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

Greenhouse gas emissions in the Netherlands 1990–2019
National Inventory Report 2021

15 April 2021

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The emissions and activity data of the Netherlands' inventory were converted into the IPCC[1] 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 (KP and Land use), Bas van Huet (Waste), Gerben Geilenkirchen 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, data control, chart production), Kees Baas (Wastewater handling), Tim van der Zee (Agriculture). Bas Guis provided pivotal information on CO_2 emissions related to energy use.

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 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.

[1] Intergovernmental Panel on Climate Change

Synopsis

Greenhouse gas emissions in the Netherlands 1990–2019

Total greenhouse gas (GHG) emissions in the Netherlands in 2019 decreased by 3.2 percent, in comparison with 2018 emissions. This decrease was mainly the result of decreased coal combustion for energy and heat production.

In 2019, total GHG emissions (including indirect CO_2 emissions and excluding emissions from Land use, land use change and forestry (LULUCF)) in the Netherlands amounted to 180.7 Tg CO_2 eq. This is approximately 18 percent below the emissions in the base year 1990 (220.5 Tg CO_2 eq.).

CO_2 emissions in 2019 were 5.6 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 percent over this period.

This report documents the Netherlands' annual submission for 2021 of its GHG emissions inventory 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), the Kyoto Protocol (KP) and the European Union's Greenhouse Gas Monitoring Mechanism.

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 2020), the results of recalculations and planned improvements.

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

Publiekssamenvatting

Emissies van broeikasgassen tussen 1990 en 2019

In 2019 is de totale uitstoot van broeikasgassen in Nederland met 3,2 procent gedaald ten opzichte van 2018. Deze daling komt vooral doordat er minder kolen zijn gebruikt om elektriciteit te produceren.

De totale uitstoot van broeikasgassen naar de lucht wordt uitgedrukt in CO_2-equivalenten en bedroeg in 2019 180,7 miljard kilogram. Het jaar 1990 geldt als referentiejaar (basisjaar) voor de te halen doelstellingen. De uitstoot in 1990 bedroeg 220,5 miljard kilogram CO_2-equivalenten. Ten opzichte van het basisjaar is de uitstoot gedaald met 18 procent.

De uitstoot van CO_2 alleen, ligt 5,6 procent onder het niveau van het basisjaar. De uitstoot van de andere broeikasgassen (methaan, distikstofoxide en gefluoreerde gassen) is sinds 1990 met 53 procent gedaald.

Dit blijkt uit de definitieve inventarisatie van broeikasgasemissies die het RIVM jaarlijks op verzoek van het Ministerie van Economische Zaken en Klimaat (EZK) opstelt. Met deze inventarisatie voldoet Nederland aan de nationale rapportageverplichtingen voor 2021 van het Klimaatverdrag van de Verenigde Naties (UNFCCC), van het Kyoto Protocol en van het Bewakingsmechanisme Broeikasgassen van de Europese Unie. De voorlopige emissiecijfers over 2019 zijn al in het najaar van 2020 gepubliceerd.

De inventarisatie bevat verder analyses van ontwikkelingen in de uitstoot van broeikasgassen tussen 1990 en 2019, een analyse van de belangrijkste bronnen die broeikasgassen uitstoten (‘sleutelbronnen’), evenals de onzekerheid in de berekening van hun 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

Contents

Executive summary

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

This report documents the Netherlands' annual submission for 2021 of its greenhouse gas (GHG) emissions inventory, in line with the annual reporting requirements under the United Nations Convention on Climate Change (UNFCCC) and its Kyoto Protocol (KP). The report contributes to fulfilling the reporting requirements under the EU Monitoring Mechanism Regulation (EU 525/2013).

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 Kyoto Protocol (CMP).

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 2020).

The supplementary information required under Article 7, paragraph 1 of the Kyoto Protocol is reported in five additional Chapters in Part II of this report.

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 (biennial edition; in Dutch: *Balans van de Leefomgeving*) prepared by the Netherlands Environmental Assessment Agency (PBL, 2020), the 7th National Communication (NC7; EZK, 2017a), the 4th Biennial Report (BR4: EZK, 2019), the Climate and Energy Outlook 2020 (PBL, TNO, CBS and RIVM, 2020) and the National Energy and Climate Plan (EZK, 2019b).

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 2021 in PDF format, are also available on the National Systems website http://english.rvo.nl/nie.

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.

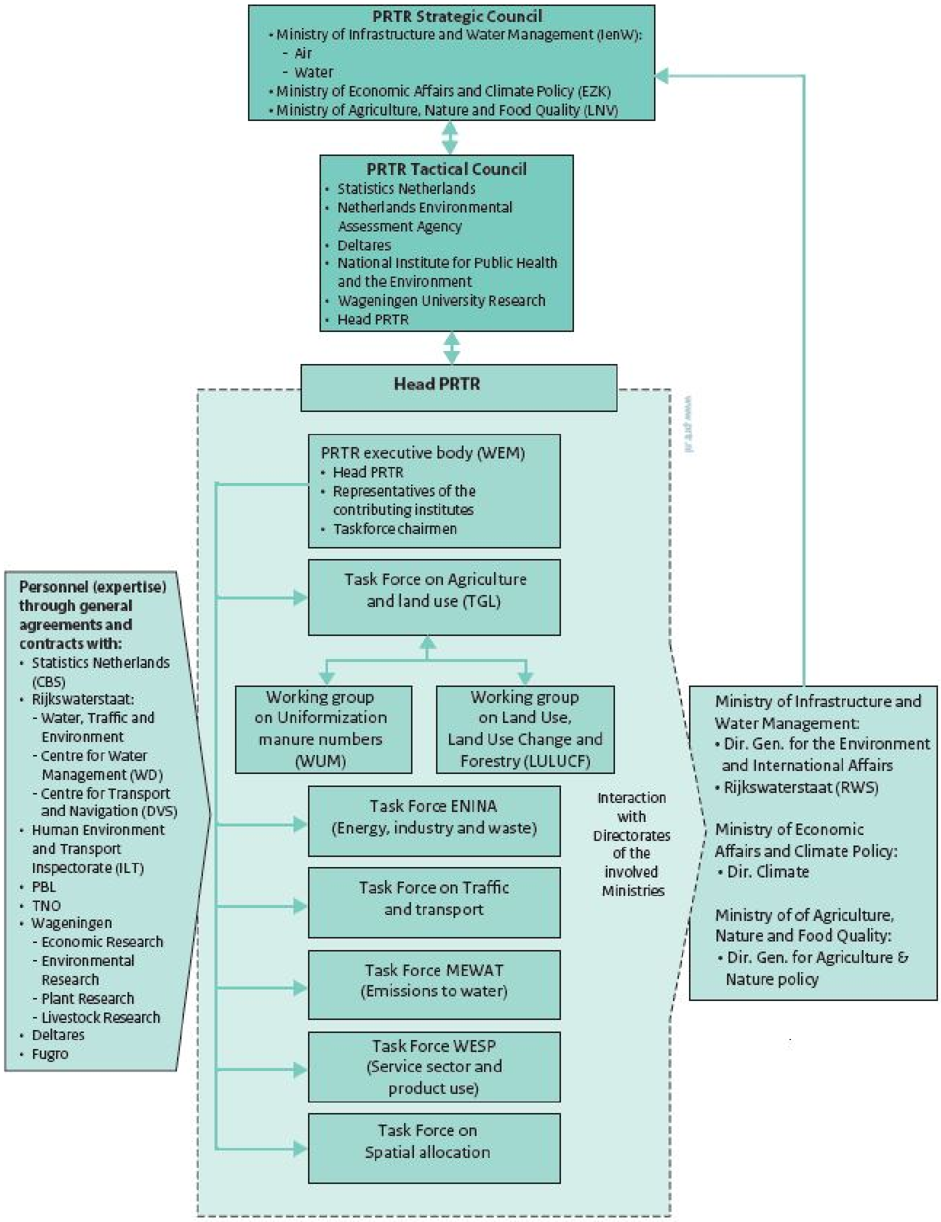


Figure ES.1 Main elements in the GHG emissions inventory compilation process.

Methodology reports
Emissions data are reported in accordance with the 2006 IPCC Guidelines (IPCC, 2006). 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 the National System website. 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 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 Olivier et al., 2009).
The key categories are those whose emissions add up to 95% of the national total (excluding LULUCF): 33 categories for annual level assessment (emissions in 2019) and 40 categories for the trend assessment. In total the Netherlands reports 118 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 55 and 59 key categories; excluding and including LULUCF, respectively.

ES2 Summary of trends in national emissions and removals
In 2019, total GHG emissions (including indirect CO_2 emissions and excluding emissions from LULUCF) in the Netherlands were estimated at 180.7 Tg (Teragram or Megaton) CO_2 equivalents (CO_2 eq.). This is approximately 18% below total emissions in the base year (220.5 Tg CO_2 eq.).

CO_2 emissions (excluding LULUCF) in 2019 were about 5.6% lower than in 1990. CH_4 emissions in 2019 were 45.9% lower than 1990 levels, mainly due to decreases in emissions from the Waste sector and the Agricultural sector. N_2O emissions decreased by 54.9% in 2019 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 N2O mainly from energy industries and transport) increased.

Compared with the base year, the emissions of F-gases (HFCs, PFCs and SF_6) decreased by 67.6%, 95.6% and 46.2%, respectively (see Table ES.1). Total emissions of all F-gases were 75.9% 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 indirect CO_2 emissions), 1990–2019.

	CO_2 excl. LULUCF	**CH_4 excl. LULUCF**	**N_2O excl. LULUCF**	**HFCs**	**PFCs**	**SF_6**	**Total excl. LULUCF**
1990 (base yr)	162.7	31.8	17.5	5.6	2.7	0.2	220.5
1995	173.0	29.6	17.6	7.5	2.3	0.3	230.3
2000	171.6	24.2	15.5	4.6	1.9	0.3	218.1
2005	177.4	19.8	13.9	1.4	0.4	0.2	213.0
2010	182.0	19.4	8.2	2.1	0.3	0.2	212.1
2015	164.7	18.1	8.3	1.8	0.1	0.1	193.2
2018	159.5	17.3	8.0	1.7	0.2	0.1	186.8
2019	153.6	17.2	7.9	1.8	0.1	0.1	180.7

Compared with 2018, overall 2019 GHG emissions decreased by about 3.2%. The changes for the specific gases were as follows:

- CO_2 emissions (excluding LULUCF) decreased by 3.7% (-5.9 Tg), mainly due to less coal combustion (-7.1 Tg). The decreased use of coal has been offset by an increase in gas consumption for (1A1a) Electricity and heat production (+4.1 Tg CO_2). Besides, the amount of energy from renewables and waste in the Netherlands showed an increase of c. 14% in 2019 compared to 2018.
- CH_4 emissions slightly decreased by 0.7% (-0.1 Tg CO_2 eq.), mainly in category 3A1 (enteric fermentation cattle) and category 5A1 (Managed waste disposal on land).
- N_2O emissions decreased by about 1.4% (-0.1 Tg CO_2 eq.), mainly due to a decrease of emissions in categories 3Da (Direct N_2O emissions form agricultural soils).
- F-gas emissions increased by 5.1% (0.1 Tg CO_2 eq.). This was primarily caused by an increase in HFC emissions of 9.5% (0.16 Tg CO_2 eq.). Emissions of both PFCs and SF_6 slightly decreased. Fluctuations in F-gas emissions over the past few years are mainly due to market circumstances.

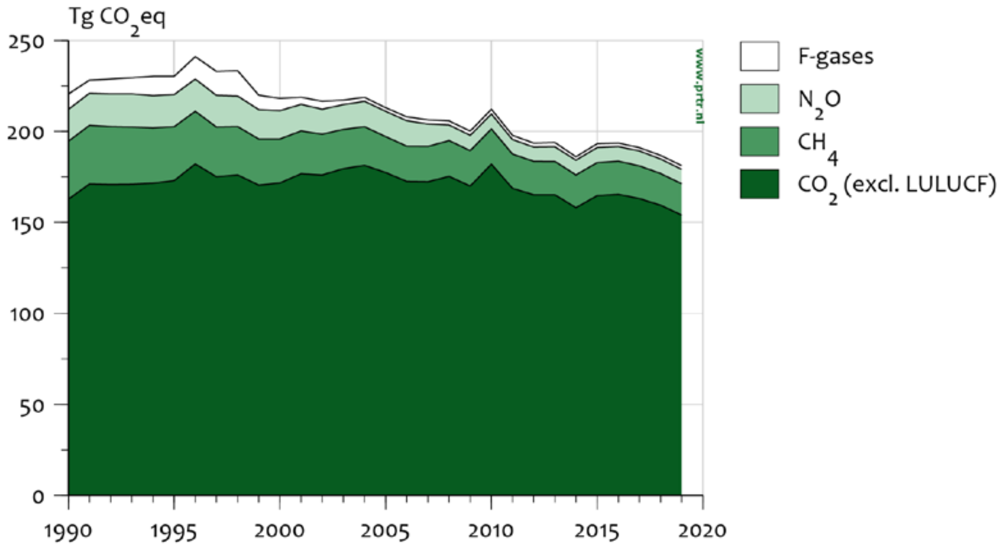


Figure ES.2 Overview of the trends in GHG emissions (excl. LULUCF), 1990–2019.

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 2019 were c. 5.4% lower than in 1990. Emissions from all sectors were lower than in the base year, the largest decreases being in Waste, IPPU and Agriculture.

Source categories showing the largest increase in CO_2-equivalent emissions since 1990 are Transport (1A3) and Energy industries (1A1) (10.7% and 7.7%, respectively).

Table ES.2 Summary of emissions trends per sector (Tg CO_2 equivalents, including indirect CO_2 emissions), 1990–2019.

	Energy (1)	IPPU (2)	Agri-culture (3)	LULUCF (4)	Waste (5)	Total incl. LULUCF	Total excl. LULUCF
1990 (base yr)	158.6	23.3	24.5	6.1	14.2	226.6	220.5
1995	169.2	24.9	23.6	5.9	12.5	236.2	230.3
2000	167.0	21.3	20.1	5.5	9.8	223.6	218.1
2005	172.9	16.1	17.7	5.2	6.3	218.2	213.0
2010	178.8	11.2	17.6	5.0	4.6	217.2	212.1
2015	161.2	10.2	18.2	4.9	3.4	198.1	193.2
2018	155.5	10.4	17.9	4.6	3.0	191.4	186.8
2019	150.0	10.2	17.7	4.5	2.9	185.3	180.7

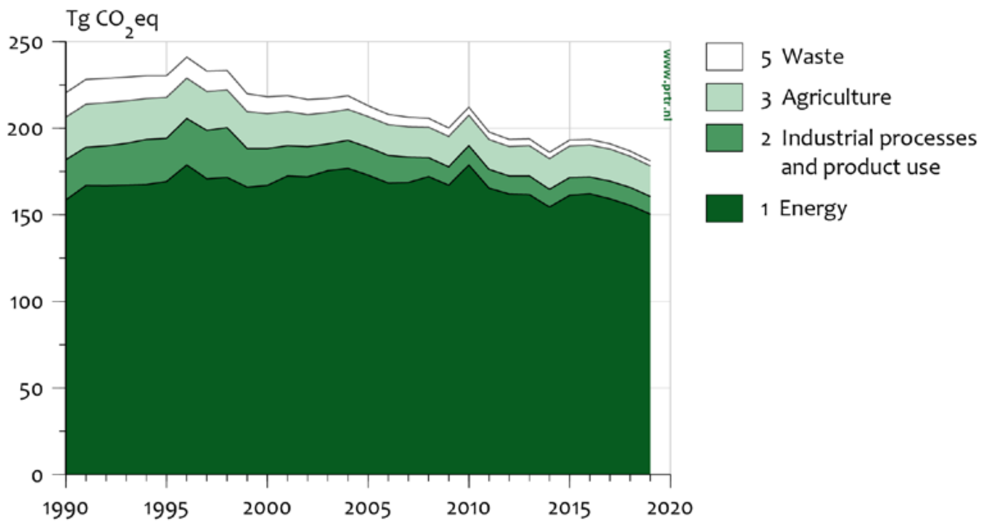


Figure ES.3 Overview of trends in GHG emissions per sector (excl. LULUCF), 1990–2019.

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 (excluding LULUCF) in 2019 is ±3%. This means that, with a confidence level of 95%, total emissions of greenhouse gases in the Netherlands are between 175 and 186 Tg CO_2 eq. The ***trend*** uncertainty in total CO_2-eq. emissions (excluding LULUCF) for 1990–2019 is ±2%. This means that the trend in total CO_2-eq. emissions between 1990 and 2019 (excluding LULUCF), which is calculated to be a 18% decrease, will range between a 16% decrease and a 20% decrease.
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 ±2%, ±9%, ±38% and ±35%, respectively. The uncertainties in the trend for the individual gases are ±1%, ±5%, ±6% and ±9%, respectively.
Annex 2 provides details of the uncertainties not only in 2019, 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 missing activity data;
- CO_2 from Road paving (2A4d), due to missing activity data;
- CH_4 from Enteric fermentation of poultry (3A4), due to missing emission factors;
- N_2O from Industrial wastewater treatment (5D2) and 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 2020 (Ruyssenaars et al., 2020), some improvements to the inventory (including recalculations) have been implemented, and these are documented in this NIR 2021. The rationale behind the recalculations is documented in Chapters 3–8 and their impacts on the inventory are summarised in Chapter 10. Table ES.3 shows the results of these recalculations in the NIR 2021 in comparison with the figures reported in the NIR 2020.

Table ES.3 Differences between the NIR 2020 and NIR 2021 for the period 1990–2018 due to recalculations (Units: ***Tg CO_2 eq.;*** *for F-gases:* ***Gg CO_2 eq****.).*

Gas	Source	1990	2000	2010	2015	2018
CO_2 [Tg]	NIR 2021	168.7	177.1	186.9	169.5	164.0
Incl. LULUCF	NIR 2020	169.8	178.4	187.7	171.8	165.4
	Difference	-0.6%	-0.76%	-0.44%	-1.37%	-0.9%
CO_2 [Tg]	NIR 2021	162.7	171.6	182.0	164.7	159.5
Excl. LULUCF	NIR 2020	163.3	172.4	182.6	166.8	160.6
	Difference	-0.4%	-0.5%	-0.3%	-1.30%	-0.7%
CH_4 [Tg]	NIR 2021	31.8	24.2	19.4	18.1	17.3
	NIR 2020	31.8	24.3	19.4	18.2	17.3
	Difference	0.0%	-0.4%	-0.2%	-0.3%	0.2%
N_2O [Tg]	NIR 2021	17.5	15.5	8.2	8.3	8.0
	NIR 2020	18.0	16.2	8.7	8.9	8.4
	Difference	-3.1%	-4.2%	-6.3%	-6.6%	-5.2%
PFCs [Gg]	NIR 2021	2,662.9	1,902.8	313.8	104.2	163.0
	NIR 2020	2,662.9	1,902.8	313.8	104.2	163.0
	Difference	0.0%	0.0%	0.0%	0.0%	0.0%
HFCs [Gg]	NIR 2021	5,606.3	4,608.5	2,128.8	1,801.2	1,660.2
	NIR 2020	5,606.3	4,765.2	2,660.9	1,801.2	1,641.6
	Difference	0.0%	-3.3%	-20.0%	0.0%	1.1%
SF_6 [Gg]	NIR 2021	206.7	258.8	153.8	139.5	123.7
	NIR 2020	206.7	258.8	153.8	139.5	123.7
	Difference	0.0%	0.0%	0.0%	0.0%	0.0%
Total	NIR 2021	226.6	223.6	217.2	198.1	191.4
[Tg CO_2-eq.]	NIR 2020	228.1	225.8	219.0	201.0	193.1
Incl. LULUCF	Difference	-0.7%	-1.0%	-0.9%	-1.4%	-0.9%
Total	NIR 2021	220.5	218.1	212.1	193.2	186.8
[Tg CO_2-eq.]	NIR 2020	221.7	219.8	213.7	195.9	188.2
Excl. LULUCF	Difference	-0.5%	-0.8%	-0.8%	-1.4%	-0.8%

Improving the QA/QC system

The QA/QC (quality assurance/quality control) programme is up to date and all procedures and processes meet 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 2019 by 45.5% and 60.9%, respectively. For SO_2, the reduction was 88.4%; for NO_x, the 2018 emissions were 64.0% 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., 2021).

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

	1990	1995	2000	2005	2010	2015	2017	2018	2019
Total NO_X	662	563	472	416	350	282	259	253	238
Total CO	1148	928	762	730	666	562	596	628	626
Total NMVOC	606	434	335	267	268	251	248	245	237
Total SO_2	197	136	78	67	36	31	27	25	23

Part I: Annual inventory report

1 Introduction

1.1 Background information on greenhouse gas inventories and climate change

This report documents the Netherlands' annual submission for 2021 of its greenhouse gas (GHG) emissions inventory, in line with the annual reporting requirements under the United Nations Convention on Climate Change (UNFCCC) and its Kyoto Protocol (KP). The report is also in line with the reporting requirements under the EU Monitoring Mechanism Regulation (EU 525/2013). Chapter 1 provides accompanying information to the national greenhouse gas inventory, like a description of the national system, QA/QC procedures, key categories, uncertainties and a general description on data sources.

