b]]	2.F.1 Refrigeration and air conditioning – HFCs (I.15, 2021) (I.28, 2019) Comparability
Is finding an issue/problem	-
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	The Party reported in CRF table 2(II).B-Hs2 notation key IE for manufacturing and disposal emissions from refrigeration and air conditioning. During the review, the Party clarified that it adapted the notation key to IE as the data on manufacturing and disposal are not available. The ERT noted that the emissions from manufacturing and disposal are missing in the inventory. 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: (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 retrofit or maintenance; (d) The volume of dismantled installations. Furthermore, IPCC Guidebook factors are used to calculate emissions from refrigerant management of containers. Disposed refrigerants are also registered, but it is supposed that disposal is done in a responsible way without further losses apart from the dismantling. The ERT was unable to understand why during the disposal of the refrigeration and air conditioning systems no emissions of F-Gases occur. The ERT noted that the Party is collecting data from volume of refrigerant used in new installations and volume of refrigerant to fill operating installations. During the review the Party clarified that all types of emissions are taken account off (refilling, dismantling, re-use, leakage). However, these cannot be distinguished along the lines of columns of table 2(II)B-Hs2: (a) Column ‘manufacturing’ is indicated as IE, since data on new filling and refilling cannot be distinguished (and there is no HFC production in the Netherlands); (b) Column ‘From disposal’ should be IE, since data cannot be distinguished. The Party do not calculate emissions from incineration of disposed HFC’s; (c) Column ‘Recovery’ should remain IE because the Party calculate emissions from leakage from working systems by taking the amount that is filled yearly. This is a combination of new and recovered refrigerants, the Party do not make a distinction; (d) Therefore, the column ‘From stock’ will contain the total emission. Furthermore, the Party clarified that it is using for the data collected from the ‘Refrigerants

	registration system” for the PRTR, with a threshold for the registration of systems of a HFC content >= 5000 kg CO2-eq. The new method with this data source led to lower emissions than those calculated with the old stock-model method. The exchange of the ERT and the Party did not lead to a common definition of the term used for the reporting of F-Gas emissions in the columns “from manufacturing”, “from stocks” and “from disposal”. Furthermore, the ERT and the Party could not agree if the new model is leaving an important amount of emissions out, because of the threshold for registration.

Sector	IPPU
NLD Response in NIR /CRF 2023	Emission can not be splitted, therefore notation key IE is used.
Paragraph or table number in: NIR, CRF and or Methodology report (MR)	-

Sector	IPPU
ID# PMF 2022	I.21
Table PMF 2022	1
Adressing/Not resolved/ New from 2022 review	-
Issue and/or problem classification[a[, b]]	2.F.1 Refrigeration and air conditioning – HFCs (I.29, 2021) Consistency
Is finding an issue/problem	-
Recommendation made in previous review report	The ERT recommends that the Netherlands provide explanations for the increases in emissions observed for 2013 and 2015 or revise the estimates.
ERT assessment and rationale	The Party provided in its NIR (chap. 4.7.3, p.155) the explanation that emissions fluctuate because of the use of different refrigerants with different GWP's.
NLD Response in NIR /CRF 2023	Emissions fluctuate because of the use of different refrigerants with different GWP's.
Paragraph or table number in: NIR, CRF and or Methodology report (MR)	NIR 4.7.3

Sector	IPPU
ID# PMF 2022	I.22
Table PMF 2022	1
Adressing/Not resolved/ New from 2022 review	-
Issue and/or problem classification[a[, b]]	2.F Product uses as substitutes for ozone-depleting substances – HFCs(I.30, 2021) Transparency
Is finding an issue/problem	-

Sector	IPPU
Recommendation made in previous review report	The ERT recommends that the Netherlands 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. Additionally, the ERT recommends that the Party 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, which 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 the reporting as confidential of the corresponding AD and emissions; (f) Information on the number of importers of methylene diphenyl diisocyanates in the Netherlands and a justification for the reporting of these data as confidential; (g) Information on the number of companies using HFCs in aerosols (it is stated in the NIR that less than 10 per cent of companies in the Dutch aerosol association use HFCs); (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 the reporting of these emissions as confidential.

Sector	IPPU
ERT assessment and rationale	The Party did not disaggregate the emissions for categories 2.F.2–2. F.5 and also did not provide detailed information 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, that is described in the methodology report and new emission data were calculated as presented in the NIR (section 4.7.2 and methodology report 2.2.3.11). However, the ERT noted that the referred documents did not contain the information addressing the recommendation made in the previous review report. The Party further clarified that it was not possible to report disaggregated data from 2015 onwards owing to the lack of activity data. The ERT noted that the new method is not delivering the necessary data to report the emissions differentiated according to the subsectors, that are requested in the CRF tables
NLD Response in NIR /CRF 2023	Netherlands used a method als dercribed in the Methodology report since the 2022 submission. This method is based on using emissions data from adjacent countries. However, Netherlands woulkd 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# PMF 2022	I.23
Table PMF 2022	1
Adressing/Not resolved/ New from 2022 review	-
Issue and/or problem classification[a[, b]]	2.G.1 Electrical equipment – SF6 (I.31, 2021) Comparability
Is finding an issue/problem	-
Recommendation made in previous review report	The ERT recommends that the Netherlands report emissions from electrical equipment separately under category 2.G.1. in future annual submissions and either use the same data source for 2007–2008 or explain in the NIR why a different methodology has been used for those years.
ERT assessment and rationale	The Party reported in CRF table 2(II)B-Hs1 SF6 emissions from electrical equipment separately in 2G1. Furthermore, the Party explained in its NIR (chap. 4.8.2, p.160) the switch of the method from 2006 to 2007 and from 2008 to 2009. During the review, the Party clarified that further improvements will be implemented in the NIR 2023.
NLD Response in NIR /CRF 2023	Unfortunately it was too late to split up emissions from electrical equipment and other. This will be done for the 2024 submission. In the 2023 submission total emissions are reported onder 2G, including those from electrical equipment.
Paragraph or table number in: NIR, CRF and or Methodology report (MR)	NIR 4.8.1

Sector	IPPU
ID# PMF 2022	I.24
Table PMF 2022	1
Adressing/Not resolved/ New from 2022 review	-
Issue and/or problem classification[a[, b]]	2.G.2 SF6 and PFCs from other product use – SF6 (I.32, 2021) Completeness
Is finding an issue/problem	-
Recommendation made in previous review report	The ERT recommends that the Netherlands 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. The ERT also recommends that the Netherlands correct the error in the lifetime in the calculation of emissions from soundproof windows.
ERT assessment and rationale	The Party corrected in its NIR (chapter 4.8.5, p. 162) the error in the lifetime in the calculation of emission from soundproof windows. But it did not report about 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 about further sources for SF6 emissions. The Party plans to check emissions from particle accelerators and magnesium production. The ERT made an estimation of SF6 emissions from particle accelerators and magnesium production, scaling SF6 emissions for these activities reported in Germany's 2022 submission based on population numbers. On this basis, the ERT considers that SF6 emissions from these activities might be considered insignificant in line with paragraph 37(b) of the Revision of the UNFCCC reporting guidelines on annual inventories for Parties included in Annex I to the Convention
NLD Response in NIR /CRF 2023	Due to lack of time, it will be tried to perform this check for a later submission

Sector	**IPPU**
Paragraph or table number in: NIR, CRF and or Methodology report (MR)	-

Sector	**IPPU**
ID# PMF 2022	I.25
Table PMF 2022	1
Adressing/Not resolved/ New from 2022 review	-
Issue and/or problem classification[a[, b]]	2.G.3 N_2O from product uses – N_2O (I.16, 2021) (I.29, 2019) Comparability
Is finding an issue/problem	-
Recommendation made in previous review report	Report the AD for category 2.G.3.b (other (N_2O from aerosol cans)) in kt in the next submission.
ERT assessment and rationale	The Party did not report the AD for category 2.G.3.b (other (N_2O from aerosol cans)) in kt, rather the number of cans. During the review, the Party clarified that it plans to include this information in the next submission.
NLD Response in NIR /CRF 2023	In the CRF the AD is reported in kt now, instead of number of cans.
Paragraph or table number in: NIR, CRF and or Methodology report (MR)	CRF 2(I).A-Hs2

Sector	IPPU
ID# PMF 2022	I.26
Table PMF 2022	1
Adressing/Not resolved/ New from 2022 review	-
Issue and/or problem classification[a[, b]]	2.H Other (IPPU) – CO2 (I.33, 2021) Transparency
Is finding an issue/problem	-
Recommendation made in previous review report	The ERT recommends that the Netherlands provide further information in the NIR of the non-energy use of fuels in this sector and the processes leading to CO2 emissions.
ERT assessment and rationale	The Party reported in its additional report (Honig et al. 2022) (chap. 2.2.3.7, p.47) that this category comprises CO2 emissions related to food and drink production (2H2) in the Netherlands. CO2 emissions in this source category are related to the non-energy use of fuels. Carbon is oxidized during these processes, resulting into CO2 emissions. The ERT was unable to understand why carbon is oxidized. During the review, the Party clarified that this piece of text was inserted in the wrong section of the report. This is about CO2 emission that is produced by using the lime in sugar production, which is reported under 2A2 (lime production). Formally it was reported under 2H2, and with the shift to 2A2 it was forgotten to move the corresponding text too. The Party plans to amend this in the next submission.
NLD Response in NIR /CRF 2023	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# PMF 2022	A.1
Table PMF 2022	1
Adressing/Not resolved/ New from 2022 review	-
Issue and/or problem classification[a[, b]]	3. General (agriculture) – CH4 and N2O (A.1, 2021) (A.1, 2019) (A.8, 2017) Completeness
Is finding an issue/problem	-
Recommendation made in previous review report	Collect livestock data and estimate emissions associated with mules and asses for the period 1990–2009, or, alternatively, use an extrapolation technique to ensure time-series consistency.
ERT assessment and rationale	The Party reported in its NIR (chap. 5.1.2, p.169) and CRF table 3.B(a)s1 that the estimated number of mules and asses for the period 1990–2009 was based on expert judgment. The number of mules and asses was set at 1000 animals.
NLD Response in NIR /CRF 2023	No action required.
Paragraph or table number in: NIR, CRF and or Methodology report (MR)	-

Sector	Agriculture
ID# PMF 2022	A.2
Table PMF 2022	1
Adressing/Not resolved/ New from 2022 review	-
Issue and/or problem classification[a[, b]]	3. General (agriculture) – CH4 and N2O (A.6, 2021) (A.17, 2019) Transparency
Is finding an issue/problem	-
Recommendation made in previous review report	Noting some evidence that there may now be alpaca farms in the Netherlands, investigate the issue of the existence of alpacas and llamas 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	The Party did not report any emissions in CRF from alpacas and llamas and stated in its NIR (chap. 5.1.2, p.169) that the emissions from alpacas in the Netherlands have not been estimated owing to the lack of detailed information on their numbers and they are mostly kept as pets or as a tourist attraction. During the review, the Party clarified that the emissions caused by alpacas are negligible. Changes to the European Animal Health Regulation in 2022 could make the registration of alpacas mandatory, thereby enabling the calculation of correspondent emissions in future.
NLD Response in NIR /CRF 2023	there is still no data available on the number of alpaca present in the Netherlands.
Paragraph or table number in: NIR, CRF and or Methodology report (MR)	-

Sector	Agriculture
ID# PMF 2022	A.3
Table PMF 2022	1
Adressing/Not resolved/ New from 2022 review	-
Issue and/or problem classification[a[, b]]	3. General (agriculture) – CH_4 and N_2O (A.7, 2021) (A.18, 2019) Comparability
Is finding an issue/problem	-
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	The Party reported in its CRF table3.B(a)s1, table3.B(b) and table3.B(a)s2 the values for average cattle weights. The ERT noted that “NA” notation key has been used for the weight of mature dairy cattle in table3.As2 even though the weight of growing and other mature cattle were reported in CRF table 3.B(b). During the review, the Party clarified that the weight of cattle is not used in the calculation of GHG emissions and the notation key NE is not appropriate, so they changed the notation key to NA in CRF Table3.As2.
NLD Response in NIR /CRF 2023	No action required.
Paragraph or table number in: NIR, CRF and or Methodology report (MR)	-

Sector	Agriculture
ID# PMF 2022	A.4
Table PMF 2022	1
Adressing/Not resolved/ New from 2022 review	-
Issue and/or problem classification[a[, b]]	3. General (agriculture) – CH4 and N2O (A.8, 2021) (A.19, 2019) Convention reporting adherence
Is finding an issue/problem	-
Recommendation made in previous review report	(1) Develop a QA/QC plan in accordance with the 2006 IPCC Guidelines (vol. 1, section 6.5) for agriculture and include in the NIR details of all the QA/QC procedures; and, if they do not already occur, develop a timeline to include: (a) Procedures to ensure the accuracy of data transcription to the calculations used; (b) Comparisons of emissions estimated using tier 2 and 3 methods with those estimated using a tier 1 method, providing in the body of the NIR explanations of any differences; (c) Comparisons of country-specific EFs and other variables with those of other countries, providing in the body of the NIR explanations of any differences; (d) Reviews of country-specific EFs, parameters, variables and allocations that are not updated annually and are used in the estimation of emissions; (e) Peer review of the NIR before submission to the secretariat to ensure references are accurate; (f) Peer review of the methodology report for the agriculture sector submitted with the NIR by an external agriculture inventory expert to ensure transparency, completeness and consistency; (2) As carrying out an extensive QA/QC process may be resource intensive and not feasible in the first year following this recommendation, document in the QA/QC plan when each procedure is expected to be implemented, and submit the QA/QC plan as a supplementary document to the NIR in future submissions and update it regularly.

Sector	Agriculture
ERT assessment and rationale	The Party reported its NIR (chapter 1.2.3, p.30) QA/QC programme, QA/QC procedures, QA/QC activities, verification activities for the CRF and NIR, archiving, and overall coordination in its NIR and also provided in the methodology report for agriculture (T.C. van der Zee et al., 2022) (p.38–40) an overview of the different steps that are taken every year for QA/QC purposes. During the review, the Party clarified that QA/QC section has been extended in the methodology report (section 2.5) and the Party plans to further improve the QA/QC section in the future methodology report.
NLD Response in NIR /CRF 2023	In the Methodology report of 2023 the QA/QC section is not further developed. We will further improve this section in 2024.
Paragraph or table number in: NIR, CRF and or Methodology report (MR)	-

Sector	Agriculture
ID# PMF 2022	A.5
Table PMF 2022	1
Adressing/Not resolved/ New from 2022 review	-
Issue and/or problem classification[a[, b]]	3.A.1 Cattle – CH_4 (A.9, 2021) (A.20, 2019) Transparency
Is finding an issue/problem	-

Sector	Agriculture
Recommendation made in previous review report	(1) Provide in the methodology report submitted with the 2019 NIR the following details on the tier 3 method used for estimating emissions from mature dairy cattle: (a) The assumptions made concerning the degradation characteristics of starch, crude protein and fibre, and where any data used are sourced from; (b) The calculations for manure and mineral data prepared by the working group on uniformity of calculations to determine dry matter intake, including the equations and variables and where these have been sourced from; (c) The variables informing the recorded production level and where these are sourced from; (d) The internal parameters (and therefore those parameters that do not change each year) and how they were determined; (e) How the variables used in the enteric fermentation calculations relate to those used for estimating CH4 and N2O emissions from manure management; (2) Include in the NIR references to external sources where the information is presented, if the Party considers it is not practical to include all the information above in the NIR.
ERT assessment and rationale	The Party referred to in its NIR (section 5.2.2, p.172–173) the methodology document (Van der Zee et al. , 2022) (chap. 3, pp.42-45) that contained detailed information on calculation methods and EFS used for estimating emissions from mature dairy cattle. An overview of the activity data can be found in CBS data (2011–2021); and Van Bruggen et al. (2022).
NLD Response in NIR /CRF 2023	No action required.
Paragraph or table number in: NIR, CRF and or Methodology report (MR)	-

Sector	Agriculture
ID# PMF 2022	A.6
Table PMF 2022	1
Adressing/Not resolved/ New from 2022 review	-
Issue and/or problem classification[a[, b]]	3.B Manure management – CH_4 and N_2O (A.12, 2021) (A.4, 2019) (A.1, 2017) (A.2, 2016) (A.2, 2015) (41, 2014) (52, 2013) Accuracy
Is finding an issue/problem	-
Recommendation made in previous review report	Continue and enhance efforts to improve the consistency between the CH_4 and N_2O emission estimates and report correct values for the fractions of the different MMS in the NIR and the CRF tables.
ERT assessment and rationale	The Party reported in its NIR (section 5.3.2, p.179–180) that a tier 2 approach is used to calculate CH_4 emissions from manure management for the key categories of cattle, swine, and poultry. And, the emissions are 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 clarified that a tier 1 method is used to calculate the emissions from fur-bearing animals, rabbits, horses, goats, and mules and asses. Therefore, no further information is required in the CRF. The ERT noted that the Party provided MMS for fur-bearing animals (liquid manure), rabbits (solid manure), horses (solid manure, PRP), goats (solid manure), and mules and asses (solid manure, PRP) in CRF table Table3.B(b). However, the Party used “NO” and “NA” notation keys in CRF table3.B(a)s2 except for mules and asses for allocation of MMS. The ERT noted that the inconsistent MMS values for these animals between the CH_4 and N_2O emission estimates have not been resolved.