1.1.1 Background information on climate change reporting

Climate Convention, Kyoto Protocol and EU Monitoring Mechanism Regulation

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 Kyoto Protocol (KP) under the Convention entered into force. Rules for Monitoring, Reporting and Verification (MRV), initially agreed under the Convention itself, were further elaborated in the KP under the Articles 5, 7 and 8, and have been implemented successively. The National System for the Netherlands under Article 5.1 of the KP was reviewed (Article 8 of the KP) and accepted in 2007. The greenhouse gas (GHG) inventory is prepared on an annual basis under this National System (Article 7.1 of the KP). The latest UNFCCC review of the inventory in September 2019 confirmed that the Netherlands' inventory and inventory process are still in line with the rules for National Systems.

This National Inventory Report (NIR) 2021, accompanied by the Common Reporting Format (CRF), reports on the national GHG emissions of the Netherlands. The methodologies applied for calculating the emissions are in accordance with the 2006 IPCC Guidelines.

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, including reporting elements under the Kyoto Protocol. Part I of this NIR, together with the CRF, represents the 2021 national emissions inventory of GHGs under the UNFCCC and the KP. Additional reporting requirements under the KP, such as supplementary information under Article 7 of the Kyoto Protocol, are included in Part II of this report.

Geographical coverage

The reported emissions are those that derive from the legal territory of the Netherlands. This includes inland water bodies and coastal water in a zone stretching 12 miles from the coastline. It excludes Aruba, Curaçao and Sint Maarten, which are constituent countries of the Kingdom of the Netherlands. 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 included in the Kyoto Protocol: 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 called the F-gases). NF_3 emissions cannot be reported separately due to the confidentiality of the data. Therefore, NF_3 emissions are included in the PFC emissions.
The Netherlands reports total GHG emissions including indirect CO_2 emissions. 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 of the trends in GHG emissions per gas and per sector for the period 1990–2019. 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 Netherlands' State of the Environment Report 2020 (biennial edition; in Dutch: *Balans van de Leefomgeving*) (PBL, 2020), the 7th Netherlands National Communication under the United Nations Framework Convention on Climate Change (NC7: EZK, 2017a), the 4th Biennial Report (BR4: EZK, 2019), the Climate and Energy Outlook 2020 (PBL, TNO, CBS, RIVM 2020) and the National Energy and Climate Plan (EZK, 2019b).

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, as described in Box 1 below. The GHG emissions inventory and the PRTR share underlying data, which ensures consistency between the inventories and other internationally reported data such as data reported to the United Nations Economic Commission for Europe (UNECE) Air Convention and the EU's National Emission Ceilings (NEC) Directive.

In line with the requirements of the National System and in accordance with Article 5.1 of the KP, both the National System and the methodologies for calculating GHG emissions in the Netherlands are kept up to date on an annual basis. Information on the latest changes to the National System is included in Chapter 13 of this report.
Since 2015, emissions data have been calculated according to the 2006 IPCC Guidelines (IPCC, 2006).
The methodologies applied in the Netherlands are documented in five methodology reports. The NIR 2021 is based on these methodologies.

The methodology reports are an integral part of this submission (see Annex 7) and are available at the National System website: http://english.rvo.nl/nie. The methodology reports are prepared- and approved under the lead of the chair of the PRTR Task Force concerned. 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 24/CP.19 Annex III (UNFCCC, 2013) and the 4th IPCC Assessment Report (ARR4). 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 published on the website http://english.rvo.nl/nie.

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

Supplementary information on Land use, land use change and forestry according to the Kyoto Protocol definitions (KP-LULUCF) is included in chapter 11 of this NIR and pertains to activities under Article 3, paragraph 3, and supplementary information on Forest management pertains to the mandatory activity under Article 3, paragraph 4. The Netherlands has chosen not to include any other activities under Article 3, paragraph 4, of the Kyoto Protocol.

Information on the accounting of Kyoto units is also provided in the SEF file *RREG1_NL_2020_2_1.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 by the end of 2005. The National System is described in greater detail in the Seventh Netherlands National Communication under the United Nations Framework Convention on Climate Change (NC7: EZK, 2017a).

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 RVO as the NIE, the single national entity required under the Kyoto Protocol.

As well as coordinating the establishment and maintenance of a National System, the RVO was tasked with the coordination of improved QA/QC activities as part of the National System and the coordination of support/response to the UNFCCC review process.
The National Institute for Public Health and the Environment (RIVM) has been 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. The 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 the registering and reporting of emissions data for approximately 375 policy-relevant compounds and compound groups that are present in air, water and soil. The emissions data are produced in an annual (project) cycle (RIVM, 2020).

In addition to the 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, the 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 the RIVM (see figure 1.3). The Strategic Board formally approves the Annual Work Plan.
The PRTR project leader at the 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 650 emission sources. After intensive checking, national emissions figures are accepted by the project leader of the PRTR project and the dataset is stored in the Central Database.

The 650 emissions sources are logically divided into 55 work packages. An emissions expert is responsible for one or more work packages, the collection of the data and the calculation of the emissions. The experts are also closely involved in developing the methodologies for calculating the emissions. Work packages are assigned to five Task Forces, as 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, CBS, 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, CBS, 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 CBS.

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

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 the RVO in its role as NIE. The RVO prepares most of the NIR Part II. The RIVM integrates all information into the NIR. The RVO takes care of 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

The supplementary information, as required according to Article 7 of the Kyoto Protocol, is reported in the NIR Part II. This information is prepared by the RVO using information from various other organisations involved, such as the NEa (Dutch Emissions Authority), WUR and EZK.

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. The RVO is responsible for coordinating QA/QC and responses to the EU and for providing additional information requested by the UNFCCC after the NIR and the CRF have been submitted. The RVO is also responsible for coordinating the submission of supporting data for the UNFCCC review process. The EZK formally approves the NIR before it is submitted; in some cases, approval follows consultation with other ministries.

For KP-LULUCF, consistency with the values submitted for the Convention is assured by using the same base data and calculation structure. The data, as required in the KP-LULUCF CRF tables, are derived from calculations required by the UNFCCC and specifically aggregated to the KP-LULUCF activities. The data and calculations are thus subject to the same QA/QC procedures (Arets et al., 2021).
The calculated values were generated using the LULUCF bookkeeping model at Wageningen Environmental Research and checked by the LULUCF sectoral expert. Subsequently, they were sent to the NL-PRTR for the data to be entered in the CRF database for all sectors, and checked again. Any unexpected or incomplete values were reported to the LULUCF sectoral expert, checked and, if necessary, corrected.

1.2.3.1 Information on the QA/QC plan

As part of its National System, the Netherlands has developed and implemented a QA/QC programme. This programme is assessed annually and updated, if necessary. The key elements of the current programme (RVO, 2020) are summarised in this chapter, notably those relating to the current NIR.

1.2.3.2 QA/QC procedures for the CRF/NIR 2021

The system of methodology reports was developed and implemented in order to increase the transparency of the inventory (including methodologies, procedures, tasks, roles and responsibilities with regard to inventories of GHGs). Transparent descriptions of all these aspects 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 time 1990–2019 (with the exception of LULUCF).
This standard format database is uploaded to- and stored in the national emissions database.
After a first check of the data by the RIVM for completeness, the (corrected) data are made available to the relevant Task Forces for consistency checks and trend analyses (comparability, accuracy). For that purpose, the Task Forces are granted access to the national emissions database.
Several weeks before the dataset was fixed, a trend verification workshop was organised by the RIVM (3 December 2020). The verification process is described in more detail in section 1.2.3.3. The conclusions of this workshop (including how the experts should resolve the issues for improvement, as identified during this workshop) are

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

QA for the current NIR 2021 also includes the following activities:

- Taking into account any remaining issues from former UNFCCC reviews and ESD reviews and making the requested improvements (summarised in Annex 10).
- A peer and public review on the basis of the draft NIR in January/February 2021. Results of these reviews are summarised in Chapter 10. Issues will be addressed in upcoming NIRs.

The QA/QC system must operate within the available resources (both capacity and finance). Within those limitations, QA/QC activities focus on: *The QA/QC programme* (RVO, 2020), which has been developed and implemented as part of the National System. This programme includes quality objectives for the National System, the QA/QC plan and a schedule for the implementation of the activities. It is updated annually as part of an 'evaluation and improvement cycle' for the inventory and National System and is kept available for review. Figure 1.1 summarises the main elements of the annual QA/QC cycle, including the corresponding timeline. To ensure high-quality and continuous improvement, the annual inventory process is implemented as a cyclical project. This cycle is a key quality management tool (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., 2020).

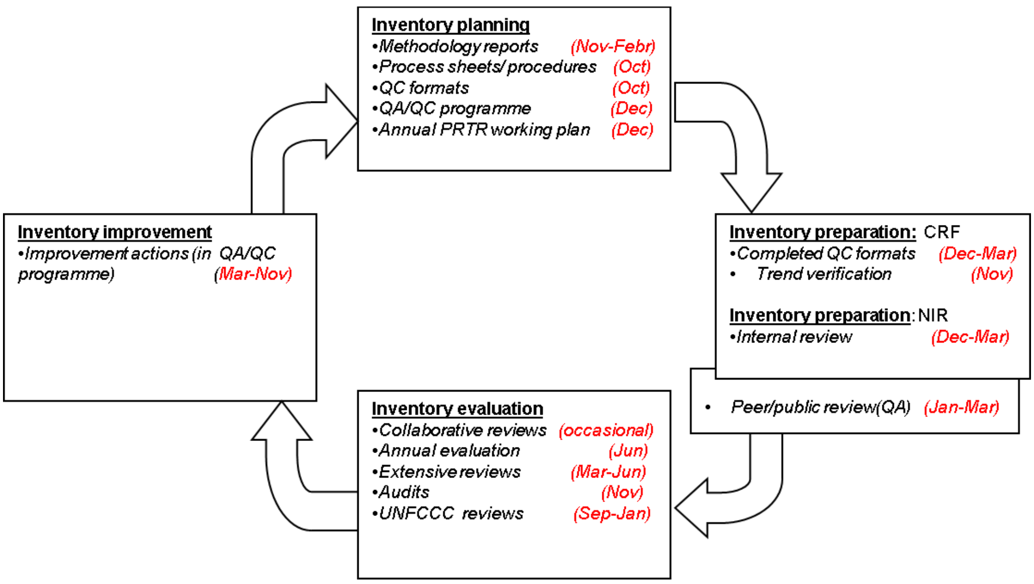


Figure 1.1 QA/QC cycle (including timeline).

- *Adaptation of the PRTR project to the quality system* of the RIVM (ISO 9001:2008 system), completed in 2012.
- *The annual Work Plan* of the RIVM (RIVM, 2020). 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 strict 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 the 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 themselves to delivering capacity for the work/products specified in that Work Plan. The role and responsibilities of each institute have been described (and agreed upon) within the framework of the PRTR Work Plan.
- *Specific procedures* that have been established to fulfil the QA/QC requirements of the UNFCCC and Kyoto Protocol. 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. This is the Netherlands' interpretation of the IPCC Good Practice Guidance requirement in section 8.7.1.4: '[…] *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 on the basis of the draft NIR in January/February 2021. Results of this review are summarised in Chapter 10. 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 the RIVM about forthcoming internal audits. Furthermore, the 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 are agreed (in the PRTR annual Work Plan) for general data collection and the storage of fixed datasets in the RIVM database, including the documentation/archiving of QC checks. To improve transparency, the implemented QC checklists have also been documented and archived, as part of the QA/QC plan. Since 2012, the RIVM database has held storage space

where the Task Forces can store the 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).
  - The RVO (as NIE) maintains the National System website and a central archive of relevant National System 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, the Task Forces are invited to draft proposals for the improvement of their emissions estimates. The proposals are prioritised in a consensus process and budgets are made available for the selected improvements. The available resources have to be shared between the different items of the inventory (GHG, air pollutants and water emissions). GHG-related issues are given high priority when they relate to improvements of key source estimates and/or if the reviews ask for specific improvements in methods or activity data. Proposals for improvements that contribute to a decrease in the uncertainty of emissions estimates are given priority over others. All planned improvements are documented in the annual Work Plan.
- *Evaluation*: Those involved in the annual inventory tasks are invited once a year to participate in an evaluation of the process. The results are used for the annual update of the QA/QC programme and the annual Work Plan.
- *General QC checks:* To facilitate general QC checks, a checklist was developed and implemented. A number of general QC checks have been added to the annual Work Plan of the PRTR and are also mentioned in the methodology reports. The QC checks included in the Work Plan are aimed at covering issues such as the consistency, completeness and correctness of the CRF data. 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, 2020).
- *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 reduce uncertainties substantially through independent verification (measurements) – at least not on a national scale – this issue has received low priority in recent years.
  In the PRTR project over the last two years, efforts have been made to improve and update the assessment of uncertainties and the sector-specific QC activities. A revised uncertainty assessment (Approach 2 using Monte Carlo analysis) of Dutch GHG emissions is performed on an annual basis. The results of Approach 2 hardly differ from the results of Approach 1. Primarily the results of Approach 1 are documented in the respective subsections on uncertainties in chapter 3-8. Approach 2 is more specifically documented in Annex 2.

1.2.3.3 Verification activities for the CRF/NIR 2021

Two weeks prior to the trend analysis meeting, a snapshot from the database was made available by the RIVM in a web-based application (Emission Explorer, EmEx) for checking by the institutes and experts involved (PRTR Task Forces). This allowed 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 were then brought up for discussion at the trend analysis workshop and subsequently documented.
During the trend analysis, the GHG emissions for all years between 1990 and 2019 were checked in two ways:

1. The datasets from previous years' submissions were compared with the current submission; emissions from 1990 to 2018 should be identical to those reported last year for all emissions for which no methodological changes have been announced.
2. The data for 2019 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 have been specifically looking at:
   - 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. Items on this list must either 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. Communications (emails) between the participants in the data checks were centrally collected and analysed. This resulted in a checklist of actions to be taken. This checklist was used as input for the trend verification workshop and was supplemented by the actions agreed in this workshop. Table 1.1 shows the key verification actions for the CRF tables/NIR 2020.

The completion of an action was reported on the checklist. Based on the completed checklist and the documentation of trends, chairmen of the Task Forces approved the dataset of their respective Task Force. Next the dataset has been fixed by the Head of the PRTR (RIVM project leader) and formally agreed to by the principal institutes: RIVM, PBL CBS, 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 the RIVM.

Table 1.1 Key actions for the NIR 2021

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	08-07-2020	RIVM-PRTR	List of remaining issues/actions from last inventory	Actiepunten voorlopige cijfers 2018 v 8 juli 2020. xls
sheets for comparing final data 2018 and 2019	26-11-2020	RIVM	Input for trend analyses	Verschiltabel_LuchtIPCC_26-11-2020.xlsx
Trend analysis	3-12-2020	Task Forces	Updated action list	Actiepunten definitieve cijfers 1990-2019 v7 december 2020.xls
Resolving the issues on the action list	Until 21-12-2020	Task Forces RIVM/ TNO National Inventory Compiler (NIC)	Final dataset	Actiepunten definitieve cijfers 1990-2019 v17 december 2020.xls
Comparison of data in CRF tables and E-PRTR database	Until 10-02-2021	NIC/TNO	First draft CRF sent to EU final CRF to EU	15-01-2021 15-03-2021
Writing and checks of NIR	Until 15-3-2021	Task Forces/ NIC/TNO/NIE	Draft texts	R:\.\NI National Inventory Report\NIR 2021\NIR redactie
Generation of tables for NIR from CRF tables	Until 15-3-2021	NIC/TNO	Final text and tables NIR	R:\….\NIR 2021\CRF….\Tables and Figures v4.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. For these data items, the Netherlands uses the code 'C' in the CRF. All confidential data can be made available to the official review process of the UNFCCC.

1.3 Inventory preparation: data collection, processing and storage

1.3.1 GHG and KP-LULUCF inventory

The primary process of 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.

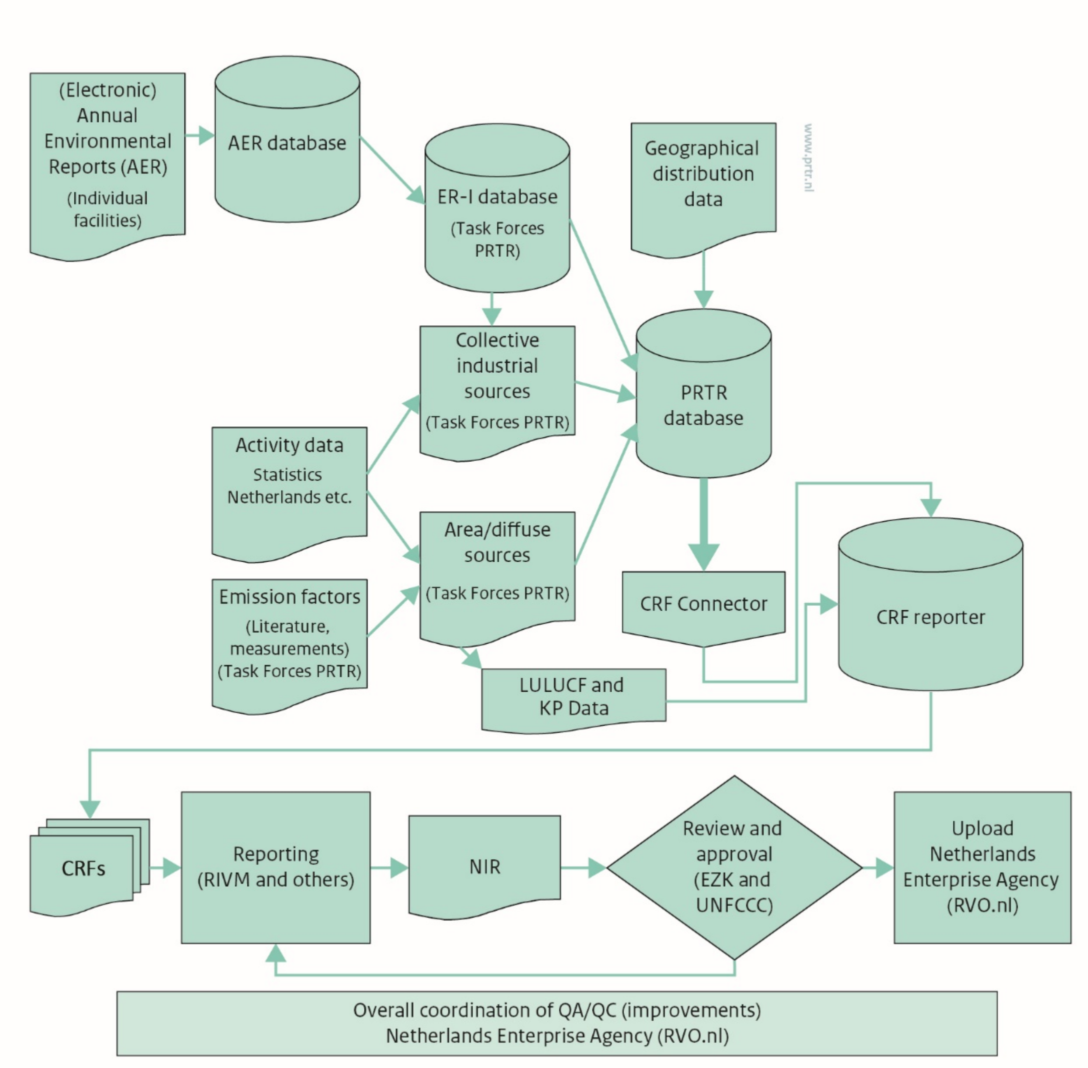


Figure 1.2 Main elements in the GHG emissions inventory process.

The preparation of the KP-LULUCF inventory is combined with the work for reporting LULUCF under the UNFCCC by the unit Wettelijke Onderzoekstaken Natuur & Milieu, part of Wageningen UR. The LULUCF project team (which is part of the Task Force Agriculture) is responsible for data management, the preparation of the reports on LULUCF, and the QA/QC activities, and decides on further improvements.

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 the CBS 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, relevant agreements with CBS 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 provincial and occasionally local authorities), which also issue environmental permits to these companies.

Every 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 (which need not be made available to the general public). 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 a very open and constructive communication (on activity levels and emissions) between plant operators and competent authorities (although these data are not available to the general public). 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.
Whenever these reports from major industries 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 just a single company. This is the reason why the Netherlands cannot report activity data (confidential business information) in the NIR or CRF on the most detailed level. Although this may hamper the review process, all confidential data can and will be made available to the ESD and UNFCCC review teams (on request).

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, the RIVM makes contracts and financial arrangements with various agricultural institutes and the 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 the RIVM, these activities are also part of the PRTR.

1.3.3 Data processing and storage

Data processing and storage are coordinated by the 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 satisfying – in an efficient and effective manner – 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 that are 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. The RIVM commissioned the TNO to assist in the compilation of the CRF tables (see Figure 1.3).

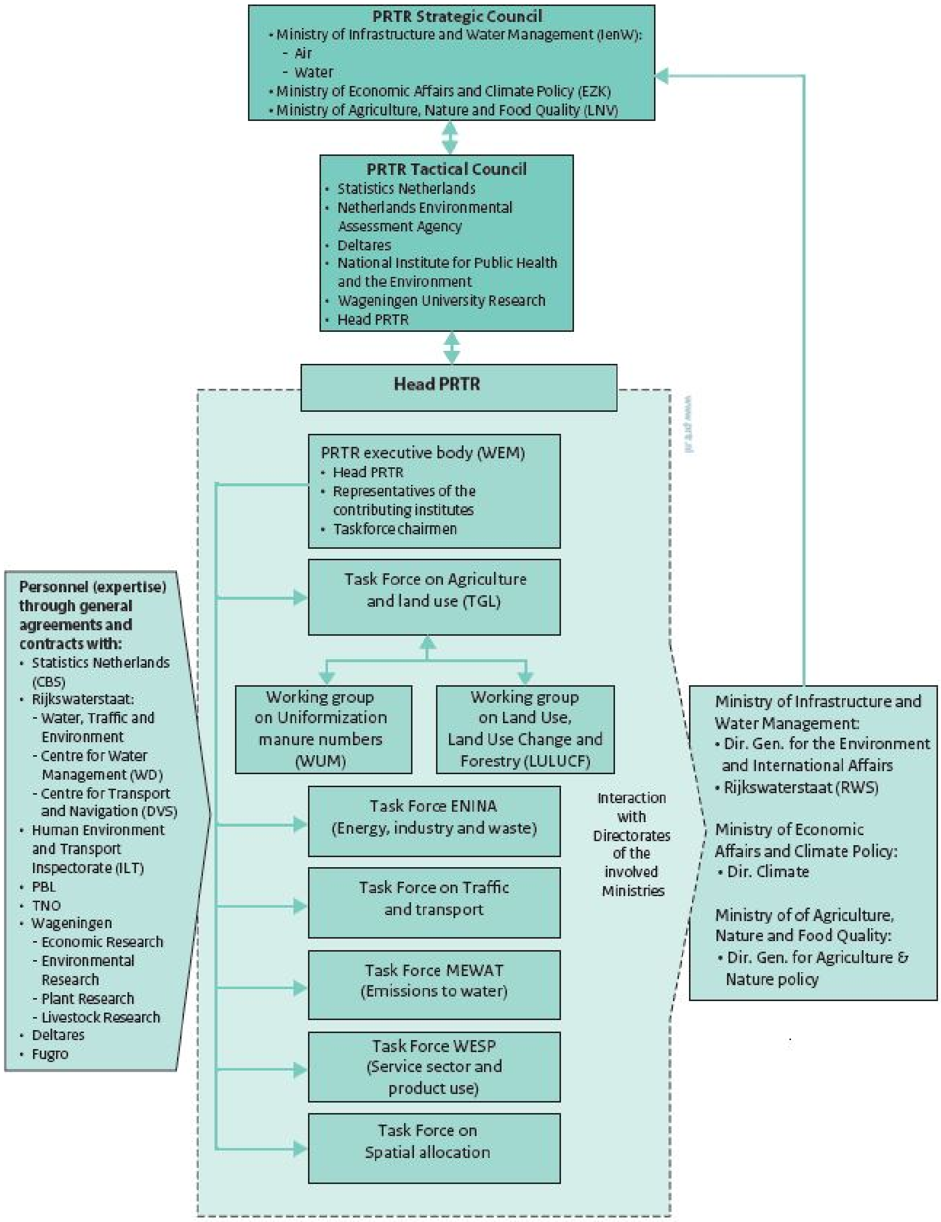


Figure 1.3 Organisational arrangements for PRTR project.

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,T3	CS,D
A. Fuel combustion	CS,T1,T2	CS,D	T1,T2,T3	CS,D	D,T1,T2,T3	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,T3	CS,D	T1,T2	CS,D
4. Other sectors	T1,T2	CS,D	T1,T2	CS,D	T1,T2,T3	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	CS	CS	T1,T2	PS
C. Metal industry	T1a,T2	CS,D				
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	D
C. Rice cultivation						
D. Agricultural soils(3)					T1,T1b,T2	CS,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
E. Prescribed burning of savannas						
F. Field burning of agricultural residues						
G. Liming	T1	D				
H. Urea application	T1	D				
I. Other carbon-containing fertilizers						
J. Other						
4. Land use land-use change and forestry	CS,T1,T2	CS,D	CS,T1	CS,D	CS,D,T1	CS,D
A. Forest land	T1,T2	CS,D	T1	CS,D	T1	CS,D
B. Cropland	CS,T1	CS,D			D,T1	CS
C. Grassland	CS,T1,T2	CS,D	CS	D	CS,D,T1	CS,D
D. Wetlands	T1,T2	CS,D			D,T1	CS
E. Settlements	CS,T1,T2	CS,D			T1	CS
F. Other land	CS,T1,T2	CS,D			T1	CS
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	T1,T2	D
E. Other						
6. Other *(as specified in summary 1.A)*						

	HFCs		PFCs		SF_6		Unspecified mix of HFCs and PFCs		NF_3	
	Method applied	Emission factor	Method applied	Emission factor	Method applied	Emission factor	Method applied	Emission factor	Method applied	Emission factor
2. Industrial processes	T2	CS			T1,T3	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										
F. Product uses as ODS substitutes	T2	CS					T2	CS		
G. Other product manufacture and use					T1,T3	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) national energy statistics from the CBS (Energy Monitor); (2) natural gas and diesel consumption in the agricultural sector (Wageningen Economic Research (WecR); (3) (residential) bio fuel data: national renewable energy statistics from the CBS (Renewable Energy).
- Transport statistics: (1) monthly statistics for traffic and transport; (2) national renewable energy statistics from the CBS (Renewable Energy).
- Industrial production statistics: (1) AERs from individual companies; (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 plant - because it had a site permit for the AERs, therefore N_2O emission data is not available on 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 of this gas in the Netherlands. In case not all suppliers provide their data, gap-filling is performed on the basis of market shares.
- Spray cans containing N_2O: the Dutch Association of Aerosol Producers (Nederlandse Aerosol Vereniging, NAV).
- Animal numbers and Manure production and handling: CBS/WecR agricultural database, data from the annual agricultural census and the I&R system of the 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 three National Forest Inventories: HOSP (1988–1992), fifth National Forest Inventory (NFI-5, 2001–2005) and sixth National Forest Inventory (NFI-6 2012–2013);
  - harvest data: wood balance data from the National Forest Inventories NFI-5 and NFI-6, in combination with FAO harvest statistics.
- 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).
- Soil maps: de Vries et al. (2003) and 2014 update (de Vries et al., 2014).
- Soil information system: information on soil profiles, soil organic matter, bulk density (Finke et al., 2001; Kuikman et al., 2003; de Groot et al., 2005a; Lesschen et al., 2012).

- Waste production and handling and CH_4 recovery from landfills: Working Group on Waste Registration (WAR), Rijkswaterstaat Environment and the CBS.

Many recent statistics are available at Statistics Netherlands' statistical website StatLine and in the CBS/PBL/RIVM Environmental Data Compendium. It should be noted, however, that the units and definitions used for domestic purposes on those websites occasionally 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).

1.4.3 *KP-LULUCF inventory*

Methodologies

The methods used to estimate data on sinks and sources as well as the units of land subject to Article 3.3 Afforestation/Reforestation (AR) and Deforestation (D) and Article 3.4 Forest management (FM) are similar to the methods used for LULUCF. Mostly the same base data are used; only the aggregation to the KP activities differs from the aggregations to the UNFCCC LULUCF categories.
The methodology used by the Netherlands to assess emissions from LULUCF is based on a wall-to-wall approach for the estimation of area per category of land use. For the wall-to-wall map overlay approach, harmonised and validated digital topographical maps dated 1 January 1970, 1990, 2004, 2009, 2013 and 2017 were used (Kramer and van Dorland, 2009; Kramer et al., 2007; Kramer and Clement, 2016; Kramer and Clement, 2015; Kramer, 2019; Arets et al., 2021). The results were national-scale land use and land use change matrices (1970-1990, 1990–2004, 2004–2009, 2009–2013 and 2013–2017; see Arets et al., 2021).

To distinguish between mineral soils and peat soils, overlays were made with the Dutch Soil Map (de Vries et al., 2004, 2003) and its 2014 update of organic soils (de Vries et al., 2014). The result was a map with national coverage that identifies for each pixel whether it was subject to AR, D or FM between 1990 and 2017, whether it is located on a mineral soil or on an organic soil (peat or peaty) and, if on a mineral soil, what the aggregated soil type is. Land use changes after 2017 are extrapolated from the latest land use change matrix. These changes will be updated once a new land use map becomes available. A future land use map is anticipated with a map date of 1 January 2021.

Data sources

The base data sources used for calculating emissions and removals for KP-LULUCF are the same as those used for reporting under the convention. Like the GHG emissions inventory, it uses:

- Forest and wood statistics:
    - stem volume, annual growth, carbon balance: data from three National Forest Inventories: HOSP (1988–1992), fifth National Forest Inventory (NFI-5, 2001–2005) and sixth National Forest Inventory (NFI-6 2012–2013);

    - harvest data: wood balance data from the National Forest Inventories NFI-5 and NFI-6, in combination with FAO harvest statistics.
- 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).
- Soil maps: de Vries et al. (2003) and 2014 update (de Vries et al., 2014).
- Soil information system: information on soil profiles, soil organic matter and bulk density (Finke et al., 2001; Kuikman et al., 2003; de Groot et al., 2005; Lesschen et al., 2012).

1.5 Brief description of key categories

1.5.1 GHG emissions inventory

The analysis of key categories is performed in accordance with the 2006 IPCC Guidelines. To facilitate the 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. Per sector, the key categories are also listed in the first section of each of Chapters 3 to 9 (in overview tables). 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.

Compared with the NIR 2019, one source is no longer a key category:
- 3G Liming (CO2).

The Netherlands includes 4 extra source categories in the Key category Analysis in 2021 compared to 2020:
- 1A1 Energy industries “all fuels” N2O;
- 2A1 Cement production CO2;
- 2B10 Other N2O;
- 5D Wastewater treatment CH4;

The IPCC Approach 1 method shows 33 categories for annual level assessment (emissions in 2019) and 40 categories for the trend assessment out of a total of 118 source categories. A combination of Approach 1 and 2 and level and trend assessment, shows a total of 55 key categories (excluding LULUCF) and 59 including LULUCF.

1.5.2 KP-LULUCF inventory

Key Categories included in this NIR are primarily assessed excluding LULUCF. This section intends to put the LULUCF sources in perspective of the Key Category Analysis.
The smallest key category based on the Approach 1 level analysis including LULUCF, is category 1A4 Liquids (excl 1A4c) (CO2), 573 Gg CO2 eq. With net emissions of -625 Gg CO_2 eq, the absolute annual contribution of Afforestation/Reforestation under the KP-LULUCF in 2019 is larger than the smallest key category. Deforestation under the KP-LULUCF in 2019 causes a net emission of 1327.3 Gg CO_2, which is also more than the smallest key category. With a net emission of -1028.5 Gg

CO_2 eq, the absolute contribution of Forest management is larger than the smallest key category, too.

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) in order to obtain an estimate of the uncertainties in annual emissions, as well as in the trends.
The IPCC Approach 2 methodology for estimating uncertainty in annual emissions has been applied to all of the emission categories in order to obtain an estimate of the uncertainties in annual emissions (and to compare this 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 (Olivier et al., 2009):

- estimates used for reporting uncertainty in GHG emissions in the Netherlands that were discussed at a national workshop in 1999 (Amstel et al., 2000);
- default uncertainty estimates provided in the 2006 IPCC Guidelines;
- RIVM fact sheets on calculation methodology and data uncertainty (RIVM, 1999);
- other information on the quality of data (Boonekamp et al., 2001);
- a comparison with uncertainty ranges reported by other European countries, which has led to a number of improvements in (and increased underpinning of) the Netherlands' assumptions for the present Approach 1 assessment (Ramírez-Ramírez et al., 2006).

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 CBS emissions experts. They prepared, independent from one another, uncertainty estimates. Their views were discussed to reach a consensus on the estimates.
This was followed by an estimation of the uncertainty in the emissions in 1990 and 2019 according to the IPCC Approach 1 methodology – for both annual emissions and the emissions trend for the Netherlands. All uncertainty figures should be interpreted as 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 results in an overall uncertainty of approximately 3% in 2019, based on calculated uncertainties of 2%, 9%, 38% and 35% for CO_2 (excluding LULUCF), CH_4, N_2O and F-gases, respectively.

The uncertainty in CO_2-equivalent emissions including emissions from LULUCF has not been elaborated in this report, but is also calculated to be 3%.

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 as a 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)). For the sectors Agriculture and Waste, the expert elicitation was combined with a recent Approach 1 uncertainty calculation (Agriculture and Waste). For LULUCF, a sector-specific Approach 2 uncertainty calculation was already available from the Task Force.
The expert elicitations were set up following the expert elicitation guidance in the 2006 IPCC Guidelines (motivating, structuring, conditioning, encoding and verification). These expert elicitations 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 on the level of the CRF categories).
Correlations between activity data and the EFs of different emissions sources have been included in the Monte Carlo analysis (as far as possible). 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 number of the same? 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 of the sources that use 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 holds 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 uncertainty assessment (Monte Carlo analysis) for 2019.

CRF category	CO_2	CH_4	N_2O	F-gases	Total (CO_2 eq.)
1	3%	35%	30%		3%
2	15%	62%	24%	26%	12%
3	19%	10%	39%		14%
4	35%				35%
5		22%	37%		21%
Total	**3%**	**9%**	**28%**	**26%**	**3%**

Results of the uncertainty analyses
The results of the calculated Approach 2 uncertainty analysis are of the same order of magnitude as the Approach 1 uncertainty assessment for total CO_2 equivalents. For methane, nitrous oxide and F-gases, the uncertainty according to Approach 2 is somewhat lower.
Table 1.4 shows the currently estimated values for the Approach 1 and Approach 2 analyses.

Table 1.4 Approach 1 and the Approach 2 uncertainty assessment of 2019 emissions (without LULUCF).

Greenhouse gas	Approach 1 annual uncertainty	Approach 2 annual uncertainty
CO_2	2%	3%
CH_4	9%	9%
N_2O	38%	28%
F-gases	35%	26%
Total	**3%**	**3%**

Table 1.4 shows that taking into account the correlations between source categories increases the uncertainty of the national CO_2 emissions. For the other gases, the Approach 2 analysis yields lower uncertainties. The lower uncertainties in the Approach 2 calculations are also caused by lower initial uncertainties.

Table 1.5 shows the estimates of the trend uncertainties for 1990–2019 calculated according to the IPCC Approach 1.

Table 1.5 Uncertainty in the emission trend 1990-2019 (without LULUCF).

Greenhouse gas	Emission trend 1990-2019	Uncertainty in emissions trend
CO_2	- 5.6%	+/- 1%
CH_4	- 45.9%	+/- 5%
N_2O	- 54.9%	+/- 6%
F-gases	- 75.9%	+/- 9%
Total	**- 18%**	**+/- 2%**

The result is a trend uncertainty in total CO_2-equivalent emissions (including LULUCF) for 1990–2019 of ±2%. This means that the trend in total CO_2-equivalent emissions between 1990 and 2019 (excluding LULUCF), which is calculated to be a 18% decrease, will be between a 16% and a 20% decrease.

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.

An independent verification of emissions levels and emissions trends using, for example, comparisons with atmospheric concentration measurements is therefore encouraged by the 2006 IPCC Guidelines (IPCC, 2006). In the Netherlands, such approaches, funded by the National Research Programme on Global Air Pollution and Climate Change (NOP-MLK) or by the Dutch Reduction Programme on Other Greenhouse Gases (ROB), have been used for several years. The results of these studies can for instance be found in Berdowski et al. (2001), Roemer and Tarasova (2002) and Roemer et al. (2003).
Several institutes involved in the Netherlands' PRTR are currently involved in the Horizon 2020 projects VERIFY and CoCO2. Progress in this project is closely followed, with a view to considering linking the resulting approach to the Netherlands' inventory system.

Base year (1990) uncertainties

As a result of a recommendation in the 2019 inventory review, Annex 2 also includes an overview of uncertainties in the base year. Because the Netherlands uses the uncertainties in the current year as an instrument to set priorities for further inventory improvement, we have paid little attention in the past to reporting the uncertainties in the base year. Table 1.6 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 current, more detailed, methodology (taking into account the specific uncertainties for all source categories).

Table 1.6 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%**

1.6.2 KP-LULUCF inventory

The uncertainty analysis uses Monte Carlo simulations to combine different types of uncertainties and correctly represent the uncertainties in the land use matrix (see chapter 14 in Arets et al. (2021) 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 analysis is performed for Forest Land and is based on the same data and calculations used for the KP Article 3.3 categories and Article 3.4 Forest Management. Thus, the uncertainty for total net emissions from units of land under Article 3.3 Afforestation/ Reforestation are estimated at +10% to -12%, which is equal to the uncertainty in Land converted to Forest Land.

Similarly, the uncertainty for total net removals from units of land under Article 3.4 Forest Management is estimated at +26% to -21%, which equals the uncertainty of Forest Land remaining Forest Land (see Section 6.4.3).

1.7 General assessment of completeness

1.7.1 GHG emissions inventory

DNV GL (2020) has been commisoned 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 very minor sources are not included:

- CO_2 from Asphalt roofing (2D3), due to missing activity data;
- CO_2 from Road paving (2D3), due to missing activity data;
- CH_4 from Enteric fermentation of poultry (3A4), due to missing emission factors;
- N_2O from Industrial wastewater (5D2) and septic tanks, due to negligible amounts;
- part of CH_4 from Industrial wastewater (5D2 sludge), due to negligible amounts.

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 6 presents the assessment of completeness and sources, potential sources and sinks for this submission of the NIR 2021 and the CRF tables.

1.7.2 KP-LULUCF inventory

The inventory for KP-LULUCF in general is complete. Changes in carbon stocks are reported for all significant pools for Afforestation, Reforestation (AR), Deforestation (D) and Forest Management (FM).
In the Netherlands, the conversion of non-forest to forest (AR) involves a build-up of carbon in litter. However, because good data are lacking to quantify this sink, we report the accumulation of carbon in litter for AR conservatively as 'not a source' (notation key NR in CRF Table NIR 1) and as 'not estimated' (NE) in the CRF Tables 4(KP-I)A.1 and 4(KP-I)B.1.
Because no other land use category includes carbon in dead wood, the conversion of non-forest to forest involves a build-up of carbon in dead wood. But as it is unlikely that much dead wood will accumulate in a forest of very young trees, the accumulation of carbon in dead wood in AR plots is a very small sink. We therefore report this carbon sink during the first 20 years conservatively as zero. Once forest becomes older (>20 years), changes in carbon stocks in dead wood are estimated in the same way as is done for Forest land remaining forest land under the Convention.

Fertilisation in Re/afforested areas and areas under Forest management does not occur in the Netherlands, so is reported as 'NO' (not occurring). Fertilisation on Grassland and cropland is included in the Agriculture sector.

2 Trends in GHG emissions

2.1 Emissions trends for aggregated GHG emissions

This chapter summarises the trends in GHG emissions over the period 1990–2019 by GHG and by sector. More sectoral details are provided in chapters 3–8. In 2019, total GHG emissions (including indirect CO_2 emissions and excluding emissions from LULUCF) in the Netherlands were estimated at 180.7 Tg CO_2 eq. This is 18% lower than the 220.5 Tg CO_2 eq. reported for the base year (1990).

Figure 2.1 shows the trends and contributions of the different gases to the aggregated national GHG emissions. In the period 1990–2019, emissions of carbon dioxide (CO_2) decreased by 5.6% (excluding LULUCF). Emissions of non-CO_2 GHGs methane (CH_4), nitrous oxide (N_2O) and F-gases decreased by 45.9%, 54.9% and 75.9%, respectively.

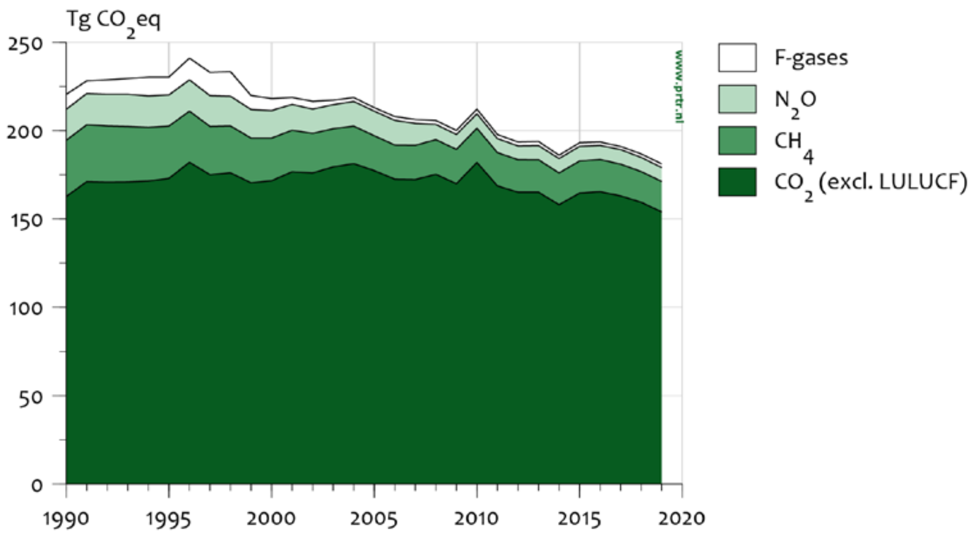


Figure 2.1 Greenhouse gases: emission levels and trend (excl. LULUCF), 1990-2019.