Sector	Agriculture
NLD Response in NIR /CRF 2023	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, we will change the notation keys to match the notation keys of N2O from manure management.
Paragraph or table number in: NIR, CRF and or Methodology report (MR)	-

Sector	Agriculture
ID# PMF 2022	A.7
Table PMF 2022	1
Adressing/Not resolved/ New from 2022 review	-
Issue and/or problem classification[a[, b]]	3.B Manure management – CH4 and N2O (A.17, 2021) (A.27, 2019) Transparency
Is finding an issue/problem	-
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.

Sector	Agriculture
ERT assessment and rationale	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 include manure separation, nitrification/denitrification, creation of mineral concentrates, incineration of manure, drying of manure and/or digesting of manure. This information was supposed to go under the NIR (chap. 5.3.2), unfortunately the paragraph was accidentally omitted during the final stages of the NIR drafting. Furthermore, The Party also clarified that this information will be included in the next submission.
NLD Response in NIR /CRF 2023	Included in the NIR
Paragraph or table number in: NIR, CRF and or Methodology report (MR)	section 5.3.2 in the NIR

Sector	Agriculture
ID# PMF 2022	A.8
Table PMF 2022	1
Adressing/Not resolved/ New from 2022 review	-
Issue and/or problem classification[a[, b]]	3.B Manure management – CH4 and N2O (A.19, 2021) (A.29, 2019) Transparency
Is finding an issue/problem	-
Recommendation made in previous review report	Adjust the statement that if the manure is treated, it is assumed that the storage time is shortened since it is beneficial for the farmer (p.167 of the 2019 NIR), in order to clarify that manure digestion is assumed to occur within 24 hours after manure has been produced, because digestion efficiency decreases when manure is stored for a longer time.

Sector	Agriculture
ERT assessment and rationale	The Party reported in its NIR (chap. 5.3.2, p.179) an assumption that the manure storage time is short as it is beneficial for the farmer to treat the manure as soon as possible.
NLD Response in NIR /CRF 2023	No action required.
Paragraph or table number in: NIR, CRF and or Methodology report (MR)	-

Sector	Agriculture
ID# PMF 2022	A.9
Table PMF 2022	1
Adressing/Not resolved/ New from 2022 review	-
Issue and/or problem classification[a[, b]]	3.B Manure management – CH_4 and N_2O (A.20, 2021) (A.30, 2019) Transparency
Is finding an issue/problem	-
Recommendation made in previous review report	Include in the NIR a discussion of the emission trends under manure management to ensure clarity regarding the factors affecting these trends, and also include information that explains the fluctuations in the trends, such as the increased N content in grass in 2017 due to a dry summer.
ERT assessment and rationale	The Party reported in its NIR (chap. 5.3.1, p.176–177) a detailed explanation of the trends of CH_4 and N_2O emissions under manure management.
NLD Response in NIR /CRF 2023	No action required.

Sector	Agriculture
Paragraph or table number in: NIR, CRF and or Methodology report (MR)	-

Sector	Agriculture
ID# PMF 2022	A.10
Table PMF 2022	1
Adressing/Not resolved/ New from 2022 review	-
Issue and/or problem classification[a[, b]]	3.B.1 Cattle – CH_4 and N_2O (A.22, 2021) (A.32, 2019) Convention reporting adherence
Is finding an issue/problem	-
Recommendation made in previous review report	Review the methodology report for agriculture submitted with the NIR to ensure that information contained in it is internally consistent to ensure clarity, in particular when describing where manure was produced for cattle categories.
ERT assessment and rationale	The Party reported in its NIR and methodology report (Van Bruggen et al., 2022) a consistent and clear information on where manure was produced for cattle categories.
NLD Response in NIR /CRF 2023	No action required.
Paragraph or table number in: NIR, CRF and or Methodology report (MR)	-

Sector	Agriculture
ID# PMF 2022	A.11
Table PMF 2022	1
Adressing/Not resolved/ New from 2022 review	-
Issue and/or problem classification[a[, b]]	3.B.3 Swine – CH4 (A.23, 2021) (A.6, 2019) (A.4, 2017) (A.7, 2016) (A.7, 2015) Transparency
Is finding an issue/problem	-
Recommendation made in previous review report	Include in the NIR an explanation for the different trends between CH4 emissions and changes in the swine population.
ERT assessment and rationale	The Party reported in its NIR (chap. 5.3.2, p.180) an explanation for the different trends between CH4 emissions and changes in the swine population.
NLD Response in NIR /CRF 2023	No action required.
Paragraph or table number in: NIR, CRF and or Methodology report (MR)	-

Sector	Agriculture
ID# PMF 2022	A.12
Table PMF 2022	1
Adressing/Not resolved/ New from 2022 review	-
Issue and/or problem classification[a[, 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
Is finding an issue/problem	-
Recommendation made in previous review report	Include in the NIR numeric data on annual removal of agricultural crop residues.
ERT assessment and rationale	The Party did not report in its NIR numeric 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 De Ruijter and Huijsmans (2019), and they 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 Van der Zee et al. 2022 (the agricultural emissions methodology report).
NLD Response in NIR /CRF 2023	These are described in the methodology report chapter 12.7
Paragraph or table number in: NIR, CRF and or Methodology report (MR)	Chapter 12.7 of the MR

Sector	Agriculture
ID# PMF 2022	A.13
Table PMF 2022	1
Adressing/Not resolved/ New from 2022 review	-
Issue and/or problem classification[a[, b]]	3.D Direct and indirect N2O emissions from agricultural soils – N2O (A.26, 2021) (A.34, 2019) Transparency
Is finding an issue/problem	-
Recommendation made in previous review report	Include in the NIR an explanation for the reduction in grassland renewal, referencing the relevant policy measures explained to the ERT during the review, and its connection to the reduction in crop residues left on the field.
ERT assessment and rationale	The Party included in its 2022 NIR (chap. 5.4.1, pp.184–185) an explanation for the trends in grassland renewal, and relevant policies influencing the trends.
NLD Response in NIR /CRF 2023	No action required.
Paragraph or table number in: NIR, CRF and or Methodology report (MR)	-

Sector	Agriculture
ID# PMF 2022	A.14
Table PMF 2022	1
Adressing/Not resolved/ New from 2022 review	-
Issue and/or problem classification[a[, b]]	3.D Direct and indirect N2O emissions from agricultural soils – N2O (A.27, 2021) (A.35, 2019) Transparency
Is finding an issue/problem	-
Recommendation made in previous review report	(1) Include in the NIR a reference for the country-specific EF for compost applied to soils; (2) If the EF is based on expert judgment, ensure that it is documented in accordance with the 2006 IPCC Guidelines (vol. 1, annex 2A.1).
ERT assessment and rationale	The Party reported in its 2022 NIR (chap. 5.4.2, table 5.9) a reference for the country-specific EF for direct N2O emissions arising from compost applied to agricultural soils.
NLD Response in NIR /CRF 2023	No action required.
Paragraph or table number in: NIR, CRF and or Methodology report (MR)	-