Emissions from LULUCF-related sources decreased over the period 1990–2019 by 25.5%. Total GHG emissions in the Netherlands for the year 2019 (including LULUCF) were 185.3 Tg CO_2 eq.
Figure 2.2. shows the index of economic development (GDP) since 1990, compared with the development in GHG emissions over the period 1990–2019. The economy increased by more than 80%; total GHG emissions decreased in the same period by 18%. The trend in total GHG emissions was largely determined by the emission reductions achieved in non-CO_2 gases (53% reduction in 2019 compared with 1990; CO_2 emissions were reduced over the same period by 5.6%).
The following sections will provide more details of the trend developments in the individual GHGs over the period 1990–2019.

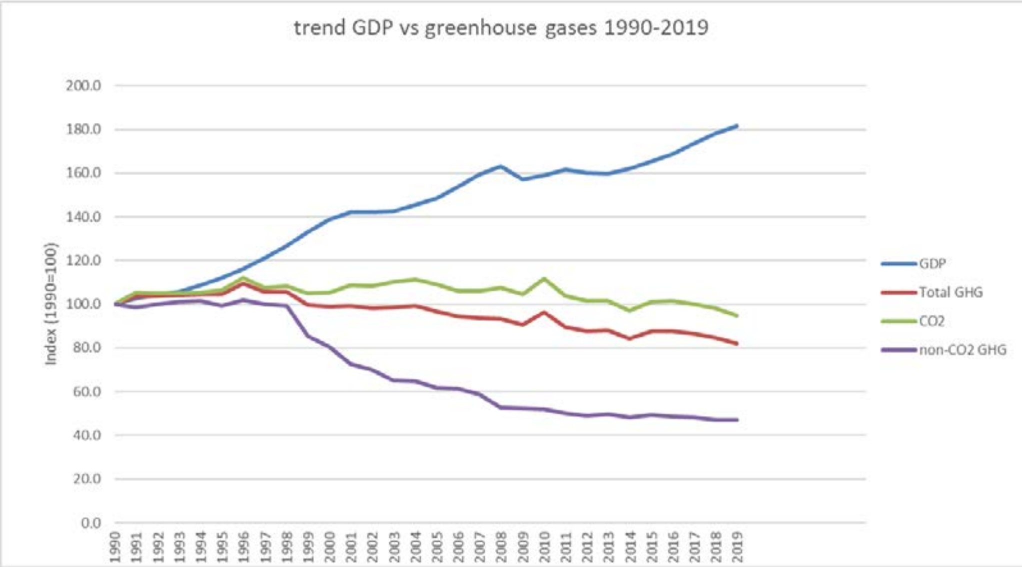


Figure 2.2. Development of greenhouse gas emissions compared with economic growth over the period 1990–2019.

Energy consumption – most important source of greenhousegas emissions

About 83% 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 NCV per year). The upper part of Figure 2.3 shows that primary energy consumption in the period 1990–2019 increased by about 6.7%. However, energy demand decreased over the last couple of years. In 2019, primary energy demand decreased by c. 1.6% compared with 2018.
Final energy consumption slightly decreased between 2018 and 2019 to 1,855 PJ (compared to 1,882 in 2018); in 2019 it was 3.7% above 1990 levels. Most energy is consumed in the built environment, followed by industry and transport.

The effect of the economic crisis in 2008 is most clearly visible in the industrial sector. The energy consumption of industry has not returned to the pre-2008 level. In 2019 it is at about the same level as in 2009.

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.

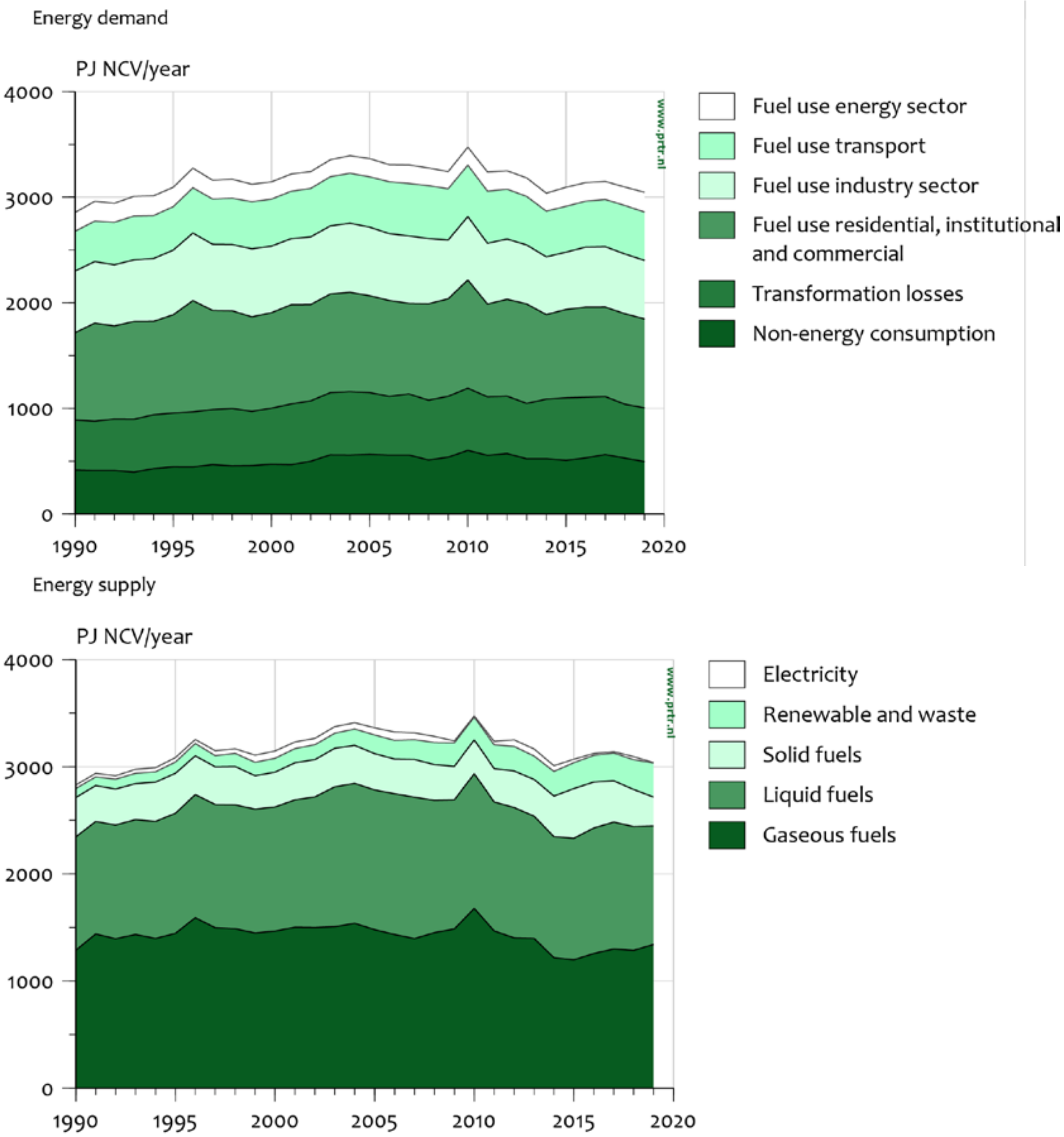


Figure 2.3 Overview of energy supply and energy demand in the Netherlands, 1990–2019 ('Electricity' refers to imported electricity only).

Energy mix

The lower part of Figure 2.3 shows the energy mix. Natural gas (44%) and oil (36%) are the most important energy sources in the Netherlands. The amount of coal used is decreasing; in 2019 by about 22% compared to 2018. This is a result of the energy policy (Energy Agreement) in the Netherlands, leading to a closure of old coal-fired powerplants. The total amount of coal used in the Netherlands in 2019 decreased by c. 42% compared to 2016. In 2016 and 2017, there was a shift from coal to natural gas for electricity production. In 2018, the lower use of coal was compensated by an increase in electricity importation (29 PJ, or 7% of total electricity consumption; CBS, 2019); and by an increase in energy from renewables and waste. In 2019, due to market circumstances, electricity importation decreased by c. 89% compared to 2018 (to 3 PJ), whereas there was an increase in the use of natural gas (c. 4%).

Figure 2.3 shows that also the amount of energy from renewables and waste in the Netherlands is increasing (an increase of c. 14% in 2019 compared to 2018). Figure 2.4 shows the mix of renewable energy sources in the Netherlands and the trend. Renewables accounted for 181 PJ in 2019 (8.7% of total energy use in the Netherlands).

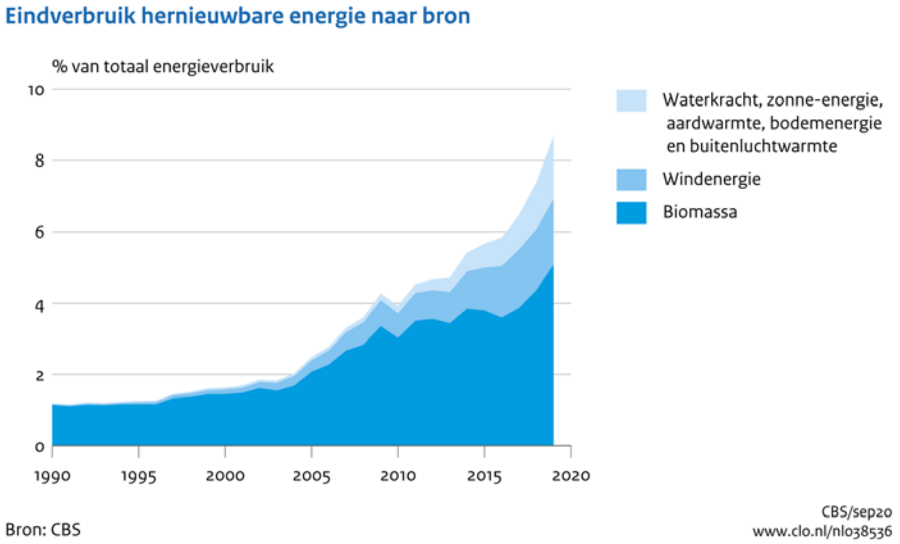


Figure 2.4 Development of renewable energy as a percentage of total energy demand in the Netherlands, 1990–2019 (CLO, 2020)[2].

Energy efficiency

The efficiency for final energy consumption, as measured by the so-called technical ODEX has improved by around 1.8% per year since 2000[3]. Smaller than average gains have been registered in transport (0.3% per year including international aviation) and services (1.3% per year). Larger gains of 2.8% per year occurred in the residential sector and in industry, where efficiency improved by 2.4% per year. The slowdown of efficiency improvements from 2008 until 2015 in industry may have been due to lower investments in new equipment since the crisis. A speed-up in efficiency in industry is visible after 2015.

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 (excluding LULUCF). In the period 1990–2019, national CO_2 emissions decreased by 5.6% (from 162.7 Tg CO_2 eq. to 153.6 Tg CO_2 eq.).

In 2019, total CO_2 emissions decreased by about 3.7% compared with 2018 (-5.9 Tg CO_2 eq.). The main reasons for the decrease were:

- reduction in coal combustion for Electricity and heat production (1A1a), compensated by an increase in gas consumption and energy from renewables and waste;

[2] https://www.clo.nl/en/indicators/en0385-renewable-energy-use (consulted 26 January 2021).
[3] https://www.odyssee-mure.eu/publications/efficiency-trends-policies-profiles/netherlands.html (consulted 03 March 2020)

- total energy use decreased (for the second year in row), by about 1.6% compared with 2018.

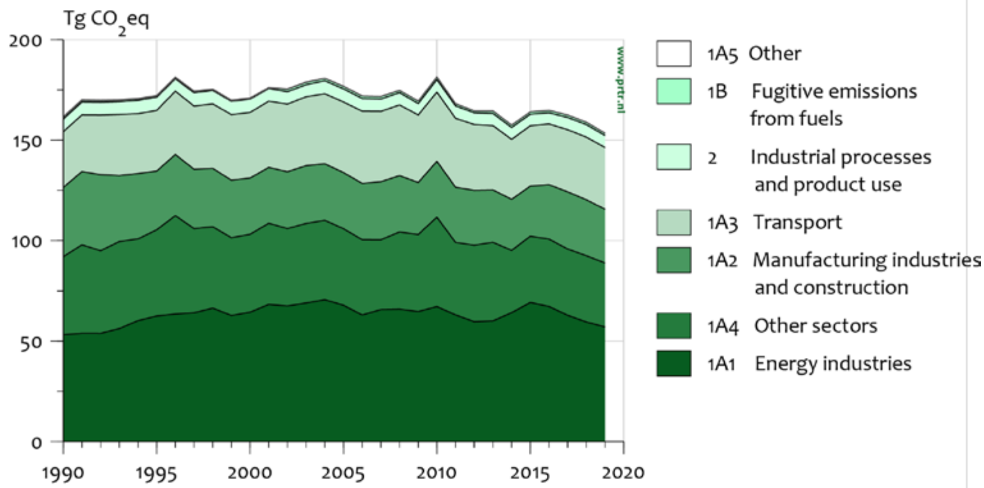


Figure 2.5 CO_2 trend and emissions levels of sectors (excl. LULUCF), 1990–2019.

Energy industries (1A1)
The Energy sector (Energy industries, Category 1A1) is the largest contributor to total CO_2 emissions in the Netherlands (36.9%). Figure 2.6 shows the emissions trend in category 1A1 between 1990 and 2019.

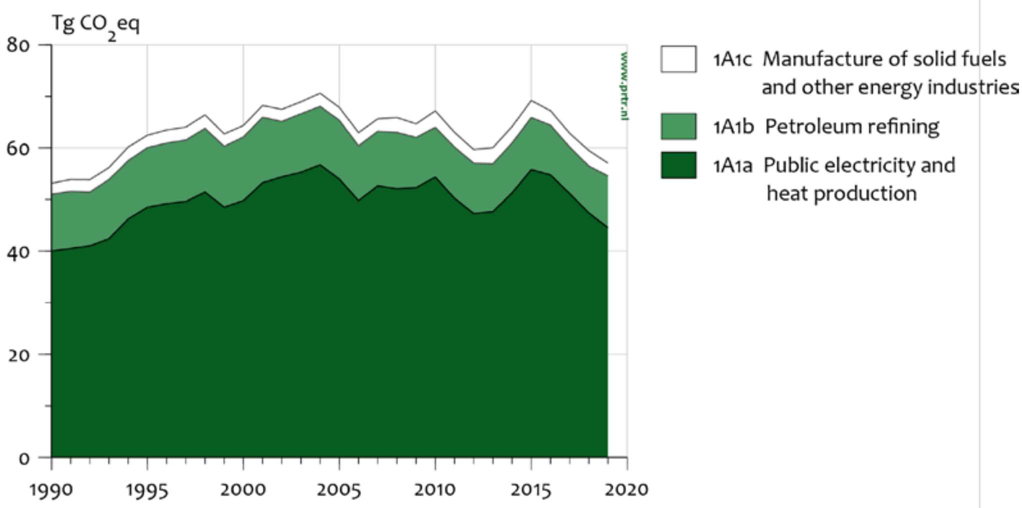


Figure 2.6 1A1 Energy industries – trend in total GHG emission by sub-category, 1990–2019.

The Dutch electricity sector (1A1a) has a few notable features: it has a large share of coal-fired power stations and a large proportion of gas-fired cogeneration plants, many of the latter being operated as joint ventures with industries. The increase in electric power production corresponds to a substantial increase in CO_2 emissions from fossil fuel combustion by power plants, though over the last couple of years there is a substantial reduction (less coal combustion).

Over the years there has been a fluctuation in CO_2 emissions in 1A1a due to market circumstances. Influencing factors have been:

- In some years the import of electricity was higher (e.g. 1999–2008, 2012–2014) than in other years;
- an increase in natural gas combustion due to a change in the ownership structure of plants (which resulted in a substantial shift of natural gas combustion allocation from 1A2 to 1A1a) in 1990–1998;
- new, large coal-fired power plants in 2015 and 2016, resulting in a shift from natural gas to coal;
- closure of old coal-fired power plants in 2015–2017, resulting in a decrease in coal consumption (and a shift to natural gas and renewables & waste).

There are five large refineries in the Netherlands, which export approximately 50% of their products to the European market. As a consequence, the Dutch petrochemical industry (category 1A1b) is relatively large. Between 1990 and 2019, total CO_2 emissions from the refineries (including fugitive CO_2 emissions from hydrogen production reported in 1B2a-iv Refining) fluctuated between 10 and 13 Tg CO_2. CO_2 emissions from this source sub-category increased from 2008 onwards, mainly due to the operation of less productive sites for oil and gas production, compared with those operated in the past. This fact explains the steady increase over time shown by this category with respect to gas consumption. Between 2014 and 2019, the production of natural gas was reduced by more than 50%, which also resulted in a decrease in the amount of natural gas combusted in this sector.

Manufacturing Industries (1A2)

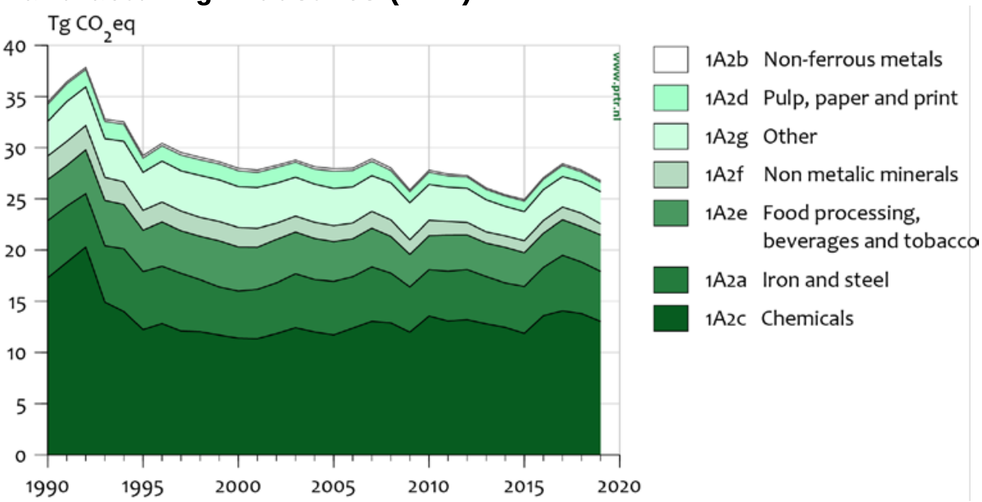


Figure 2.7 1A2 Manufacturing industries and construction – trend and emissions levels of source categories, 1990–2019.

Manufacturing industries consists of 7 sub-categories. As Figure 2.7 shows, category 1A2c Chemicals is the most important one. CO_2 emissions from this sub-category have decreased since 1990. A shift in the ownership of cogeneration plants in category 1A2c to joint ventures in the 1990s, has led to a reallocation of emissions to energy industries (category 1A1).

Figure 2.7 clearly shows the effect of the economic crisis in 2008. Besides the effects indicated above in 1A2c, emissions in the category

1A2 generally follow production in the manufacturing industries: over 2016 and 2017, emissions tended to increase because of positive economic development. In 2018 and 2019 there was a decrease, especially in category 1A2c (chemicals) as a result of less natural and residual gas combustion.

Road transport (1A3)

GHG emissions from road transport steadily increased between 1990 and 2006; see Figure 2.8. The increase was more or less in line with the increase in road transport volumes.

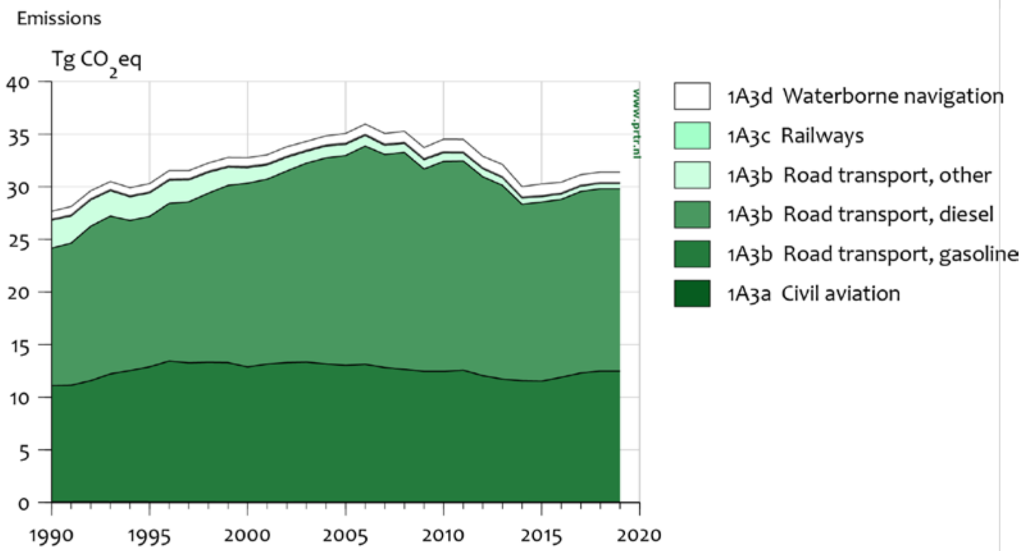


Figure 2.8 1A3 Transport – emissions levels of source categories, 1990–2019.

Between 2006 and 2008, emissions stabilised due to an increase in the use of biofuels in road transport[4].

Between 2011 and 2014, CO_2 emissions decreased by 13%. 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., 2021). Since 2014 GHG emissions have increased again by c. 1% per year. In 2019, GHG emissions from transport were 1.6% lower than in 2018, caused by a decrease in transport volumes.

Other sectors (1A4)

The principal developments in Other sectors (1A4) 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).
- In the residential category (1A4b), CO_2 emissions have decreased since 1990, while the number of households has increased. This is mainly due to the improved insulation of

[4] CO^2 emissions from biofuels are reported separately in the inventory and are not part of the national emissions totals

dwellings and the increased use of high-efficiency boilers for central heating.

More information is provided in Section 3.2.7.

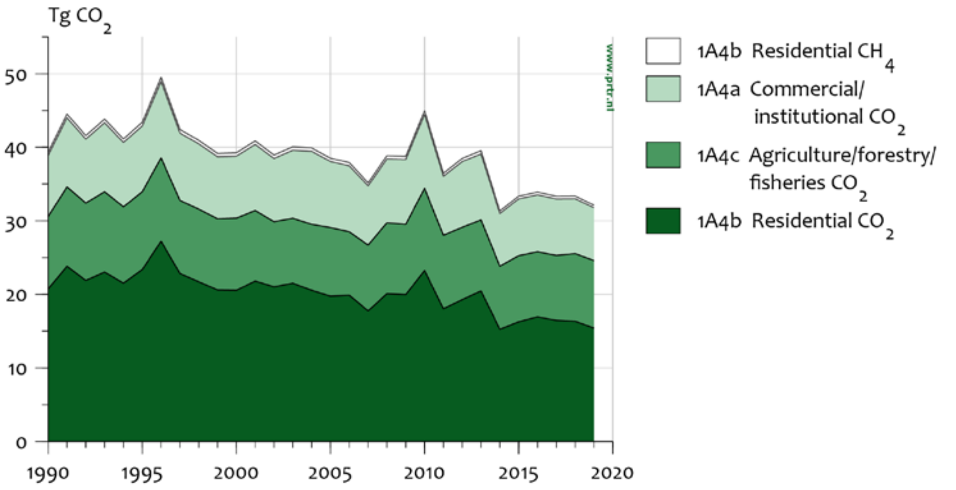


Figure 2.9 1A4 (Other sectors) – trend and emissions levels of source sub-categories, 1990–2019.

2.2.2 *Methane*

Figure 2.10 shows the contribution of the most relevant sectors to the trend in total CH_4 emissions. National CH_4 emissions decreased by 45.9%, from 31.8 Tg in to 17.2 Tg CO_2 eq., between 1990 and 2019. The Agriculture and Waste sectors (69.5% and 15.8%, respectively) were the largest contributors in 2019.

Compared with 2018, national CH_4 emissions decreased by about 0.7% in 2019 (-0.1 Tg CO_2 eq.). CH_4 emissions mainly decreased in category 3A1 (Enteric fermentation) and category 5A1(Solid waste disposal on land). The 1990–2019 trend shows a relatively strong reduction in CH_4 emissions between 1990 and 2005 (especially in category 5 Waste). After 2005, emissions were further reduced, but at a slower pace.

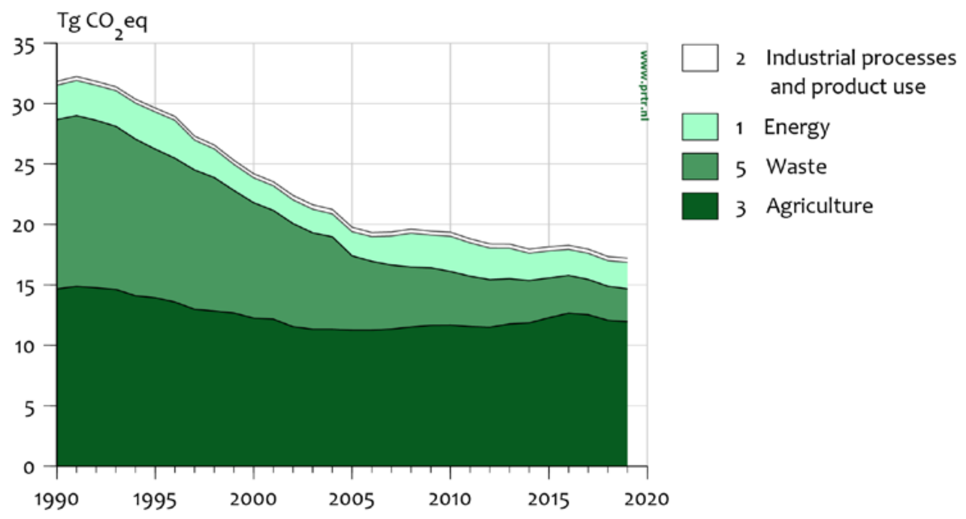


Figure 2.10 CH_4 – trend and emissions levels of sectors, 1990–2019.

Emissions from the Waste sector decreased by 80.6% between 1990 and 2019 (from 14.0 Tg CO_2 eq. in 1990 to 2.7 Tg CO_2 eq.), mainly due to an 82.7% reduction in CH_4 from Landfills (5A1). The main reductions in 5A1 were achieved between 1990 and 2005 (-57.4%). Between 2018 and 2019, CH_4 emissions from landfills decreased by 4.7%.
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 decrease in the organic waste fraction in the waste disposed;
- increased methane recovery from landfills (from 4% in 1990 to 13% in 2019).

CH_4 emissions from Agriculture (categories 3A and 3B) reduced by 18.5% overall between 1990 and 2019. After an initial decrease of 23.2% between 1990 and 2005, emissions increased again (slightly) in the following period. In the past few years (2017 – 2019), CH_4 emissions from enteric fermentation and manure management decreased again. The trend in emissions is mainly explained by the change in the number of mature dairy cattle. The number of dairy cattle has decreased since the 1990s (and milk production per cow has increased). Over the period 2009-2015 the number of cows has increased, due to the fact that the European Commission slightly raised the milk quota, anticipating the cancellation of the milk quota in 2015. Over the past few years, the number of cows decreased again.

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 54.9%, from 17.5 Tg CO_2 eq. in 1990 to 7.9 Tg CO_2 eq. in 2019.
The IPPU sector contributed the most to this decrease; N_2O emissions decreased by 80.3% compared with the base year. This is a result of a change in the process of nitric acid production (2B2), leading to a substantive emission reduction in this source category (from 5.4 Gg CO_2 eq. in 2005 to 0.3 Gg CO_2 eq. in 2010).

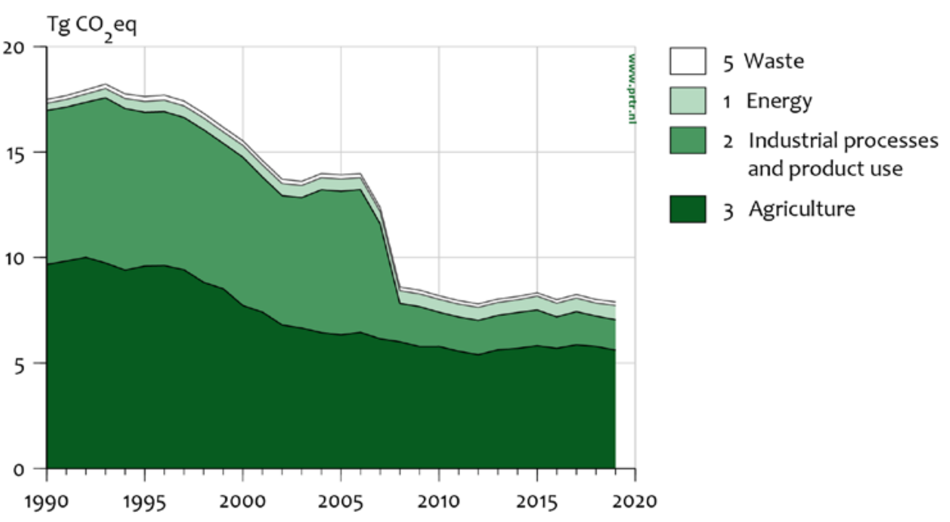


Figure 2.11 N_2O – trend and emissions levels of sectors, 1990–2019.

Compared with 2018, total N_2O emissions decreased by 1.4% in 2019 (-0.1 Tg CO_2 eq.) This was mainly due to a decrease in emissions in category 3DA (Direct N_2O emissions from agricultural soils) -0.14 Tg CO_2 eq.).

In 2019 agricultural soils were responsible for 25.7% of total GHG emissions in the Agriculture sector. As Figure 2.11 shows, total N_2O emissions from agricultural soils decreased by 44.8% between 1990 and 2019 (Table 5.8). In 2019, N_2O emissions from grazing decreased by about 2.9% compared to 2018. Emissions from both organic and inorganic N fertilizers decreased by 6.0% respectively 2.9% in 2019 compared to 2018, due to a decrease in application. Emissions from crop residues in 2019 were similar to those of 2018.

The decrease in total N_2O emissions from 1990 was caused by a relatively large decrease in N input into soil (from inorganic fertilizer and organic N fertilizer application and production of animal manure on pasture during grazing; Figure 5.6). 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.However, indirect N_2O emissions are lower because of reduced atmospheric deposition of NH_3 and NO_x, resulting from EU policies on air pollution (specifically the NECD Directive (2016/2284/EU)) and the Gothenburg Protocol under the UNECE Convention on Long Range Transboundary Air Pollution (LRTAP).

2.2.4 *Fluorinated gases*

Figure 2.12 shows the trend in F-gas emissions included in the National GHG Emissions Inventory. Total emissions of F-gases have decreased by 75.9% from 8.5 Tg CO_2 eq. in 1990 to 2.0 Tg CO_2 eq. in 2019. Emissions of hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs) have decreased by 67.7% and 95.6%, respectively, during the same period, while sulphur hexafluoride (SF_6) emissions have decreased by 46.2%. 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% in the period 1995–1998, due to increased production of HCFC-22. In the period 1998–2001, however, emissions of HFC-23 decreased by 69% following the installation of a thermal converter (TC) at the plant. The improved removal efficiency of the TC (kg HFC-23 processed in TC/kg HFC-23 in untreated flow/year) was the primary factor and a decrease in production levels the secondary factor influencing the variation in emissions during the 2000–2008 period.

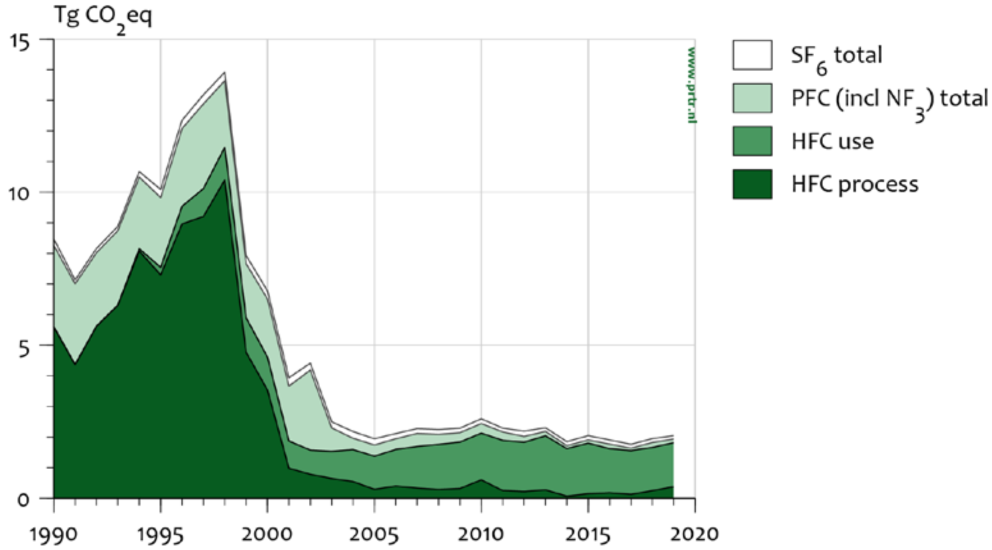


Figure 2.12 Fluorinated gases – trend and emissions levels of individual F-gases, 1990–2019.

Primarily as a result of the economic recovery since the economic crisis of 2008, the production level of HCFC-22 was substantially higher in 2010, resulting in higher HFC-23 emissions in 2010, compared with 2009. After 2010 the emission fluctuations were mainly caused by fluctuations in the handling activities, which depend on market circumstances.

From 2003 onwards, the level of 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. Closure of 2 companies resulted in a decrease of emissions in 2013/2014. The restart under the name Klesch Aluminium Delfzijl at the end of 2014 resulted in increases in PFC emissions in 2015 and 2016.

There is a substantial increase since 1990 of HFC consumption as a substitute for (H)CFC use (2F). In 2019, this category accounted for 0.8% of national total emission of GHG emissions (1.4 Tg CO_2 eq.).

Between 2018 and 2019 aggregated emissions of F-gases increased overall by 5.1%. HFC emissions increased by 9.5%; PFC and SF_6 emissions decreased by 28% and 10.1%, respectively, between 2018 and 2019. The increase in HFC emissions was mainly a result of emissions in category 2B9 (Fluorochemical production). The emissions in this category (especially in sub-category 2B9b3 Handling activities) fluctuated significantly during the period 1992–2019. This can be explained by the large fluctuations in handling activities, which depend on market circumstances. 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 in total emissions of CO_2, CH_4, N_2O and the sum of the F-gases is estimated to be ±1%, ±5%, ±6% and ±9%, respectively.

The uncertainty estimates in ***annual emissions*** for CO_2, CH_4 and N_2O are ±2%, ±9% and ±38%, respectively, and for HFCs, PFCs and SF_6 ±35% (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 71.9% in the base year and 83% in 2019). The emissions of the Energy sector decreased by 5.4% in the period 1990–2019.
Total GHG emissions of all other sectors (IPPU, Agriculture, LULUCF and Waste) decreased, by 56%, 28%, 25.5% and 79.6%, respectively, in 2019 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.

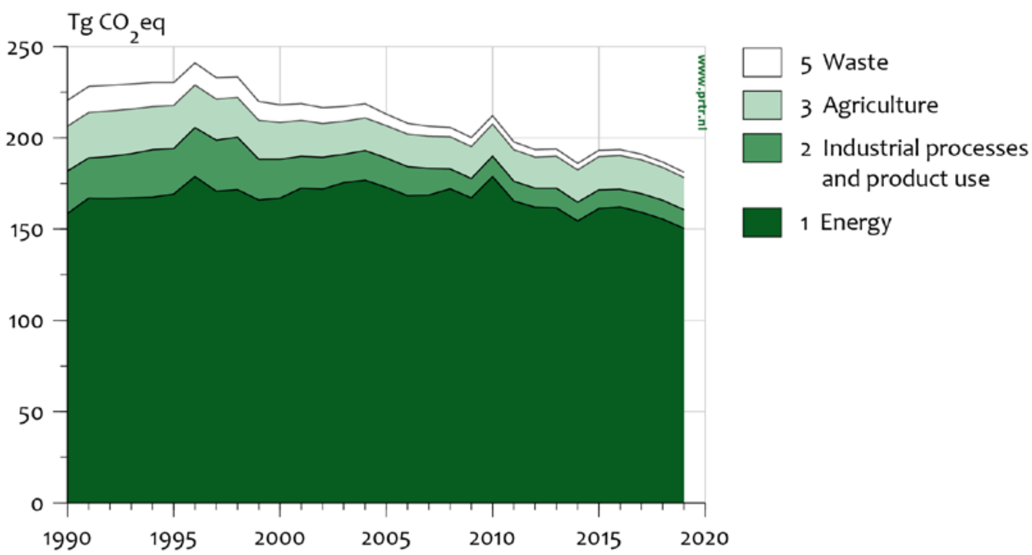


Figure 2.13 Aggregated GHGs – trend and emissions levels of sectors (excl. LULUCF), 1990–2019.

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) and Waste (5) are about ±2%, ±10%, ±19% and ±20%, respectively; for the LULUCF sector (4) the uncertainty is estimated at ±35%.
The uncertainty in the trend of CO_2-equivalent emissions per sector is calculated for sector 1 (Energy) at ±2% in the 2% decrease, for sector 2

(IPPU) at ±6% in the 51% decrease, for sector 3 (Agriculture) at ±7% in the 27% decrease and for sector 5 (Waste) at ±1% in the 79% 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 reduced by 45.5%, 64.0%, 60.9% and 88.4%, respectively, in 2019 compared with 1990 levels. 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 have not been verified for those years.

The uncertainty in the EFs for NO_x, CO and NMVOC from fuel combustion is estimated to be in the range 10–50%. The uncertainty in the EFs of SO_2 from fuel combustion (basically the sulphur content of the fuels) is estimated to be 5%. For most compounds, the uncertainty in the activity data is relatively small compared with the uncertainty in the EFs. Therefore, the uncertainty in the overall total of sources included in the inventory is estimated to be in the order of 25% for CO, 17% for NO_x, 20% for SO_2 and 54% for NMVOC.

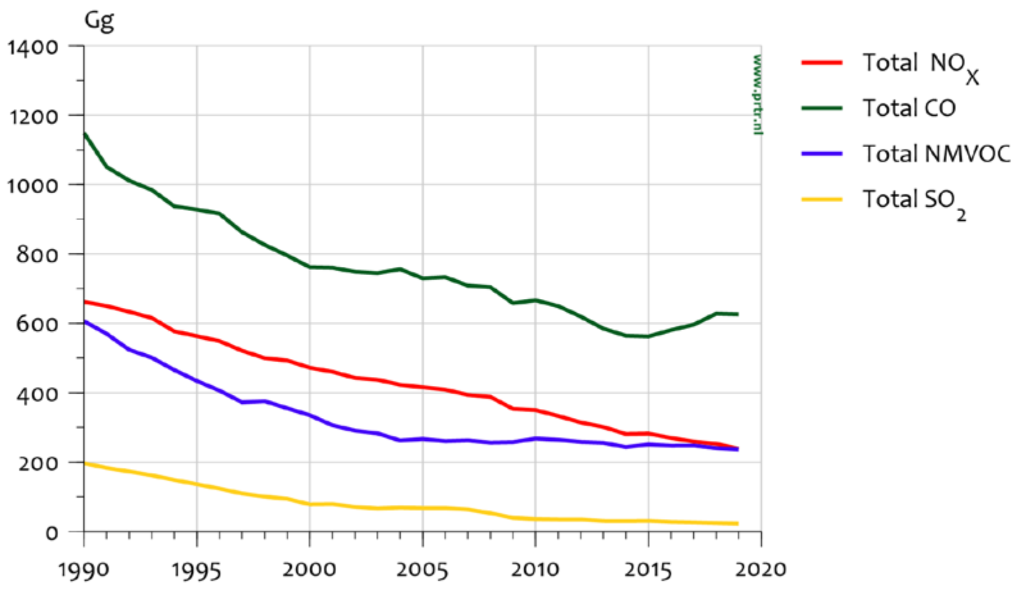


Figure 2.14 Emissions levels and trends of NO_x, CO, NMVOC and SO_2, 1990–2019 (Gg)

3 Energy (CRF sector 1)

Major changes in the Energy sector compared with the National Inventory Report 2020	
Emissions:	In 2019, GHG emissions related to the Energy sector decreased by 3.7% compared with 2018.
Key categories:	New: 1A1, Energy industries (N_2O)
Methodologies:	Emissions calculation of mobile machinery has been updated (1A2gvii, 1A4aii, 1A4bii and 1A4cii).
Activity data:	• Energy statistics for 2015-2018 have been improved (1A1, 1A2, 1A3, 1A4, 1A5).
Other changes:	• Activity data for natural gas has been split in a fossil part and a biogenic part. Emissions from the biogenic part have been reallocated from gaseous fuels to biomass. • Part of the emissions from chemical waste gas in 1A2c has been reallocated to 2B10 for the years 2012-2018.

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 used the most, followed by liquid fuels and solid fuels. The contribution of non-fossil fuels, including renewables and waste streams, is small.

Part of the supply of fossil fuels is not used for energy purposes, but it is used as feed stocks in the (petro-)chemical or fertiliser industries. Emissions from fuel combustion are consistent with national energy statistics.