Sector	Agriculture
ID# PMF 2022	A.15
Table PMF 2022	1
Adressing/Not resolved/ New from 2022 review	-
Issue and/or problem classification[a[, b]]	3.D Direct and indirect N2O emissions from agricultural soils – N2O (A.31, 2021) Transparency
Is finding an issue/problem	-
Recommendation made in previous review report	The ERT recommends that the Party 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	The Party reported in its 2022 NIR (chap. 5.4.5, p.188) category-specific recalculations for 3.D direct and indirect N2O emissions from agricultural soils. However, during the review, the Party commented that this specific issue is no longer relevant as the recalculations that this issue refers to do not occur in the current submission. The ERT noted that category-specific recalculations are given in the 2022 NIR with sufficient detail.
NLD Response in NIR /CRF 2023	No action required.
Paragraph or table number in: NIR, CRF and or Methodology report (MR)	-

Sector	Agriculture
ID# PMF 2022	A.16
Table PMF 2022	1
Adressing/Not resolved/ New from 2022 review	-
Issue and/or problem classification[a[, b]]	3.D.a.3 Urine and dung deposited by grazing animals – N2O (A.29, 2021) (A.36, 2019) Accuracy
Is finding an issue/problem	-
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	The Party reported in its NIR (table 5.9, p.186) country specific emission factors for 3.D.a.3 Urine and dung deposited by grazing animals resolved by soil type. During the review, the Party clarified that groundwater levels were already reduced in the 1990's and referred to Van der Zee et al. (2022) (the agriculture emissions methodology report). The ERT consider that the Party did not improve transparency by explaining in the NIR how research results were used to calculate the current EF3.
NLD Response in NIR /CRF 2023	Not clear if action is required.
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

Sector	Agriculture
ID# PMF 2022	L.1
Table PMF 2022	1
Adressing/Not resolved/ New from 2022 review	-
Issue and/or problem classification[a[, b]]	4. General (LULUCF) – CO2 (L.3, 2021) (L.18, 2019) Comparability
Is finding an issue/problem	-
Recommendation made in previous review report	Report “NA” for cases where a tier 1 assumption of carbon stocks in equilibrium is applied.
ERT assessment and rationale	The Party updated in its NIR (table 6.2, section 6.1.2, p.199) “NA” for all cases where carbon stocks are assumed to be in equilibrium, including for mineral soils under remaining lands. (See also ID# L.3 below).
NLD Response in NIR /CRF 2023	Was solved already in NIR 2022
Paragraph or table number in: NIR, CRF and or Methodology report (MR)	-

Sector	LULUCF
ID# PMF 2022	L.2
Table PMF 2022	1
Adressing/Not resolved/ New from 2022 review	-
Issue and/or problem classification[a[, b]]	4.A Forest land – CO_2 (L.15, 2021) Transparency
Is finding an issue/problem	-
Recommendation made in previous review report	The ERT recommends that the Party include information in its NIR on forest age structure that justifies the trend in removals so as to improve the transparency of reporting.
ERT assessment and rationale	The Party did not provide information in its NIR on forest age structure. During the review, the Party clarified that Schelhaas et al 2022 (available at: https://edepot.wur.nl/571720) provides information on age class distribution (chap. 7, “Kiemjaar”), harvesting (chap. 15, “Velling”) and growing stock (chap. 16, “Mutaties houtvoorraad”).
NLD Response in NIR /CRF 2023	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# PMF 2022	L.3
Table PMF 2022	1
Adressing/Not resolved/ New from 2022 review	-
Issue and/or problem classification[a[, b]]	4.A.1 Forest land remaining forest land – CO2 (L.5, 2021) (L.19, 2019) Comparability
Is finding an issue/problem	-
Recommendation made in previous review report	Report “NA” for cases where a tier 1 assumption of carbon stocks in equilibrium is applied, in particular for CSC in mineral soils in CRF table 4.A for forest land remaining forest land instead of “NO”.
ERT assessment and rationale	In accordance with paragraph 27(e) of the conclusions and recommendations from the 16th meeting of GHG inventory lead reviewers, the Party changed from “NO” to “NA” the notation keys reported in CRF table 4.A for the carbon pools in which no CSC occurs on the basis of a tier 1 assumption from the 2006 IPCC Guidelines (e.g. figure 2.3 (p.2.22), chap. 2, vol. 4).
NLD Response in NIR /CRF 2023	Was solved already in NIR 2022
Paragraph or table number in: NIR, CRF and or Methodology report (MR)	-

Sector	LULUCF
ID# PMF 2022	L.4
Table PMF 2022	1
Adressing/Not resolved/ New from 2022 review	-
Issue and/or problem classification[a[, b]]	4.A.1 Forest land remaining forest land – CO2 (L.6, 2021) (L.20, 2019) Transparency
Is finding an issue/problem	-
Recommendation made in previous review report	Provide in the NIR information regarding the use and calibration of EFISCEN, including evidence that the model is able to reproduce observed trends for before 2013 in the CSC of living biomass.
ERT assessment and rationale	The Party reported in its NIR (section 6.1.3, p.206) that the 7th National Forestry Inventory (NFI-7) is now available and provides observational data for growing stock and biomass. This has replaced the previous data used from the EFISCEN model.
NLD Response in NIR /CRF 2023	No action required.
Paragraph or table number in: NIR, CRF and or Methodology report (MR)	-

Sector	LULUCF
ID# PMF 2022	L.5
Table PMF 2022	1
Adressing/Not resolved/ New from 2022 review	-
Issue and/or problem classification[a[, b]]	4.B Cropland – CO2 (L.7, 2021) (L.10, 2019) (L.8, 2017) (L.9, 2016) (L.9, 2015) Accuracy
Is finding an issue/problem	-
Recommendation made in previous review report	Correct the errors in reporting land-use area data in the CRF tables and ensure complete and consistent coverage of land areas within the country.
ERT assessment and rationale	The Party reported in its NIR (section 6.6.2, p.232, table 6.13 (table 6.11 in NIR 2021) that the differences in land use areas between CRF table 3.D and CRF tables 4.B and 4.C are explained by the fact that the total area of organic soil is reported under 4.C, but the carbon stock changes and associated emission under CRF table 3.D only considers cultivated areas.
NLD Response in NIR /CRF 2023	Was solved already in NIR 2022
Paragraph or table number in: NIR, CRF and or Methodology report (MR)	-

Sector	**LULUCF**
ID# PMF 2022	L.6
Table PMF 2022	1
Adressing/Not resolved/ New from 2022 review	-
Issue and/or problem classification[a[, b]]	4.C Grassland – CO_2 (L.16, 2021) Transparency
Is finding an issue/problem	-
Recommendation made in previous review report	The ERT recommends that the Party report information in the NIR on the exact methodology applied in the estimation of CSCs in orchards.
ERT assessment and rationale	The Party did not update the methodology 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). Statistics Netherlands (CBS) confirmed that on average 700 ha of high standard fruit trees were included in the more recent time series. The Party expects this to have a small impact on net removals (approx. 4 kt CO_2) and therefore decided not to make a correction in this inventory cycle.
NLD Response in NIR /CRF 2023	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# PMF 2022	L.7
Table PMF 2022	1
Adressing/Not resolved/ New from 2022 review	-
Issue and/or problem classification[a[, b]]	4.C.1 Grassland remaining grassland – CO2 (L.8, 2021) (L.13, 2019) (L.10, 2017) (L.10, 2016) (L.10, 2015) Accuracy
Is finding an issue/problem	-
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	The Party reported in its NIR (chap. 6.6, p.235 and chap. 6.6.1 p.230) that the correction of the misallocation of land converted to grassland that changes within the 20-year transition period from one grassland (non- trees outside forest) category has not yet been implemented and the Party plans to update the LULUCF model for the 2023 NIR. 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.
NLD Response in NIR /CRF 2023	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# PMF 2022	L.8
Table PMF 2022	1
Adressing/Not resolved/ New from 2022 review	-
Issue and/or problem classification[a[, b]]	4.D Wetlands –CO2 (L.17, 2021) Accuracy
Is finding an issue/problem	-
Recommendation made in previous review report	The ERT recommends that the Party report in the NIR and CRF table 4.D the correct estimation results for mineral soils under wetlands remaining wetlands.
ERT assessment and rationale	The Party reported in its NIR (section 6.7.6, p.237) that the misallocation of land converted to wetlands, that within the 20-year transition period changes from one wetland sub-category to another, will be implemented in a further update of the LULUCF model.
NLD Response in NIR /CRF 2023	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.
Paragraph or table number in: NIR, CRF and or Methodology report (MR)	CRF Table 4.D

Sector	LULUCF
ID# PMF 2022	L.9
Table PMF 2022	1
Adressing/Not resolved/ New from 2022 review	-
Issue and/or problem classification[a[, b]]	4.G HWP –CO2 (L.19, 2021) Accuracy
Is finding an issue/problem	-
Recommendation made in previous review report	The ERT recommends that the Party include carbon inflows for the years before 1990 in its estimation of CSCs for HWP.
ERT assessment and rationale	The Party reported in its NIR (Annex 10, p.488) that in 2022 they continue to report CSCs from HWP under the convention using the same methods as those used for the Kyoto Protocol based on the Kyoto Protocol Supplement to maintain consistency. The Party also confirmed that starting from the NIR 2023 the methodologies will be updated to include carbon inflows for the years before 1990 in its estimation of CSCs for HWP.
NLD Response in NIR /CRF 2023	In 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# PMF 2022	L.10
Table PMF 2022	1
Adressing/Not resolved/ New from 2022 review	-
Issue and/or problem classification[a[, b]]	4.G.2 Paper and paperboard – CO2 (L.11, 2021) (L.25, 2019) Convention reporting adherence
Is finding an issue/problem	-
Recommendation made in previous review report	(1) 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; (2) 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	The Party did not provide information on the QC procedures applied to HWP source data in its NIR. During the review, the Party clarified that Probos data is used to compare CBS national statistics and Vereniging Nederlandse Papier (VNP) data. Further QC procedures on the PROBOS data are not performed as the Party considers it to be the most reliable data for the Netherlands. The Party reported in its NIR (table 6.16, p.243) information on the balance of produced, imported and exported wood pulp. However, no information on the industrial and trade practices that justify accumulation of carbon stocks in the paper pool being reduced to zero for 1994 onward was provided. During the review, the Party clarified that Oldenburger et al 2022 (section 3.1.5) indicates that paper and cardboard produced in the Netherlands is produced from imported cellulose (wood pulp) and recycled paper. As the Party applies a production approach for HWP, no gains in paper and paperboard are expected.

Sector	**LULUCF**
NLD Response in NIR /CRF 2023	In the NIR 2023 we now have explicitily 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# PMF 2022	L.11
Table PMF 2022	1
Adressing/Not resolved/ New from 2022 review	-
Issue and/or problem classification[a[, b]]	4(II) Emissions/removals from drainage and rewetting and other management of organic/mineral soils – CO_2 and CH_4 (L.14, 2021) (L.27, 2019) Transparency
Is finding an issue/problem	-
Recommendation made in previous review report	Update the NIR to include a correct description of rewetting activities in the country.
ERT assessment and rationale	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 NIR 2023.
NLD Response in NIR /CRF 2023	CH_4 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

Sector	**Waste**
ID# PMF 2022	W.1
Table PMF 2022	1
Adressing/Not resolved/ New from 2022 review	-
Issue and/or problem classification[a[, b]]	5.A Solid waste disposal on land – CH4 (W.1, 2021) (W.1, 2019) (W.1, 2017) (W.2, 2016) (W.2, 2015) (52, 2014) Transparency
Is finding an issue/problem	-
Recommendation made in previous review report	Include important AD, such as the amount and composition of disposed waste, in the NIR.
ERT assessment and rationale	The Netherlands reported in its NIR (section 7.2.2, p.251) data on the composition of landfilled waste (household residual, bulky household, commercial, fresh organic and stabilized organic waste) and in the methodology report (Honing et al., 2022) (chap. 2.3.2.2.2, p.115–118) compositions of all waste by fraction and share. During the review, the Party clarified that NIR (table 7.3) is adjusted for the most recent year and further explanation can be found in the methodology report (Honig et al., 2022) (chap. 2.3.2.2.2, table 33). The Party further clarified that the methodology report (Honing et al., 2022) (chap. 2.3.2.2.3, table c) provides details on composition and amount of commercial waste and the use of European Waste List-Codes. The Party also clarified that all the detailed information is presented in the methodology report (Honing et al., 2022) not to make the NIR bulky in terms of number of pages.
NLD Response in NIR /CRF 2023	Amount of waste included in table 7.2 (section 7.2.2). Compositition of waste in recent years in new table 7.4 in NIR 2023. Table 7.3 gives an explanation of the total amount of waste land filled and the calculation of the amount of degradable organic carbon (DOC) for the most recent year as an example.

Sector	Waste
Paragraph or table number in: NIR, CRF and or Methodology report (MR)	Section 7.2.2 NIR ENINA Methodolgy report (Honig et al., 2023) page 115-118

Sector	Waste
ID# PMF 2022	W.2
Table PMF 2022	1
Adressing/Not resolved/ New from 2022 review	-
Issue and/or problem classification[a[, b]]	5.A Solid waste disposal on land – CH_4 (W.10, 2021) Convention reporting adherence
Is finding an issue/problem	-
Recommendation made in previous review report	The ERT recommends that the Netherlands correct the DOCf values in CRF table 5.A.
ERT assessment and rationale	The Netherlands corrected the DOCf values in CRF table 5.A. The Party reported in its CRF table 5A the DOCf value of 0.5 (default value from the 2006 IPCC Guidelines) for 2004 to 2020 and 0.58 (country-specific value from Oonk et al., 1994) for 1945 to 2004.
NLD Response in NIR /CRF 2023	This value was already adjusted in the NIR 2022.
Paragraph or table number in: NIR, CRF and or Methodology report (MR)	-

Sector	Waste
ID# PMF 2022	W.3
Table PMF 2022	1
Adressing/Not resolved/ New from 2022 review	-
Issue and/or problem classification[a[, b]]	5.A Solid waste disposal on land – CH4 (W.11, 2021) Transparency
Is finding an issue/problem	-
Recommendation made in previous review report	The ERT recommends that the Netherlands apply the time series of household waste composition to update the estimated DOC values in the next annual submission.
ERT assessment and rationale	The Netherlands reported in its NIR (chap. 7.22, p.249) (chap. 7.22, p.251, table 7.3) the DOC values for waste landfilled and household waste landfilled for the entire time series. During the review, the Party clarified that NIR (table 7.3) is adjusted for the most recent year and further explanation can be found in the methodology report (Honig et al., 2022) (chap. 2.3.2.2.2, table 33). The Party further explained that household waste is only a minor stream that is being landfilled now, and the ERT was referred to the methodology report (Honig et al., 2022) (chap. 2.3.2.2.3, table A). The Party also clarified that all the detailed information is presented in the methodology report (Honing et al., 2022) not to make the NIR bulky in terms of number of pages.
NLD Response in NIR /CRF 2023	A detailed explanation concerning the DOC-values is given in the Methodology report (Honig et al., 2023) page 115-118. The amount by waste stream is given in table 7.4 in the NIR.
Paragraph or table number in: NIR, CRF and or Methodology report (MR)	ENINA Methodolgy report (Honig et al., 2023) page 115-118 NIR table 7.4 in section 'Fraction of degradable organic carbon'.

Sector	Waste
ID# PMF 2022	W.4
Table PMF 2022	1
Adressing/Not resolved/ New from 2022 review	-
Issue and/or problem classification[a[, b]]	5.A.1 Managed waste disposal sites – CH_4 (W.5, 2021) (W.11, 2019) (W.17, 2017) Consistency
Is finding an issue/problem	-
Recommendation made in previous review report	(1) Derive country-specific DOCf values for the period 2001 onward in order to ensure time-series consistency; (2) Until the studies for obtaining these country-specific DOCf values are concluded, apply the country-specific value for DOCf (0.58) for the period 1990–2004 and the IPCC default value for DOCf (0.5) for 2005 onward; (3) Explain in the NIR the use of the DOCf values throughout the time series.
ERT assessment and rationale	The Party provided in its NIR (chap. 7.2.2, p.251) and the methodology report (Honing et al., 2022, p.114) an explanation on the use of the DOCf values throughout the time series. The Party used a country-specific DOCf value (Oonk et al.,1994) for the period 1945–2004. The Party resorted to use default value from the 2006 IPCC Guidelines from 2005 onwards when their effort to revise the country-specific value was failed. The Party also clarified that all the detailed information is presented in the methodology report (Honing et al., 2022) not to make the NIR bulky in terms of number of pages.