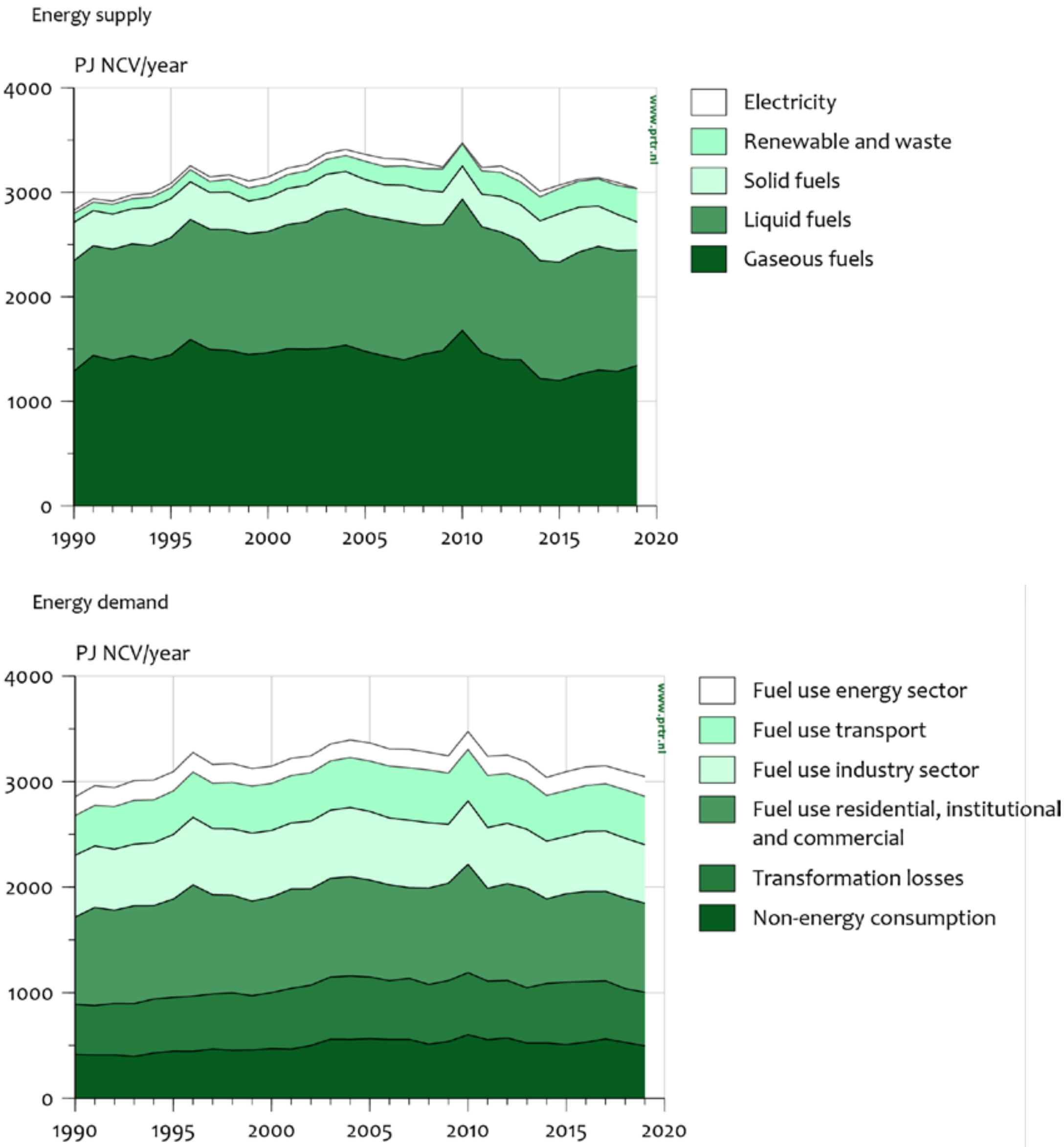


Figure 3.1 Overview of energy supply and energy demand in the Netherlands, 1990–2019 ('Electricity' refers to imported electricity only).

3.1.2 Trends in fossil fuel use and fuel mix

Natural gas represents a very large share of national energy consumption in all non-transport subsectors: Power generation, Industrial processes and Other (mainly for space heating). Oil products are primarily used in transport, refineries and the petrochemical industry, while the use of coal is limited to power generation and steel production.

In the 1990–2019 period, total fossil fuel combustion increased by 0.2%, due to a 5% increase in liquid fuel consumption, a 4% increase in gaseous fuel consumption and a 27% decrease in solid fuel consumption.
Total fossil fuel consumption for combustion decreased by about 2.5% between 2018 and 2019, due to a decrease of 22.3% for solid fuel

combustion, a 4.2% decrease in liquid fuel combustion and a 4.3% increase in gaseous fuel combustion.
Note that solid fuel consumption showed an increase in 2014 and 2015, caused by the new coal-fired power plants. The decrease in solid fuel consumption between 2016–2019 was due to the closure of three old coal-fired power plants in these years.
The winter temperature has a large influence on gas consumption, because natural gas is used for space heating in most buildings in the Netherlands. The years 1996 and 2010 both had a cold winter compared with the other years. This caused an increase in the use of gaseous fuel for space heating in these years compared with other years. The year 2014 had a warm winter compared with other years. This caused a decrease in the use of gaseous fuel for space heating in that year.

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 than 95% of the total CO_2 emissions in the country, resulting from primarily combustion and a relatively limited amount of 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	Key	1990	2018	2019	2019 vs 1990			Contribution to total in 2019 (%) by
			Emissions in Tg CO2 eq			%	sector	total gas	total CO2 eq
1 Energy	CO2		155.4	152.7	147.1	-5.3%	98.1%	93.1%	79.4%
	CH4		2.8	2.1	2.2	-23.1%	1.5%	12.7%	1.2%
	N2O		0.3	0.6	0.7	96.9%	0.5%	8.5%	0.4%
	all		158.6	155.5	150.0	-5.4%	100.0%		81.0%
1A Fuel combustion	CO2		154.5	151.6	146.1	-5.5%	97.4%	92.4%	78.8%
	CH4		0.9	1.6	1.7	91.6%	1.2%	10.0%	0.9%
	N2O		0.3	0.6	0.7	96.9%	0.5%	8.5%	0.4%
	all		155.7	153.9	148.5	-4.7%	99.0%		80.1%
1B Fugitive emissions	CO2		0.9	1.1	1.1	19.9%	0.7%	0.7%	0.6%
	CH4		1.9	0.5	0.5	-76.3%	0.3%	2.7%	0.2%
	all		2.8	1.6	1.5	-46.2%	1.0%		0.8%
Total national emissions (excl LULUCF)	CO2		162.7	159.5	153.6	-5.6%			
	CH4		31.8	17.3	17.2	-45.9%			
	N2O		17.5	8.0	7.9	-54.9%			
	total*		220.5	186.8	180.7	-18.0%			

* 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.

3.1.4 *Overview of shares and trends in emissions*

Figure 3.2 show the contributions of the source categories and emissions trends in the Energy sector. Most of the CO_2 emissions from fuel combustion stem from the combustion of natural gas. followed by liquid fuels and solid fuels. CH_4 and N_2O emissions from fuel combustion contribute less than 2% to total emissions from this sector.

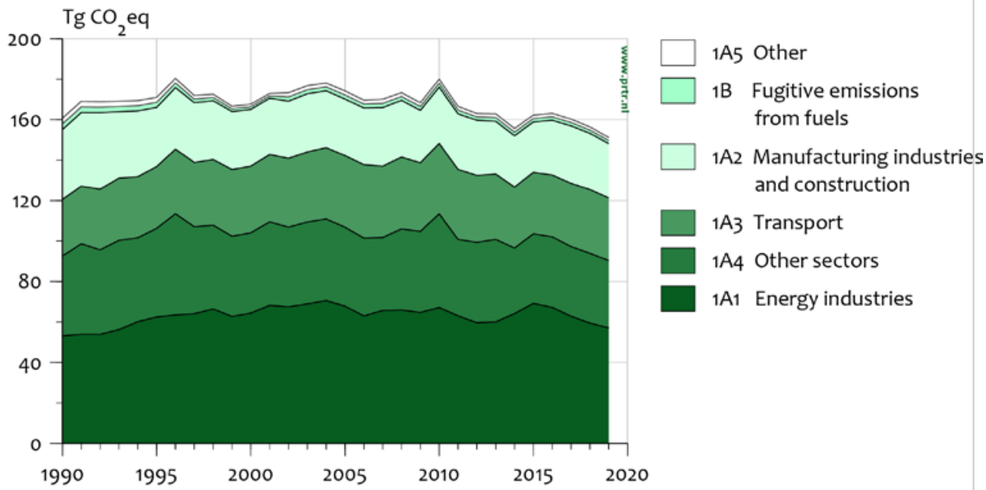


Figure 3.2 Sector 1 Energy – trend and emissions levels of total greenhouse gas emissions per source category, 1990–2019

3.2 Fuel combustion (1A)

Table 3.2 presents the source categories under category 1A in the Energy sector. Aggregated emissions by fuel type and category are used for the categorisation of key categories in 1A1, 1A2, 1A3 and 1A4. This is in line with the IPCC Guidelines (see volume 1, Table 4.1 in IPCC, 2006).

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	Key	1990	2018	2019	2019 vs 1990	Contribution to total in 2019 (%) by		
			Emissions in Tg CO_2 eq			%	sector	total gas	total CO_2 eq
1A Fuel combustion	CO_2		154.5	151.6	146.1	-5.5%	97.4%	95.1%	80.8%
	CH_4		0.9	1.6	1.7	91.6%	1.2%	10.0%	1.0%
	N_2O		0.3	0.6	0.7	96.9%	0.5%	0.0%	0.4%
	All		155.7	153.9	148.5	-4.7%	99.0%	105.1%	82.1%
1A1 Energy Industries	CO_2		53.1	59.5	56.6	6.6%	37.8%	36.9%	31.3%
	CH_4	non key	0.1	0.1	0.1	77.1%	0.1%	0.7%	0.1%
	N_2O	L,T	0.1	0.3	0.3	119.9%	0.2%	0.0%	0.2%
	All		53.4	59.9	57.1	7.0%	38.1%		31.6%
1A2 Manufacturing industries and construction	CO_2	L,T	34.4	27.8	26.8	-22.2%	17.9%	17.4%	14.8%
	CH_4	non key	0.1	0.1	0.1	-7.4%	0.0%	0.4%	0.0%
	N_2O	non key	0.0	0.0	0.0	20.5%	0.0%	0.0%	0.0%
	All		34.5	27.9	26.9	-22.1%	17.9%		14.9%
1A3. Transport	CO_2		27.7	31.2	30.7	10.7%	20.5%	20.0%	17.0%
	CH_4		0.2	0.1	0.1	-65.8%	0.0%	0.4%	0.0%
	N_2O		0.1	0.3	0.3	143.6%	0.2%	0.0%	0.1%
	All		28.0	31.5	31.0	10.7%	20.7%		17.2%
1A4. Other sectors	CO_2		38.9	33.0	31.8	-18.2%	21.2%	20.7%	17.6%
	CH_4		0.6	1.4	1.5	159.4%	1.0%	8.6%	0.8%
	N_2O	non key	0.0	0.1	0.1	2.1%	0.0%	0.0%	0.0%
	All		39.5	34.5	33.3	-15.6%	22.2%		18.4%
1A5 Other	CO_2	non key	0.3	0.2	0.2	-49.3%	0.1%	0.1%	0.1%
	CH_4	non key	0.0	0.0	0.0	-55.5%	0.0%	0.0%	0.0%
	N_2O	non key	0.0	0.0	0.0	-54.9%	0.0%	0.0%	0.0%
	All		0.3	0.2	0.2	-49.4%	0.1%		0.1%

3.2.1 Comparison of the Sectoral Approach with the Reference Approach

Emissions from fuel combustion are generally 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 2019 is shown in Table 3.3 at a relatively high aggregation level.

The Netherlands produces large amounts of natural gas, both onshore (Groningen gas) and offshore; a large share of the gas produced is exported. Natural gas represents a very large 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	5358	85
		Stock change	-2	-8	0
		Total exports	-25	-3963	-1081
		Bunkers	0	-520	0
	Consumption	Gross inland consumption	-367	-1037	-1287
		whereof: Final non-energy consumption	*-11*	*-317*	*-88*
2019	Supply	Primary production	0	38	1002
		Total imports	279	8108	1779
		Stock change	-6	-74	-7
		Total exports	-4	-6354	-1430
		Bunkers	0	-664	0
	Consumption	Gross inland consumption	-269	-1053	-1344
		whereof: Final non-energy consumption	*0*	*-383*	*-110*

Using the carbon contents of each specific fuel, a national carbon balance can be derived from the energy supply balance and, from this, national CO_2 emissions can be estimated by determining how much of this carbon is oxidised in any process within the country. To allow this, international bunkers are considered as 'exports' and not included in gross inland consumption.

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.

The carbon that is not combusted but is instead used as feedstock, as a reductant or for other non-energy purposes is then deducted.
National energy statistics are provided by the CBS. National default, partly country-specific, CO_2 EFs are taken from Zijlema (2021) (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 only for fossil fuels, 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 we used biogasoline and biodiesel consumption and excluded this from ‘imports’ 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**
	Secondary fuels	Gasoline	Additieven	Additives
			Jetfuel op benzinebasis	Gasoline type jet fuel
			Motorbenzine	Motor gasoline
			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	Heating and other gasoil
		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
		Sub-bituminous coal	IE [2)]	IE [2)]
		Lignite	Bruinkool	Lignite
		Oil shale and tar sand	NO [1)]	NO [1)]

Fuel types in the Reference Approach			Fuel types in the Netherlands' energy statistics	
Fuel type			**In Dutch**	**In English**
	Secondary fuels	BKB and patent fuel	Bruinkoolbriketten	BKB (Braunkohlenbriketts)
		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
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)	Biogeen huishoudelijk afval	Municipal waste; renewable fraction

Notes:
1. Orimulsion, shale oil, oil shale, tar sand and peat are not used in the Netherlands.
2. 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 exclude biogasoline and biodiesel. Therefore, this is allocated to the CRF fuel 'solid biomass'.

Table 3.5 presents the results of the RA calculation for 1990–2019, compared with the official national total emissions reported as fuel combustion (source category 1A).
The annual difference calculated from the direct comparison varies between -1.0% and +1.4%.

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

	1990	1995	2000	2005	2010	2015	2018	2019
Reference Approach								
Liquid fuels	50.6	52.6	53.7	56.0	52.9	48.2	47.6	47.7
Solid fuels	33.4	34.1	30.2	31.4	29.5	43.6	32.5	25.3
Gaseous fuels	68.1	76.3	77.5	78.7	87.5	61.9	67.2	69.8
Other fuels	0.9	1.5	1.9	2.8	3.1	3.5	3.6	3.8
Total RA	153.0	164.6	163.3	169.0	173.1	157.2	151.0	146.7
Sectoral Approach								
Liquid fuels	50.6	52.8	55.1	56.4	53.7	48.4	49.9	49.3
Solid fuels	33.6	34.2	29.8	31.4	29.7	43.1	32.3	25.0
Gaseous fuels	69.9	77.4	77.7	79.5	88.4	63.2	66.7	69.4
Other fuels	0.6	0.8	1.6	2.1	2.5	2.9	2.9	2.8
Total SA	154.6	165.2	164.2	169.4	174.3	157.5	151.9	146.5
Difference (%)								
Liquid fuels	0.0%	-0.4%	-2.6%	-0.6%	-1.5%	-0.5%	-4.6%	-3.2%
Solid fuels	-0.4%	-0.2%	1.3%	0.1%	-0.8%	1.2%	0.5%	1.4%
Gaseous fuels	-2.6%	-1.4%	-0.3%	-1.1%	-0.9%	-1.9%	0.8%	0.7%
Other fuels	55.6%	83.1%	22.4%	37.0%	23.0%	20.1%	24.8%	34.8%
Total	-1.1%	-0.4%	-0.5%	-0.2%	-0.7%	-0.2%	-0.6%	0.1%

The differences between the RA and the SA are due to four factors:
- There is a ‘statistical difference’ in the energy statistics, which is 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 (statline.cbs.nl), 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 fuel deliveries for international aviation more than doubled between 1990 and 1999, stabilised between 1999 and 2003 and increased again by 14% between 2003 and 2008. The economic crisis led to a decrease in fuel deliveries of 10% between 2008 and 2012, but deliveries to international aviation have since increased again by 19% to

170 PJ in 2018. In 2019, the fuel consumption has decreased slightly to 166 PJ.
There are no deliveries of aviation gasoline or biomass for international aviation reported in the Energy Balance.

Fuel deliveries for international navigation increased by 51% between 1990 and 2008, but then decreased by 28% to 494 PJ in 2019. 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 fact that the share of Dutch ports in the Northwest European bunker market decreases.
Deliveries of diesel oil for international maritime navigation almost doubled between 2014 and 2015, which can be attributed to more stringent sulphur regulation 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 3.8 PJ in 2019.

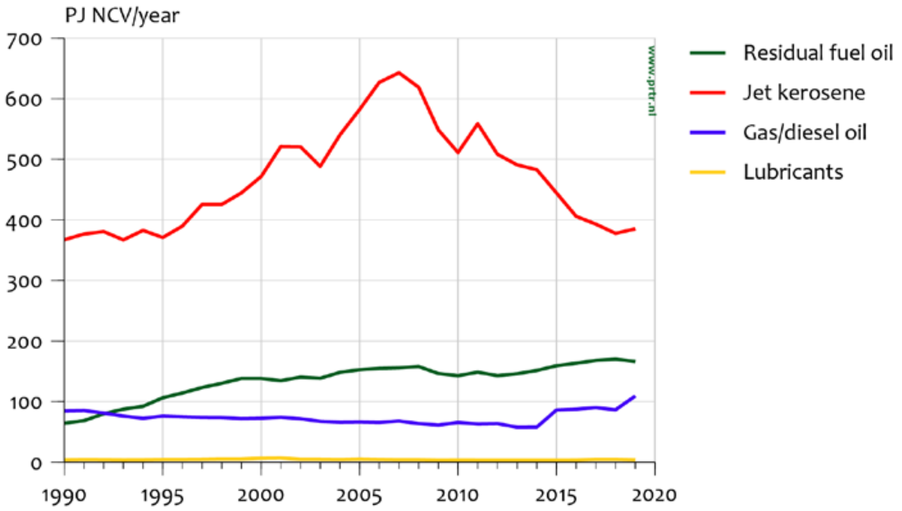


Figure 3.3 Marine and aviation bunker fuel exports, 1990–2019.

3.2.2.2 Methodological issues

CO_2 emissions from bunker fuels are calculated using a Tier 1 and 2 approach. Default 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, 2021). CH_4 and N_2O emissions resulting from the use of bunker fuels are calculated using a Tier 1 approach, using default EFs for both substances, as described in Geilenkirchen et al. (2021).

3.2.2.3 Category-specific recalculations

The energy statistics for 2015-2018 have been improved. This results in the following changes in fossil CO_2 emissions (in Gg CO_2):

	2015	2016	2017	2018
Aviation	-0.00	-	+0.01	+0.00
Navigation	+2606.54	+0.01	+0.00	-0.91

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 are stored in many products (bitumen, lubricants, etc.). A fraction of the gross national consumption of natural gas (mainly in ammonia production) and coal (mainly in iron and steel production) was also due to non-energy applications and hence the gas 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 the key categories. Figure 3.4 shows the development of total GHG emissions by sub-category of the energy industries, in the years 1990-2019.

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	Key	1990	2018	2019	2019 vs 1990	Contribution to total in 2019 (%) by		
			Emissions in Tg CO_2 eq			%	sector	total gas	total CO_2 eq
1A1 Energy Industries	CO_2		53.1	59.5	56.6	6.6%	37.8%	36.9%	31.3%
	CH_4	non key	0.1	0.1	0.1	77.1%	0.1%	0.7%	0.1%
	N_2O	L,T	0.1	0.3	0.3	119.9%	0.2%	0.0%	0.2%
	All		53.4	59.9	57.1	7.0%	38.1%		31.6%
1A1a Public Electricity and Heat Production. total	CO_2		40.0	47.4	44.1	10.3%	29.4%	28.7%	24.4%
1A1a liquids	CO_2	L,T	0.2	0.7	0.6	158.8%	0.4%	0.4%	0.3%
1A1a solids	CO_2	L,T	25.9	26.0	18.9	-26.7%	12.6%	12.3%	10.5%
1A1a gas	CO_2	L,T	13.3	17.8	21.9	64.1%	14.6%	14.2%	12.1%
1A1a other fuels	CO2	L,T	0.6	2.9	2.7	352.8%	1.8%	1.8%	1.5%
1A1b. Petroleum refining. total	CO_2		11.0	9.6	10.0	-9.0%	6.7%	6.5%	5.5%
1A1b liquids	CO_2	L,T	10.0	9.6	7.2	-28.1%	4.8%	4.7%	4.0%
1a1b gases	CO_2	L,T	1.0	9.6	2.9	174.4%	1.9%	1.9%	1.6%
1A1c Manufacture of Solid Fuels and Other Energy Industries. total	CO_2		2.1	3.0	2.5	16.9%	1.6%	1.6%	1.4%
1A1c solids & liquid	CO_2		0.9	1.4	1.0	12.7%	0.7%	0.7%	0.6%
liquids	CO_2	non key	0.0	0.0	0.0	-100.0%	0.0%	0.0%	0.0%
solids	CO_2	L,T	0.9	1.4	1.0	13.9%	0.7%	0.7%	0.6%
1A1c gases	CO_2	L,T	1.2	1.6	1.4	20.2%	0.9%	0.9%	0.8%

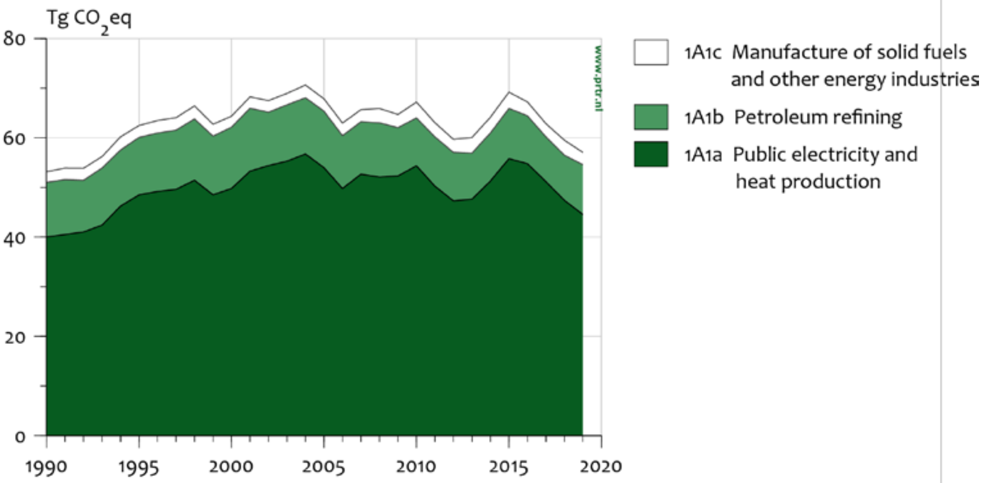


Figure 3.4 1A1 Energy industries – trend in total GHG emission by sub-category, 1990–2019.