Sector	Waste
NLD Response in NIR /CRF 2023	A new study on the country-specific values for DOCf has not yet been carried out. The values of DOCf for the period 1990-2004 (0.58) and 2005-present (0.5) are used. In section 7.2.2. 'Degradable organic carbon that decomposes' further explains the use of DOCf.
Paragraph or table number in: NIR, CRF and or Methodology report (MR)	Section Degradable organic carbon that decomposes (DOCf) in section 7.2.2 in NIR

Sector	Waste
ID# PMF 2022	W.5
Table PMF 2022	1
Adressing/Not resolved/ New from 2022 review	-
Issue and/or problem classification[a[, b]]	5.B.1 Composting – CH4 (W.8, 2021) (W.14, 2019) (W.7, 2017) (W.11, 2016) (W.11, 2015) Consistency
Is finding an issue/problem	-
Recommendation made in previous review report	Ensure the consistency of the reported time series for the CH4 EF and include in the NIR the reason for the decrease in the CH4 EF after 2009.
ERT assessment and rationale	The Party referred to in its NIR (chap. 7.3.2, p.256) the methodology report (Honing et al., 2022) (chap. 2.3.2.3.2, p.123) that explains the use of consistent value of CH4 EF for the reported time series and the reason for the decrease in the CH4 EF after 2009. The Party also clarified that all the detailed information is presented in the methodology report (Honing et al., 2022) not to make the NIR bulky in terms of number of pages.
NLD Response in NIR /CRF 2023	THE EF for CH4 of 750 g/kg for composting is used for the whole time series

Sector	**Waste**
Paragraph or table number in: NIR, CRF and or Methodology report (MR)	ENINA Methodology report (Honig et al., 2023), Section 2.3.2.3.2

Sector	**Waste**
ID# PMF 2022	W.6
Table PMF 2022	1
Adressing/Not resolved/ New from 2022 review	-
Issue and/or problem classification[a[, b]]	5.B.1 Composting – CH4 and N2O (W.12, 2021) Transparency
Is finding an issue/problem	-
Recommendation made in previous review report	The ERT recommends that the Netherlands specify in the next annual submission that the EF is based on wet weight to improve transparency and consistency between the NIR and the methodology report.
ERT assessment and rationale	The Party referred to in its NIR (chapter.7.3.2, p.256) the methodology report (Honing et al., 2022) (chap. 2.3.2.3.2, p.123) that explains that the EF is based on wet weight basis for the entire time series. The Party also clarified that all the detailed information is presented in the methodology report (Honing et al., 2022) not to make the NIR bulky in terms of number of pages.
NLD Response in NIR /CRF 2023	Text added in section 7.3.2 of the NIR
Paragraph or table number in: NIR, CRF and or Methodology report (MR)	Section 7.3.2 of the NIR ENINA Methodology report (Honig et al., 2023), Section 2.3.2.3.2

Sector	Waste
ID# PMF 2022	W.7
Table PMF 2022	1
Adressing/Not resolved/ New from 2022 review	-
Issue and/or problem classification[a[, b]]	5.C.1 Waste incineration – CH4 and N2O (W.13, 2021) Transparency
Is finding an issue/problem	-
Recommendation made in previous review report	The ERT recommends that the Netherlands improve the transparency of its reporting in the NIR by including the information provided to the ERT during the review regarding hazardous and medical waste.
ERT assessment and rationale	The Party referred to in its NIR (chap. 7.4.2, p.258) the methodology report (Honing et al., 2022) (chap. 2.3.2.1, p.92) that contains information on hazardous and medical waste. The Party reported that a small portion of hazardous (such as certain organic liquids from the chemical industry, cleaning cloths contaminated with oil and/or solvents and oil filters) is processed in waste incineration plants while other hazardous waste is incinerated abroad in rotary kilns. Hospital waste are incinerated in special facilities. The Party also clarified that all the detailed information is presented in the methodology report (Honing et al., 2022) not to make the NIR bulky in terms of number of pages.
NLD Response in NIR /CRF 2023	Text added in section 7.4.2 of the NIR
Paragraph or table number in: NIR, CRF and or Methodology report (MR)	Section 7.4.2 of the NIR ENINA Methodology report (Honig et al., 2023), Section 2.3.2.1

Sector	KP-LULUCF
ID# PMF 2022	KL.1
Table PMF 2022	1
Adressing/Not resolved/ New from 2022 review	-
Issue and/or problem classification[a[, b]]	General (KP-LULUCF) – CO2 (KL.1, 2021) (KL.12, 2019) Comparability
Is finding an issue/problem	-
Recommendation made in previous review report	Report "NE" for cases where emissions are not reported on the basis of the justification that they are not a net source.
ERT assessment and rationale	The Party updated its CRF table 4(KP-1) B.1 to report litter under forest management as "NE" based on the justification that it is not a net source.
NLD Response in NIR /CRF 2023	NA
Paragraph or table number in: NIR, CRF and or Methodology report (MR)	-

Sector	KP-LULUCF
ID# PMF 2022	KL.2
Table PMF 2022	1
Adressing/Not resolved/ New from 2022 review	-
Issue and/or problem classification[a[, b]]	General (KP-LULUCF) – CO2, CH4 and N2O (KL.11, 2021) Transparency
Is finding an issue/problem	-
Recommendation made in previous review report	The ERT recommends that the Party include information in the NIR on the main factors generating the accounted quantity that can be explained as deviations in actual policies compared with those historical policies included in the FMRL, rather than the methodological difference between the FMRL and the actual FM estimate.
ERT assessment and rationale	The requested information was not included in the NIR. During the review, the Party provided the “Technical Correction to the Forest Management Reference Level under the Kyoto Protocol for the Netherlands, Version 2022” report. The report (p.16) provides information on the policies which have resulted in higher removals in FM during the CP compared to the FMRL. This issue only relates to transparency and does not impact the level of emissions or removals.
NLD Response in NIR /CRF 2023	NA
Paragraph or table number in: NIR, CRF and or Methodology report (MR)	-

Sector	KP-LULUCF
ID# PMF 2022	KL.3
Table PMF 2022	1
Adressing/Not resolved/ New from 2022 review	-
Issue and/or problem classification[a[, b]]	Deforestation – CO2 (KL.4, 2021) (KL.14, 2019) Completeness
Is finding an issue/problem	-
Recommendation made in previous review report	Estimate and report the CO2 emissions associated with the loss of dead organic matter from deforested lands previously classified under AR where the forest is less than 20 years old, or, if this is not possible, justify why the exclusion of these emissions would not result in an underestimation of emissions from deforestation for the litter and deadwood pools.
ERT assessment and rationale	The Party reported in its NIR (section 11.3.1.2, p.301) that no accumulation of dead organic matter (DOM) is calculated for the first 20 years of conversion to forest land. This impact both the emissions and removals calculated for both deforested and AR areas younger than 20 years. In the NIR (table 11.5) the Party reported that the potential emissions from the loss of DOM on deforested areas are much lower than the potential removals from the accumulation of DOM on AR land. The exclusion of these emission is therefore justified as it does not result in an underestimation of emissions or overestimation of removals.
NLD Response in NIR /CRF 2023	NA
Paragraph or table number in: NIR, CRF and or Methodology report (MR)	-

Sector	KP-LULUCF
ID# PMF 2022	KL.4
Table PMF 2022	1
Adressing/Not resolved/ New from 2022 review	-
Issue and/or problem classification[a[, b]]	FM – CO2, CH4 and N2O (KL.10, 2021) Transparency
Is finding an issue/problem	-
Recommendation made in previous review report	The ERT recommends that the Party provide in its NIR the summary information and the disaggregated number of technical corrections to the FMRL based on the elements listed in table 2.7.1 of the Kyoto Protocol Supplement (p.2.101).
ERT assessment and rationale	The requested information was not included in the NIR. During the review, the Party provided the “Technical Correction to the Forest Management Reference Level under the Kyoto Protocol for the Netherlands, Version 2022” report. The report (p.7) provides a summary of the corrections to the FMRL in line with table 2.7.1 of the Kyoto Protocol Supplement (p.2.101). This issue only relates to transparency and does not impact the level of emissions or removals.
NLD Response in NIR /CRF 2023	NA
Paragraph or table number in: NIR, CRF and or Methodology report (MR)	-

Sector	General
ID# PMF 2022	G.3
Table PMF 2022	2
Adressing/Not resolved/ New from 2022 review	new from 2022 review
Issue and/or problem classification[a[, b]]	0
Is finding an issue/problem	Yes. Convention reporting adherence
Recommendation made in previous review report	0

Sector	General
ERT assessment and rationale	The Party reported in its NIR (Annex 6, p.396–397) categories for which emissions are reported as “NE” and provided only qualitative information to justify that the emissions form these categories are insignificant. However, the Party did not provide emission estimates for the following categories that are reported as “NE”, for which methodologies exist under the IPCC 2006 Guidelines: (a) 4.A.2 (Land converted to forest land, accumulation of dead wood and litter in newly established forest plots) (CO_2); (b) 4.A (Forest land - drainage and rewetting of organic soils) (CO_2); (c) 5.D.2 (Industrial sludge treatment) (CH_4). The ERT noted that this is not in line with paragraph 37(b) of the UNFCCC reporting guidelines on annual inventories for Parties included in Annex I to the Convention. During the review, the Party provided estimates for emissions from the categories reported as “NE”, for which methodologies exist under the IPCC 2006 Guidelines. Based on these estimates, the ERT noted that these categories can indeed be considered as insignificant in line with para 37(b) of the UNFCCC reporting guidelines on annual inventories. Include these estimates for those categories considered as insignificant and reported as “NE”, for which a methodology in the IPCC 2006 Guidelines exist, in its future submissions in order to enhance adherence to the UNFCCC reporting guidelines on annual inventories for Parties included in Annex I to the Convention.

Sector	General
NLD Response in NIR /CRF 2023	From a recent survey among IWWTPs conducted by the 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, equaling 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# PMF 2022	E.9
Table PMF 2022	2
Adressing/Not resolved/ New from 2022 review	new from 2022 review
Issue and/or problem classification[a[, b]]	Comparison with international data – AD
Is finding an issue/problem	Not an issue/problem
Recommendation made in previous review report	0
ERT assessment and rationale	The ERT observed for 2020 the following inconsistencies in stock changes for liquid fuels between the national energy balances of the Netherlands in the reference approach and IEA energy statistics for the country: crude oil (−26 per cent), natural gas liquid (41 per cent), bitumen (+18 per cent). The import of crude oil is higher in the national energy balance with 79 per cent, the difference of the total liquids being of +30 per cent. The export of the crude oil is higher with 10266 per cent in the Reference Approach, the total of the liquids being higher with 43 per cent than that reported to IEA. Nevertheless, the apparent consumption difference in total liquids is −3.1 per cent. The value for the production of waste (non-biomass fraction) given in the CRF tables in 2020 is higher than that reported to IEA (+53 per cent). Explore the differences between the national statistics and IEA data and provide an appropriate explanation in its NIR.
NLD Response in NIR /CRF 2023	A more detailed analysis of the differences between the reference approach and the IEA statistics is not yet performed.
Paragraph or table number in: NIR, CRF and or Methodology report (MR)	-

Sector	Energy
ID# PMF 2022	E.10
Table PMF 2022	2
Adressing/Not resolved/ New from 2022 review	new from 2022 review
Issue and/or problem classification[a[, b]]	1.A.2.c Chemicals – solid fuels, gaseous fuels, CO2, CH4, N2O
Is finding an issue/problem	Yes. Comparability
Recommendation made in previous review report	0
ERT assessment and rationale	The Party explains in the NIR (chapter 3.2.5.1, p.96) the variation of the CO2 IEF from combustion of the phosphorus gas, a byproduct of the solid fuels that contributed to the modification of the CO2 IEF of the natural gas combustion used in 1.A.2.c Chemicals. The plant that provided the used specific data for this activity operated during the period 1998–2012 and it reported a CO2 EF around 149.5 kg/GJ. The ERT noted a possible inconsistency in the above text of the NIR resulted from the indication that the phosphorus gas is a by-product of solid fuels, but it contributes to the CO2 IEF from combustion of the gaseous fuels. According to the 2006 IPCC Guidelines Vol. 2_Chapter 1.4.1.1 Fuel definition, Table 1.1. Definitions of fuel types, p.1.14), the derived gases, by products of the solid fuels should be reported under this type of fuels. As consequence, the phosphorus gas, being a byproduct of the solid fuels, should be allocated under the solid fuels of the category 1.A.2.c Chemicals. During the review the Party clarified that this type of fuel is part of the solid fuels. Allocate the phosphorus gas consumption and the corresponding GHG emissions to the solid fuels, in accordance with the 2006 IPCC Guidelines, starting with the next submission.
NLD Response in NIR /CRF 2023	This change in allocation is implemented.

Sector	Energy
Paragraph or table number in: NIR, CRF and or Methodology report (MR)	-

Sector	Energy
ID# PMF 2022	E.11
Table PMF 2022	2
Adressing/Not resolved/ New from 2022 review	new from 2022 review
Issue and/or problem classification[a[, b]]	1.A.3.b Road transportation – LPG – CO2, CH4, N2O
Is finding an issue/problem	Yes. Transparency
Recommendation made in previous review report	0

Sector	Energy
ERT assessment and rationale	The ERT noted in the CRF tables 1.A(a)s3 of the current submission significant recalculations for the LPG consumption in different sub-categories of the road transport, on the entire time series. For example, in 2019 the consumption of LPG in 1.A.3.b.iii - Heavy duty trucks and buses category increased by 9195.83%, in 1.A.3.b.ii - Light duty trucks increased with 66.6% and in 1.A.3.b.i Cars decreased with 30.78% in comparison with the previous submission, and this level of variation among subcategories is constantly after 2011. Nevertheless, the NIR does not mention this significant variation of the LPG consumption among the 1.A.3.b subcategories and the performed reallocation between subcategories on the entire time series, nor the impact on the corresponding emissions of the performed recalculations. During the review the Party explained that the AD used to estimate the GHG emissions in the road transport are collected from the energy balance for the sold fuels within the country territory (e.g. motor gasoline, gas diesel oil, liquefied petroleum gas, natural gas and biofuels) and a new methodology has been used to allocate the fuels among different type of transport. Within this process the allocation of the LPG was the most affected, the fuel being reallocated among cars, light duty trucks and heavy-duty trucks and buses subcategories. The total LPG consumption in the road transport is 0.46% higher in 2019 in comparison with the previous submission. Explain in its NIR the performed recalculations for each type of fuel and the corresponding affected categories and indicate the impact of the recalculations on the consumption and the corresponding GHG emissions.

Sector	**Energy**
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 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.
Paragraph or table number in: NIR, CRF and or Methodology report (MR)	-

Sector	**Agriculture**
ID# PMF 2022	A.17
Table PMF 2022	2
Adressing/Not resolved/ New from 2022 review	new from 2022 review
Issue and/or problem classification[a[, b]]	3.B Manure management – N2O
Is finding an issue/problem	Yes. Transparency
Recommendation made in previous review report	0
ERT assessment and rationale	The Netherlands reported in van der Zee et al, 2022 (section 10.3.2, pp.108) that manure exported from the Netherlands is accounted for in the emissions calculation methodology; however the ERT considered that the NIR and van der Zee et al, 2022 included insufficient information on the methodology used to account for manure exported from the Netherlands. During the review, the Party explained that the amount of N in animal manure exported is approximately 6% of the total N in manure management systems, and that the amount of manure exported is included in a report by Statistics Netherlands. Provide sufficient transparency, the Party includes in the NIR a summary of the calculation methodology for the amount of N in animal manure exported from the Netherlands.
NLD Response in NIR /CRF 2023	This is explained in the methodology report paragraph 2.2.4
Paragraph or table number in: NIR, CRF and or Methodology report (MR)	Chapter 2.2.4 of the MR
Sector	LULUCF