Public electricity and heat production (1A1a)
The Dutch electricity sector has a few notable features: it has a 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 industries. The increasing trend in electric power production corresponds to a substantial increase in CO_2 emissions from fossil fuel combustion by power plants (see Figure 3.4).

Compared with some other countries in the EU, nuclear energy and renewable energy provide very little of the total primary energy supply in the Netherlands. The two main renewable energy sources are biomass and wind. The public electricity and heat production source sub-category also includes all emissions from large-scale waste incineration, since all incineration facilities produce heat and/or electricity and the waste incinerated in these installations is therefore regarded as a fuel.
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. The biogenic part of waste is included in biomass

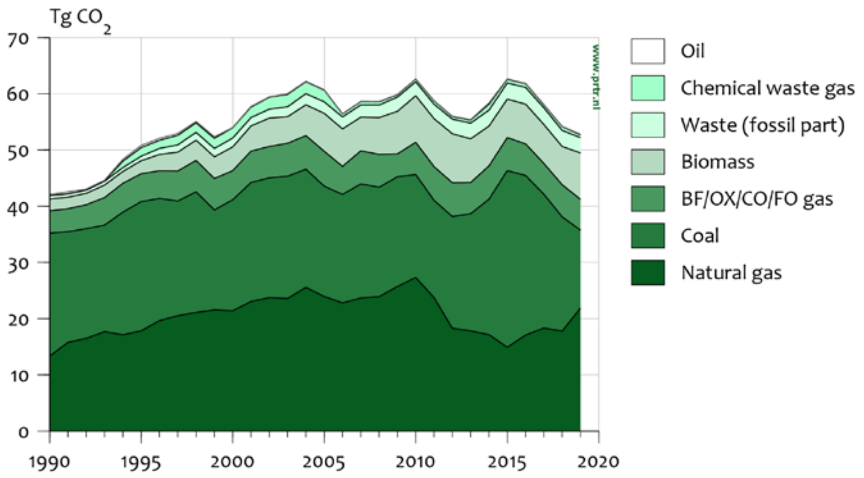


Figure 3.5 Trend in CO_2 emissions from fossil and biogenic fuel use in power plants, 1990–2019.

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 this date their use in bunker fuel has been prohibited for environmental reasons, and waste oils are either exported to Germany or recycled.

The recycling part (feedstock for chemical plants, clean-up and or distillation) results in only 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 the 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.

Emissions from waste incineration are included in 1A1a because all waste incinerators recover heat and produce electricity. Most of the combustion of biogas recovered at landfill sites occurs in combined heat and power (CHP) plants operated by utilities; therefore, it is also allocated to this category.

CO_2 emissions from the waste incineration of fossil carbon increased from 1990 until 2017, since then there is a decrease. From 1990, an increasing amount of waste was combusted instead of being deposited in landfills, which was 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 (which have 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). Half of the almost 30% increase in natural gas combustion that occurred between 1990 and 1998 is largely explained by this shift and by the similar shift of 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 in joint venture electricity and heat production facilities. This also explains the somewhat lower IEF for CO_2 from liquids since 1995.

Over the years there has been 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, resulting in a shift from natural gas to coal;
- closure of old coal-fired power plants in 2015–2017, resulting in a decrease in coal consumption;
- In some years the import of electricity was higher (e.g. 1999–2008, 2012–2014) than in other years.

Petroleum refining (1A1b)

There are five large refineries in the Netherlands, which export approximately 50% 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 2018, total CO_2 emissions from the refineries (including fugitive CO_2 emissions from hydrogen production reported in 1B2a-iv Refining) 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, being reported in the category 1B2. Combustion emissions reported in this category are calculated once the fuel used to provide the carbon for this non-combustion process is subtracted from the total fuel used 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 with the years prior to 2002. The EF for refinery gas is adjusted to obtain 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, which has a low default EF compared with most other oil products and has variable EFs for the years 2002 onward.

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

- 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).
- 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).

CO_2 emissions from this source sub-category increased from 2008 onwards, mainly due to the operation of less productive sites for oil and gas production, compared with those operated in the past. This fact explains the steady increase over time shown by this category with respect to gas consumption. Between 2014 and 2019, the production of natural gas was reduced by more than 50%, 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, which are reported in the Annual Environmental Reports (AERs) of the gas transport company.
Liquid fuels are generally not used in this sector. A small amount of liquid fuels was used in this sector only in 1990. From 1991 on no liquid fuel use was registered in the energy statistics for this sub-sector.

Fuel combustion emissions for coke production 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).

3.2.4.2 Methodological issues

Details of methodologies, data sources and country-specific source allocation issues are provided in paragraph 2.1 of the ENINA methodology report (Honig et al., 2021). This paragraph provides a brief description of the methodology.
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. This section provides a description of these two steps, and it provides 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 the CBS (see www.cbs.nl). The aggregated statistical data are based on confidential data from individual companies. When necessary, emissions 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 (see paragraph 2.1 of the ENINA methodology report (Honig et al., 2021) for more details on the CH_4 EF of gas engines) and except for waste (see the ENINA methodology report (Honig et al., 2021). For N_2O, IPCC default EFs are used, except for waste (see the ENINA methodology report (Honig et al., 2021).

For waste incineration the activity data and EFs are explained in section 7.4.

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 are used when companies report a different CO_2 EF for derived gases or other bituminous coal. For this, emissions data from the AERs and the reporting under the ETS from selected companies are used. The data are validated by the competent authority. If the 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 occurs only rarely, 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 is 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, 2021) 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, 2021) 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 any of the selected companies was 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. Since 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, 2021) are used.
- Coke oven gas: Since 2007, company-specific EFs have been derived for most companies. Since 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, 2021) are used.
- Phosphor 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, 2021) are used.
- Coal: Since 2006, company-specific EFs have been derived for most companies and for the remaining companies the default EFs are used. For years prior to 2006, EFs from the Netherlands list of fuels (Zijlema, 2021) 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 the year 2019, approximately 98% of the fossil CO_2 emissions were calculated using either country-specific or company-specific EFs. The remaining 2% of CO_2 emissions (from petroleum cokes, petroleum and bitumen) were calculated using default IPCC EFs.

An overview of the EFs used for the most important fuels (up to 95% of the 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) are IEFs. 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 EFs used for the year 2019 in the category Energy industries (1A1).

Fuel	Amount of fuel used in 2019 (TJ NCV)	IEFs (g/GJ)		
		CO_2 (x1000)	N_2O	CH_4
Natural gas	455,465	57.4	0.72	7.68
Other bituminous coal	225,739	93.9	1.10	0.59
Waste gas	107,129	61.4	0.10	3.60
Waste, biomass	38,551	127.1	6.30	0.00
Waste, fossil	34,037	80.0	4.97	0.00
Solid biomass	28,847	109.6	4.00	30.00

Natural gas
The CO_2, CH_4 and N_2O EFs for natural gas deviate from the standard EFs (56.6 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.

Coal
CO_2 emissions from coal are based on emissions data from the ETS, and the IEF is different from the country-specific EF.

Waste gas (refinery gas)
CO_2 emissions from refinery gas are occurring in refineries and in the Energy sector. The emissions are partly based on emissions data from the ETS.

Waste
The EF for N_2O emissions from waste combustion (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). This depends on how the incinerator is operated.
The EF for CH_4 from waste incineration is 0 g/GJ as a result of a study on emissions from waste incineration (section 2.3.2.1.2 of Honig et al., (2021); DHV, (2010); and NL Agency, (2010). That this is possible is stated in the 2006 IPCC Guidelines V5, section 5.2.2.3 and section 5.4.2.

The emissions are reported in the CRF file with the code 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.,2021).

The methodology for the calculation of Non-road mobile machinery (NRMM) emissions is described in Section 3.2.7.2.

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 114.4 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.
- 1A1c gaseous CO_2: The trend in the CO_2 IEF for gaseous fuels in 1A1c varies between 56.2 and 77.0 kg/GJ. The main fuels used in the production of oil and natural gas sector are regular natural gas and crude ‘wet’ natural gas (directly extracted from the wells). The EF of wet natural gas is variable and most often somewhat 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.

3.2.4.3 Uncertainty and time series consistency

Uncertainty
The uncertainty in CO_2 emissions from this category is estimated to be 3% (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 very high, with an estimated uncertainty of approximately 1%. The high accuracy in most of this activity data is due to the limited number of utilities and refineries, their large fuel consumption and the fact that the data recorded in national energy statistics 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 quite difficult to establish, and therefore a high uncertainty of 20% has been assigned. For other fuels, a 3% uncertainty is used, which relates to the amount of fossil waste being 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 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). 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 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, when the default EF is applied to other years, the uncertainty is larger: 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 quite variable composition of the derived gases used in both sectors.

For natural gas and liquid fuels in oil and gas production (1A1c), uncertainties of 5% and 2%, respectively, are assumed, which relate to the variable composition of the offshore gas and oil produced. For the CO_2 EF for other fuels (fossil waste), an uncertainty of 8% is assumed, which reflects 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 around 20%, which is an aggregate of the various sub-categories (Olivier et al., 2009).

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 in a few 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 the CBS, 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 with trends in domestic electricity consumption (production plus net imports). Large annual changes are identified and explained (e.g. changes in fuel consumption by joint ventures). For oil refineries (1A1b), a carbon balance calculation is made to check completeness. The trend in total CO_2 reported as fuel combustion by refineries is also compared with trends in activity indicators such as total crude throughput. The IEF trend tables are then checked for changes, and interannual variations are explained in this NIR.
CO_2 emissions reported by companies (both in their AERs and within the ETS) are validated by the competent authority and then compared. More details on the validation of energy data are to be found in paragraph 2.1 of the ENINA methodology report (Honig et al., 2021).

3.2.4.5 Category-specific recalculations

Natural gas activity data has been split in a fossil and a biogenic part. The fossil natural gas is mixed with a small amount of biogas (0.008% in 1990 and 0.26% in 2018). Previously, this was all included in the reporting as natural gas (allocated to gaseous fuels). In this submission, the emissions have been split between natural gas (allocated to gaseous fuels) and biogas (allocated to biomass). This results in an increase in biomass CO2 emissions of 1.1 kton CO2 in 1990 and 54.6 kton in 2018 in 1A1.
The energy statistics for 2015-2018 have been improved (some minor corrections).

These changes result in the following changes in fossil CO_2 emissions (in Gg CO_2):

	1990	2015	2016	2017	2018
1A1a	-1.1	-191.1	-210.0	-224.3	-252.8
1A1b	-0.1	-6.0	-5.1	-5.8	-17.6
1A1c	-	-	-	-	-

CH_4 and N_2O emissions have also been recalculated using the improved energy statistics.

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, emissions and key categories in the Manufacturing industries and construction sector (1A2).

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	Key	1990	2018	2019	2019 vs 1990	Contribution to total in 2019 (%) by		
			Emissions in Tg CO_2 eq			%	sector	total gas	total CO_2 eq
1A2 Manufacturing industries and construction	CO_2		34.4	27.8	26.8	-22.2%	17.9%	17.4%	14.8%
	CH_4	non key	0.1	0.1	0.1	-7.4%	0.0%	0.4%	0.0%
	N_2O	non key	0.0	0.0	0.0	20.5%	0.0%	0.0%	0.0%
	All	-	34.5	27.9	26.9	-22.1%	17.9%		14.9%
1A2 liquids	*CO_2*	*L,T*	*8.8*	*9.4*	*8.7*	*-1.2%*	*5.8%*	*5.6%*	*4.8%*
1A2 solids	*CO_2*	*L,T*	*6.6*	*4.8*	*4.6*	*-30.6%*	*3.1%*	*3.0%*	*2.5%*
1A2 gases	*CO_2*	*L,T*	*19.0*	*13.6*	*13.5*	*-29.0%*	*9.0%*	*8.8%*	*7.5%*
1A2a. Iron and steel	CO_2		5.6	5.0	4.9	-12.7%	*3.3%*	*3.2%*	*2.7%*
1A2b. Non-Ferrous Metals	CO_2		0.2	0.2	0.2	-25.7%	*0.1%*	*0.1%*	*0.1%*
1A2c. Chemicals	CO_2		17.3	13.8	13.0	-24.6%	*8.7%*	*8.5%*	*7.2%*
1A2d. Pulp. Paper and Print	CO_2		1.7	1.0	0.9	-44.6%	*0.6%*	*0.6%*	*0.5%*
1A2e. Food Processing. Beverages and Tobacco	CO_2		4.0	3.4	3.6	-11.1%	*2.4%*	*2.3%*	*2.0%*
1A2f. Non metalic minerals	CO_2		2.3	1.3	1.1	-52.7%	*0.7%*	*0.7%*	*0.6%*
1A2g. Other	CO_2		3.4	3.1	3.1	-7.1%	*2.1%*	*2.0%*	*1.7%*

Within these categories, liquid fuel and natural gas combustion by the chemical industry, solid fuel combustion in the iron and steel sector and

natural gas combustion by the food processing industries are the dominant emissions sources.
The shares of CH_4 and N_2O emissions from industrial combustion are relatively small and these are not key sources.

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); 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).

In the period 1990–2019, CO_2 emissions from combustion in 1A2 decreased by 22.2% (see Table 3.8 and Figure 3.6). The chemical industry contributed the most to the decrease in emissions in this source category.

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**	**2018**	**2019**
Gaseous fuels								
Iron and steel	11.7	13.0	13.7	12.5	12.0	11.1	11.1	11.5
Non-ferrous metals	3.8	4.3	4.2	4.0	3.6	2.7	2.9	2.8
Chemicals	170.7	138.9	117.7	105.3	97.6	94.4	106.9	106.4
Pulp, paper and print	29.2	24.4	27.4	29.7	21.0	18.3	17.1	16.3
Food processing, beverages and tobacco	63.7	68.4	73.7	67.1	57.0	56.5	58.2	60.5
Non-metallic minerals	26.1	23.8	26.5	23.5	22.6	17.8	19.7	16.9
Other	30.1	34.8	36.2	32.6	31.4	23.9	24.1	24.5
Liquid fuels								
Iron and steel	0.3	0.3	0.1	0.1	0.1	NO	NO	NO
Non-ferrous metals	NO	NO	NO	NO	NO	NO	NO	NO
Chemicals	96.2	77.6	82.6	93.2	112.7	110.0	119.7	109.2
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	22.2	23.7	26.2	24.0	21.9	19.9	22.7	23.2
Solid fuels								
Iron and steel	73.4	80.6	68.5	81.0	70.5	80.7	83.9	82.1
Non-ferrous metals	0.0	NO	NO	NO	NO	NO	NO	NO
Chemicals	12.8	0.2	0.1	NO	NO	NO	NO	NO
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	1.0	1.5	1.4
Non-metallic minerals	3.3	2.1	2.3	1.5	1.5	1.4	1.9	1.1
Other	0.4	0.2	0.3	0.5	1.6	0.5	0.8	0.9

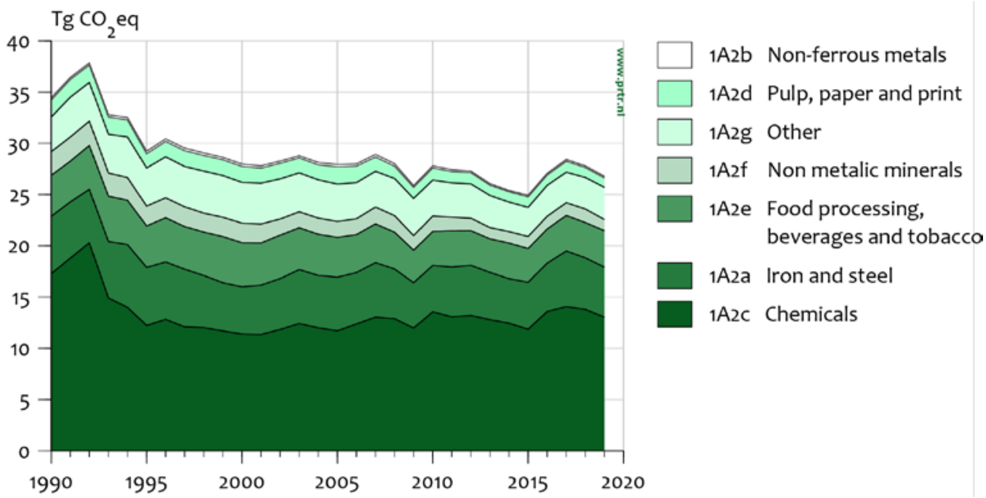


Figure 3.6 1A2 Manufacturing industries and construction – trend and emissions levels of source categories, 1990–2019.

The derivation of these figures, however, should also be considered in the context of the allocation of industrial process emissions of CO_2. Most industrial process emissions of CO_2 (soda ash, ammonia, carbon electrodes and industrial gases such as hydrogen and carbon monoxide) are reported in CRF sector 2 (IPPU). However, part of the waste gases is not directly emitted as a process emission, but is combusted for energy purposes. Therefore, the oxidation of waste gases is accounted for in the energy statistics as the production and combustion of residual gases (e.g. in the chemical industry), and the corresponding CO_2 emissions are reported as combustion in category 1A2 and not as an industrial process in sector 2.

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. Besides the integrated crude steel plant, there is a (small) secondary steel-making plant, which uses mostly 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 of this calculation method, CO_2 emissions can be determined only at plant level. 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
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 where these are 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 the by-products blast furnace gas and oxygen furnace gas, 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 explained mainly by the varying amounts of solid fuels used in this sector.

When all CO_2 emissions from the sector are combined, 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.

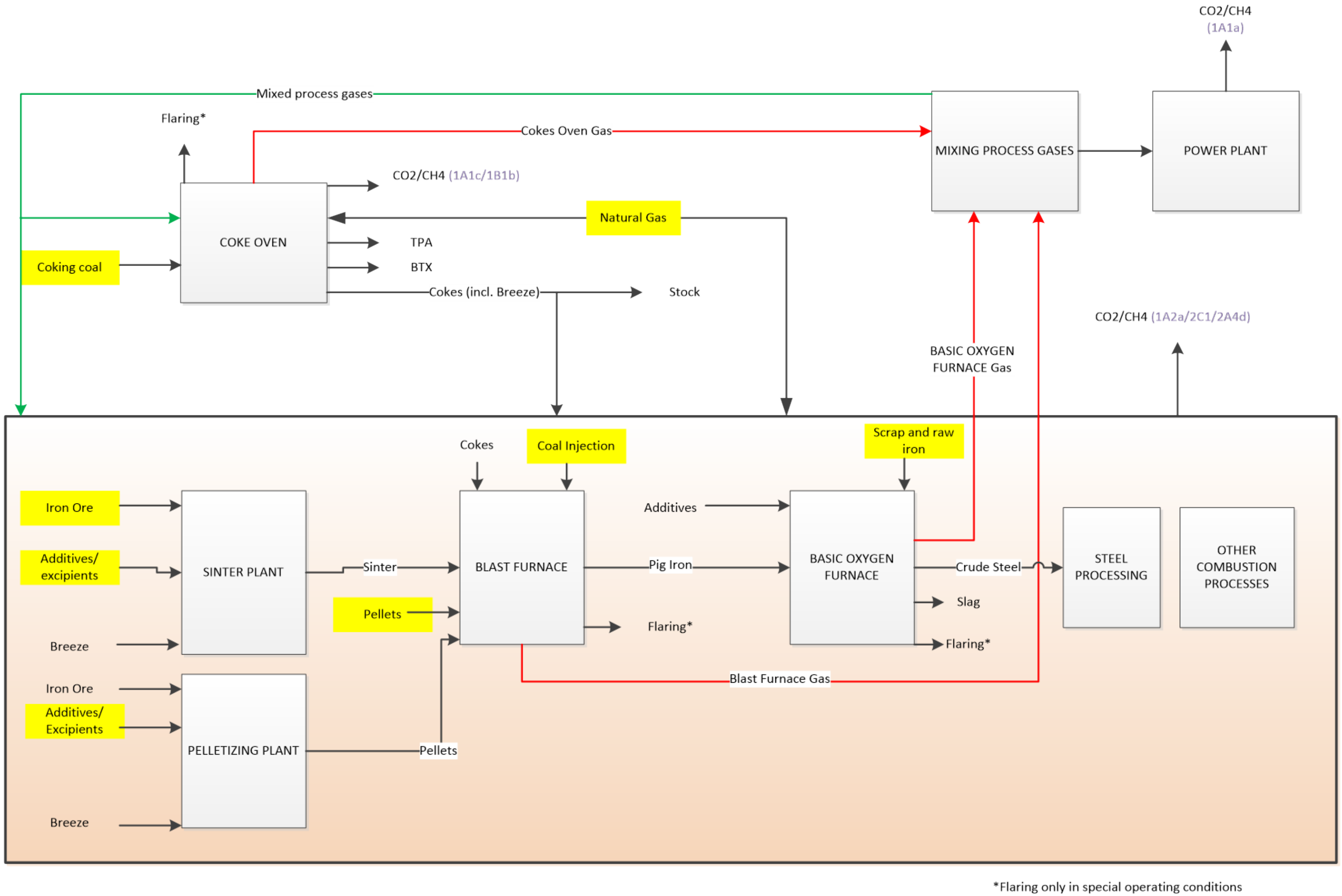


Figure 3.7 Production process of the Tata Steel integrated steel plant.