Sector	Agriculture
ID# PMF 2022	L.12
Table PMF 2022	2
Adressing/Not resolved/ New from 2022 review	new from 2022 review
Issue and/or problem classification[a[, b]]	4.D Wetlands – CO2, CH4 and N2O
Is finding an issue/problem	Not an issue/problem
Recommendation made in previous review report	0
ERT assessment and rationale	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, which are covered by the Wetlands Supplement and that possible methodological improvements will be considered on the basis of this assessment. 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
Paragraph or table number in: NIR, CRF and or Methodology report (MR)	See NIR section 6.7.6

Sector	LULUCF
ID# PMF 2022	L.13
Table PMF 2022	2
Adressing/Not resolved/ New from 2022 review	new from 2022 review
Issue and/or problem classification[a[, b]]	4.C.2.1 Forest land converted to grassland – CO2
Is finding an issue/problem	Yes. Transparency
Recommendation made in previous review report	0
ERT assessment and rationale	The Party reported in its NIR (chap. 6.4.2.3, p.223) that for conversions between forest land and grassland trees outside forest (TOF) it is assumed that no loss of biomass occurs. The ERT noted that this is not in line with CRF table 4.A and 4.C where losses and an overall net gain is assumed for both forest land (FL) converted to TOF and TOF converted to FL. 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 FL and TOF and that the additional annual carbon stock gains resulting from growth of biomass are included. The ERT noted that the justification for the same assumptions in biomass growth being applied to TOF as FL is not included in the NIR (p.228) or the referenced report. Include information in its NIR on the assumed gains and losses for conversions between FL and TOF to improve the transparency of reporting. In addition, the ERT recommends that the Party include information in its NIR to justify the assumption that biomass growth rates are the same in TOF as in FL.
NLD Response in NIR /CRF 2023	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.

Sector	LULUCF
Paragraph or table number in: NIR, CRF and or Methodology report (MR)	-

Sector	LULUCF
ID# PMF 2022	L.14
Table PMF 2022	2
Adressing/Not resolved/ New from 2022 review	new from 2022 review
Issue and/or problem classification[a[, b]]	4.C.1 Grassland remaining grassland – CO2
Is finding an issue/problem	Yes. Accuracy
Recommendation made in previous review report	0
ERT assessment and rationale	The Party did not update the methodology description for Orchards in its NIR in line with the previous recommendation (see #L.6 in table 3). During the review, the Party clarified that based on updated information from Statistics Netherlands (CBS) it estimates that removals are being underestimated in the current methodology (approximately by 4 kt CO2). Implement updated data and recalculate emissions/removals from orchards in the next submission to improve the accuracy of the estimates.
NLD Response in NIR /CRF 2023	The description has been adapted, including the estimated underestimation
Paragraph or table number in: NIR, CRF and or Methodology report (MR)	NIR section 6.6.2

Sector	LULUCF
ID# PMF 2022	L.15
Table PMF 2022	2
Adressing/Not resolved/ New from 2022 review	new from 2022 review
Issue and/or problem classification[a[, b]]	4(II) Emissions/removals from drainage and rewetting and other management of organic/mineral soils – CO2 and CH4
Is finding an issue/problem	Yes. Accuracy
Recommendation made in previous review report	0
ERT assessment and rationale	The Party did not correct the description of rewetting activities in its NIR in line with the previous recommendation (see #L.11 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, a tier 1 ditch fraction from the 2013 Wetland Supplement in combination with a country specific CH4 emission factors will be applied. 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 greater removals (81 kt CO2 eq in 1990 and 31 kt CO2 eq in 2020). Include estimates of CH4 emissions in CRF table 4(II) in its next submission to improve the accuracy of the estimates.
NLD Response in NIR /CRF 2023	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.

Annex 11 Information on changes in the National System

Extensive information on the National System is described in this National Inventory Report under the appropriate sections, as required by the UNFCCC Guidelines. More extensive background information on the National System is also included in the Netherlands' 8th National Communication, the 5th Biennial Report, and in the Initial Report. The initial review in 2007 concluded that the Netherlands' National System had been established in accordance with the guidelines.
The following are the only changes to the National System since the Initial Report:

- The coordination of the Emission Registration Project (NL-PRTR), in which emissions of about 350 substances are annually calculated was performed until 1 January 2010 by PBL. As of 1 January 2010, coordination has been assigned to the RIVM. Processes, protocols and methods remain unchanged. Many of the experts from PBL have moved to the RIVM.
- The name of SenterNovem (single national entity/NIE) changed as of 1 January 2010 to NL Agency.
- The name of NL Agency (single national entity/NIE) changed as of 1 January 2014 to Netherlands Enterprise Agency (RVO).
- In 2010 the Ministry of Economic Affairs and the Ministry of Agriculture, Nature and Food Quality (LNV) merged into the Ministry of Economic Affairs, Agriculture and Innovation (EL&I). In 2012 the name of this ministry was changed to the Ministry of Economic Affairs (EZ).
- In 2015, the Netherlands replaced the 40 monitoring protocols (containing the methodology descriptions as part of the National System) with five methodology reports, one for each PRTR Task Force. These methodology reports are also part of the National System. From 2015 onwards, the NIRs will be based on these methodology reports. The main reason for this change is that the update of five methodology reports is simpler than the update of 40 protocols. In addition, the administrative procedure is simplified because the updated methodology reports do not require an official announcement in the Government Gazette. For this reason, the Act on the Monitoring of Greenhouse Gases was updated in 2014. The methodology reports are checked by the National Inventory Entity and approved by the chairperson of the PRTR Task Force concerned. As part of the National System, the methodology reports are available on the National System website http://english.rvo.nl/nie;
- In 2017, the Ministry of Economic Affairs (EZ) was split into the Ministry of Economic Affairs and Climate Policy (EZK) and the Ministry of Agriculture, Nature and Food Quality (LNV). At the same time, the responsibility for climate policy shifted from the (former) Ministry of Infrastructure and the Environment to the Ministry of Economic Affairs and Climate Policy.
- In 2017 the ERT recommended that more information should be provided on the methodologies used in the NIR. As a result of this recommendation, since 2018, the Netherlands has included

methodology reports in the annual submission as an integral part of the NIR (see Annex 7).

These changes have had no impact on the functions of the National System.

Annex 12 Information on changes in national registry

12.1 Changes to national registry in 2022

The following changes to the national registry of Netherlands occurred in 2022. Note that the 2022 SIAR confirms that previous recommendations have been implemented and included in the annual report.

Reporting Item	Description
15/CMP.1 annex II.E paragraph 32.(a) Change of name or contact	None
15/CMP.1 annex II.E paragraph 32.(b) Change regarding cooperation arrangement	No changes.
15/CMP.1 annex II.E paragraph 32.(c) Change to database structure or the capacity of national registry	There has been 3 new EUCR releases (versions 13.6.1, 13.7.1 and 13.8.2) after version 13.5.2 (the production version at the time of the last Chapter 14 submission). No changes were applied to the database, whose model is provided in Annex A. No change was required to the application backup plan or to the disaster recovery plan. No change to the capacity of the national registry occurred during the reported period.
15/CMP.1 annex II.E paragraph 32.(d) Change regarding conformance to technical standards	The changes that have been introduced with versions 13.6.1, 13.7.1 and 13.8.2 compared with version 13.5.2 of the national registry are presented in Annex B. It is to be noted that each release of the registry is subject to both regression testing and tests related to new functionality. These tests also include thorough testing against the DES and are carried out prior to the relevant major release of the version to Production (see Annex B). No other change in the registry's conformance to the technical standards occurred for the reported period.
15/CMP.1 annex II.E paragraph 32.(e) Change to discrepancies procedures	No change of discrepancies procedures occurred during the reported period.

Reporting Item	Description
15/CMP.1 annex II.E paragraph 32.(f) Change regarding security	No changes regarding security were introduced.
15/CMP.1 annex II.E paragraph 32.(g) Change to list of publicly available information	No change to the list of publicly available information occurred during the reported period.
15/CMP.1 annex II.E paragraph 32.(h) Change of Internet address	No change to the registry internet address during the reported period.
15/CMP.1 annex II.E paragraph 32.(i) Change regarding data integrity measures	No change of data integrity measures occurred during the reported period.
15/CMP.1 annex II.E paragraph 32.(j) Change regarding test results	No change during the reported period.

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