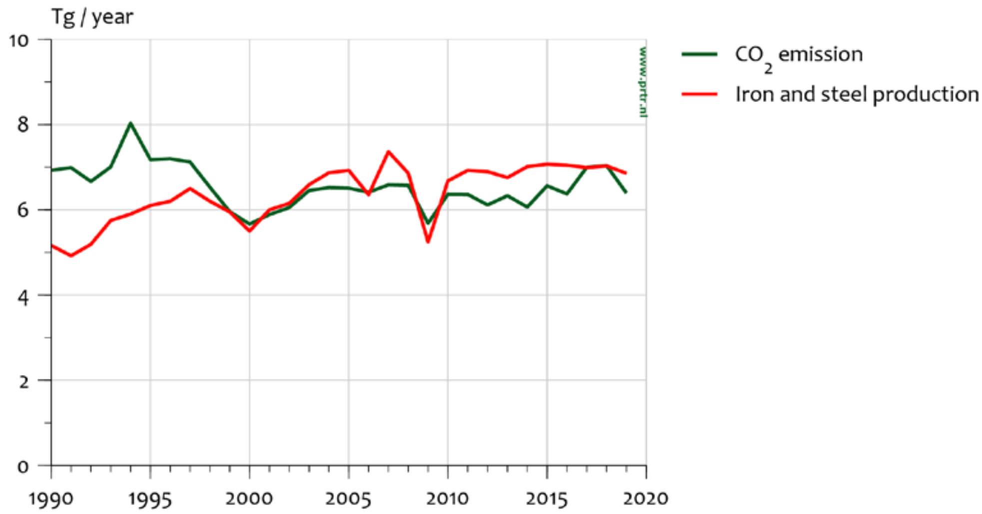


Figure 3.8 CO_2 emissions (Gg) from crude steel production compared with crude steel production, 1990–2019 (kton).

Non-ferrous metals (1A2b)
This sub-category consists mainly of two aluminum smelters. CO_2 emissions from anode consumption in the aluminum 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 production in the aluminum 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 mainly caused by a decrease of cogeneration facilities in this industrial sector.
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. This also explains the large decrease in solid fuel combustion.

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 waste gas (reported under Liquid and gaseous 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 was 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).
The increased use of chemical waste gas (included in Liquid fuels) since 2003 and the changes in the composition of the gases explain the increase in the IEF for liquid fuels from c. 55 to 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 phosphorous furnace gas (included in gaseous fuels), plant-specific values were used, with values of around 149.5 kg/GJ. The operation of the phosphorous plant started in 1998, which explains the increase in the IEF for gaseous fuels, and the plant closed in 2012, resulting in a decrease in the IEF for gaseous fuels.

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 the 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 aforementioned 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 decreased in the period 1990–2019. This 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 1990-2019 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. 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 paragraph 2.1 of the ENINA methodology report (Honig et al., 2021) and chapter 9 of the transport methodology report (Geilenkirchen et al., 2021). The emission calculation for category 1A2 follows the same steps as the calculation applied for Energy industries (1A1); see Section 3.2.4.2.

For 2019, 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 kerosene.

An overview of the EFs 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. Since some emissions data in this sector originate from individual companies, the values in Table 3.11 partly represent IEFs. 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 emission factors used (for the year 2019) in the category Manufacturing industries and construction (1A2).

Fuel	Amount of fuel used in 2019 (TJ NCV)	Implied emission factors (g/GJ)		
		CO_2 (x1000)	N_2O	CH_4
Natural gas	238,917	56.6	0.10	5.99
Waste gas	107,410	64.0	0.10	3.60
Coke oven / Gas coke	54,957	107.0	0.30	1.31
Other bituminous coal	42,680	92.6	0.27	0.44
Gas / Diesel oil	21,459	72.5	0.60	1.16

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) are used to calculate emissions from the iron and steel plant. The standard EFs are used for solid fuel combustion in other sectors. Reported CO_2 emissions from other bituminous coal and coke oven/gas coke are based on emissions data from the ETS. Therefore, the CO_2 IEFs are different from the standard country-specific EF.

Gas / Diesel oil
The N2O EF of gas / diesel oil in NRMM differs from the default N2O EF. This results in a lower implied emission factor.

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 is 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 more or less process-related, they are included in 1A2 to keep consistency 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 2% (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 25% 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 quite variable composition of the gas and its more than 50% share in the total liquid fuel use in the sector. An uncertainty of 10% is assigned to solids, which reflects the uncertainty in the carbon content of blast furnace gas/oxygen

furnace gas based on the standard deviation in a three-year average. 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 from the most relevant companies in a few 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 the CBS, 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 review recommendation of 2017, 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 are based on emissions and activity data of individual companies. The company-specific data have also been 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 with 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 with 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.
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., (2021).

3.2.5.5 Category-specific recalculations

Natural gas activity data has been split in a fossil and a biogenic part. The fossil natural gas is mixed with a small amount of biogas (0.008% in 1990 and 0.26% in 2018). Previously, this was all included in the reporting as natural gas (allocated to gaseous fuels). In this submission, the emissions have been split between natural gas (allocated to gaseous fuels) and biogas (allocated to biomass). This results in an increase in biomass CO2 emissions of 1.8 kton CO2 in 1990 and 49.2 kton in 2018 in 1A2.

The energy statistics for 2015-2018 have been improved (some minor corrections).

Part of the emissions from chemical waste gas in CRF category 1A2c has been reallocated to 2B10 for the years 2012-2018. See paragraphs 4.3.2 and 4.3.5 for more detail.

The abovementioned changes, result in the following changes in fossil CO_2 emissions (in Gg CO_2):

	1990	2015	2016	2017	2018
1A2a	-0.1	-1.3	-1.3	-1.5	-1.7
1A2b	-0.0	-0.3	-0.3	-2.9	-5.6
1A2c	-0.8	-756.1	-272.0	-449.6	-127.8
1A2d	-0.1	154.1	146.0	167.4	168.6
1A2e	-0.3	-271.8	-287.0	-259.0	-253.1
1A2f	-0.1	-2.3	13.1	23.7	33.4
1A2gi	-	-0.6	-0.4	-4.4	-3.0
1A2gii	-0.0	0.9	-0.2	-1.1	-3.7
1A2giii	-0.0	-0.2	-0.2	-0.3	-2.8
1A2giv	-0.0	-0.1	-0.1	-0.1	-0.9
1A2gv	-0.0	-0.5	6.3	-0.6	-7.8
1A2gvi	-0.0	8.0	-0.3	-8.4	-27.0
1A2gviii	-0.1	31.2	19.9	19.5	121.7

CH_4 and N_2O emissions have also been recalculated using the improved energy statistics.

NRMM data and modeling

There have been several improvements to the modelling of NRMM energy use.

1) new, commercial data on machine sales have been incorporated to more accurately extrapolate detailed machine sales data that were available until year 2014.
2) A subset of tractors was re-allocated from agriculture to construction, while forklifts were distributed over multiple sectors (industry, construction, public & commercial).
3) The calculation of fuel use (as well as air pollutant emissions) from default machine usage parameters and specific fuel consumption factors has been overhauled. New measurements allowed to generate 7 representative engine load profiles, existing of percentages of time spent in a specific engine load range (e.g. 10% of time in 20%-30% engine load). Next, the

base fuel consumption factors (in g/kWh) were converted to load specific fuel consumption factors (in g/s * kW rated) assuming a typical response curve of emission/load that is observed for CO_2 emissions. This CO_2 response curve is relatively linear, therefore limiting the effect of this change on fuel consumption. Each machine type was then assigned one of the engine load profiles, based on the typical use and machine components (e.g. hydraulics). This new calculation setup removes the need for a separate calculation of emissions from idling and allows a more direct use of measured fuel consumption and emission rates in the emission model.

Activity data and GHG emissions from biodiesel in NRMM were recalculated in this year's inventory, taking into account that part of the biodiesel used has a fossil origin. This is described in detail in Section 3.2.6.2.

3.2.5.6 Category-specific planned improvements

There are no planned improvements.

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**	**Key**	**1990**	**2018**	**2019**	**2019 vs 1990**	**Contribution to total in 2019 (%) by**		
			Emissions in Tg CO_2 eq			**%**	**sector**	**total gas**	**total CO_2 eq**
1A3. Transport	CO_2		27.7	31.2	30.7	10.7%	20.5%	20.0%	17.0%
	CH_4		0.2	0.1	0.1	-65.8%	0.0%	0.4%	0.0%
	N_2O		0.1	0.3	0.3	143.6%	0.2%	0.0%	0.1%
	All		28.0	31.5	31.0	10.7%	20.7%		17.2%
1A3a. Civil aviation	CO_2	non key	0.1	0.0	0.0	-62.5%	0.0%	0.0%	0.0%
1A3b. Road vehicles	CO_2		26.5	30.0	29.6	11.8%	19.7%	19.3%	16.4%
	CH4	non key	0.2	0.1	0.1	-67.1%	0.0%	0.4%	0.0%
	N2O	T	0.1	0.3	0.2	152.8%	0.2%	0.0%	0.1%
1a3b gasoline	CO_2	L,T	10.8	12.4	12.6	16.8%	8.4%	8.2%	7.0%
1a3b diesel oil	CO_2	L,T	13.0	17.1	16.5	26.7%	11.0%	10.7%	9.1%
1a3b LPG	CO_2	T	2.6	0.3	0.3	-89.4%	0.2%	0.2%	0.2%
1a3b Natural gas	CO_2	non key	0.0	0.1	0.2		0.1%	0.1%	0.1%
1A3c. Railways	CO_2	non key	0.1	0.1	0.1	-27.3%	0.0%	0.0%	0.0%
1A3d. Domestic Navigation	CO_2	L,T	0.7	1.0	0.9	23.4%	0.6%	0.6%	0.5%
1A3e Other Transportation	CO_2	non key	0.3	0.1	0.1	-75.3%	0.1%	0.1%	0.0%

Overview of shares and trends in energy use and emissions
Transport was responsible for 17.2% of GHG emissions in the Netherlands in 2019. Greenhouse gas emissions from transport increased by 30% between 1990 and 2006, from 28.0 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 15% to 31.0 Tg CO_2 eq. in 2019.
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

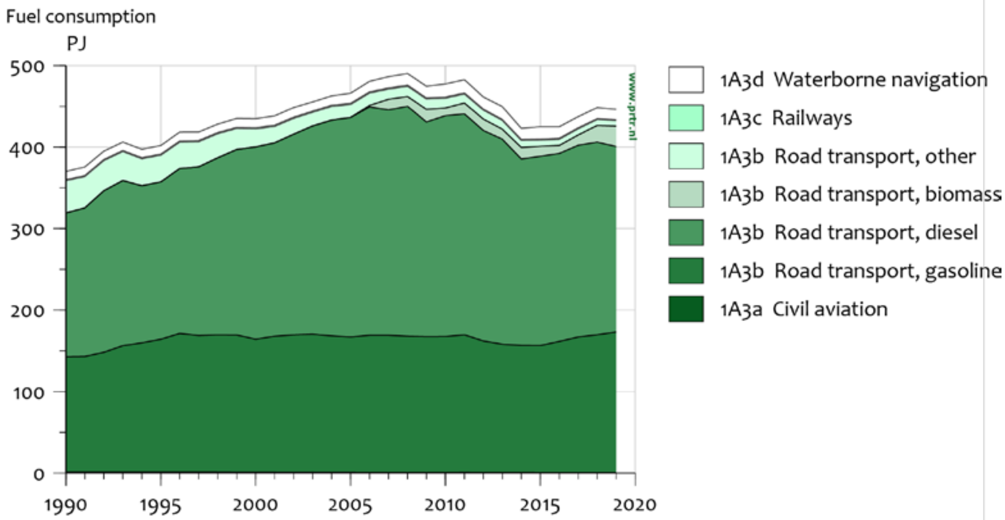


Figure 3.9 1A3 Transport – energy use of source categories in PJ, 1990–2019.

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 by 4%, 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.

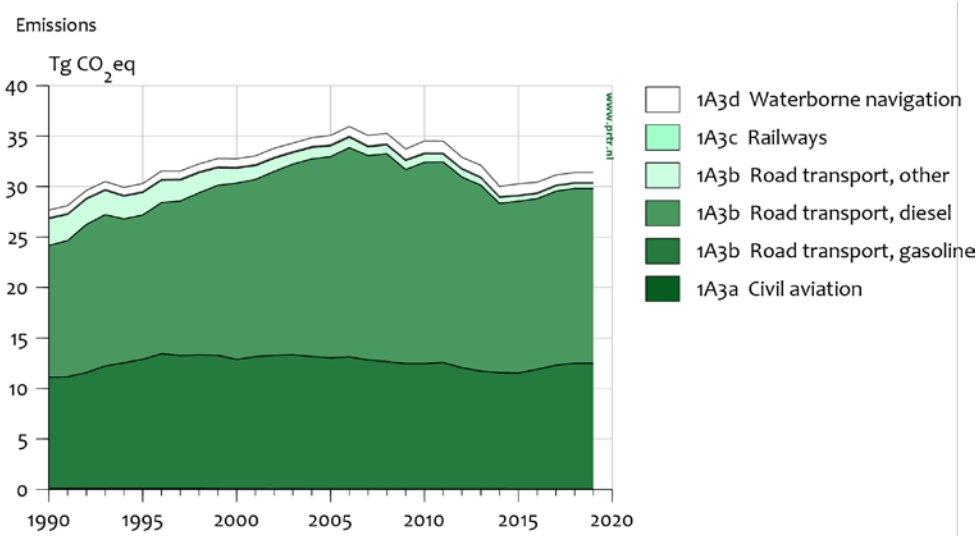


Figure 3.10 1A3 Transport – emissions levels of source categories, 1990–2019.

Between 2011 and 2014, CO_2 emissions decreased by 13%. 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 increased again, though only by approximately 1% per year. In 2019, GHG emissions from transport were 1.6% lower than in 2018. This decrease in emissions was caused by an increase in transport volumes.

Civil aviation (1A3a)
Given the small size of the country, there is hardly any domestic aviation in the Netherlands. 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 0.4 PJ in 2019, whereas the use of aviation gasoline decreased from 0.16 PJ in 1990 to 0.03 PJ in 2019. GHG emissions from civil aviation decreased accordingly.

Road transport (1A3b)
The share of road transport (1A3b) in national GHG emissions increased from 12.1% in 1990 to 16.5% in 2019. Between 1990 and 2018, total GHG emissions from road transport increased from 26.7 to 29.9 Tg CO_2 eq., resulting for the most part from an increase in diesel fuel consumption. 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 19% to 228 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). Also, road transport volumes were more or less stable between 2008 and 2014, mainly due to the economic crisis. In recent years, however, transport volumes have increased again due to the economic upturn. 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., 2021).

Gasoline consumption increased from 141 to 170 PJ between 1990 and 1996 and subsequently fluctuated between 165 and 170 PJ until 2011. Thereafter, gasoline sales to road transport decreased to 156 PJ in 2014 but then increased again to 173 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.

LPG consumption for road transport decreased steadily throughout the time series: from 40 PJ in 1990 to 4 PJ in 2019, 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 2019. The use of natural gas in road transport has increased in recent years and amounted to 3 PJ in 2019. 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 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 15 PJ in 2009, and then fluctuated between 10 and 15 PJ until 2017. From 2018, biofuel use for road transport increased to 24 PJ in 2019, accounting for 5.6% of total energy use for road transport. The large increase in the use of biofuels from 2018, that will continue until 2020, 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.

The share of CH_4 in GHG emissions from road transport (in CO_2 eq.) is very small (0.04% in 2019). CH_4 emissions from road transport decreased by about 67% between 1990 and 2019. This decrease 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 2019, primarily due to the penetration of catalyst-equipped and canister-equipped vehicles into the passenger car fleet. 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. 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. Since almost the entire gasoline car fleet is currently equipped with catalysts and carbon canisters, the decrease in VOC emissions has stagnated in recent years. Therefore, CH_4 emissions from road transport stabilised between 2014 and 2019.

The share of N_2O in total GHG emissions from road transport (in CO_2 eq.) is also small (0.2% in 2019). N_2O emissions from road transport increased from 0.1 Gg in 1990 to 0.9 Gg in 1997, but have since (slightly) decreased to 0.3 Gg in 2019. 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 gasoline cars 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). This led to an increase in N_2O emissions from heavy-duty vehicles in recent years, 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 0.04% of total GHG emissions from Transport in the Netherlands. Diesel fuel consumption by railways has fluctuated between 1.0 and 1.4 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 2019, diesel fuel consumption by railways amounted to 0.9 PJ. Passenger transport by diesel trains accounts for approximately 0.4-0.5 PJ of diesel fuel consumption annually, the remainder being used for freight transport. 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.

Waterborne navigation (1A3d)
(Domestic) waterborne navigation is a small source of GHG emissions in the Netherlands. Waterborne navigation in the Netherlands is for the most part internationally orientated, i.e. either departs or arrives abroad. Because 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 (0.6% in 2019).

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 12 PJ in 2019. These fluctuations can partially be explained by changes in offshore operations.

In line with the increase in fuel consumption, 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 0.9 Tg in 2019.

Other transportation (1A3e)
Other transportation consists of pipeline transport and the CO_2 and N_2O emissions at natural gas compressor stations. This is a minor source, which accounted for 1.2% of total GHG emissions of the Transport sector in 1990 and only 0.06% in 2019.

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 lubricants use in two-stroke engines in mopeds and motorcycles have been included under 1A3biv, in accordance with the 2006 IPCC Guidelines.
- Emissions from NRMM 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. (2021).

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 both jet kerosene and aviation gasoline. The heating values and CO_2 EFs for aviation gasoline and kerosene are derived from Zijlema (2021). Country-specific values are used for aviation gasoline, whereas

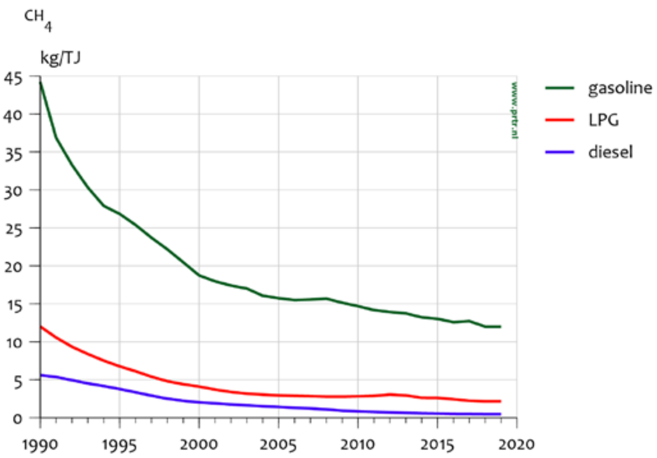
for jet kerosene default values from the 2006 IPCC Guidelines are used. Default EFs are also used for N_2O and CH_4. Since domestic civil aviation is not a key source in the inventory, the use of a Tier 1 methodology is deemed sufficient.

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), since these emissions 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 of Geilenkirchen et al. (2021) 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. They were derived from two measurement programmes, the most recent being performed in 2016 and 2017. The methodology is described in detail in the 2018 inventory report. A detailed description of the methodology that is currently used for calculating GHG emissions for road transport is provided in chapter 2 of Geilenkirchen et al. (2021). The EFs that were used are provided in Geilenkirchen (2021) 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 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.



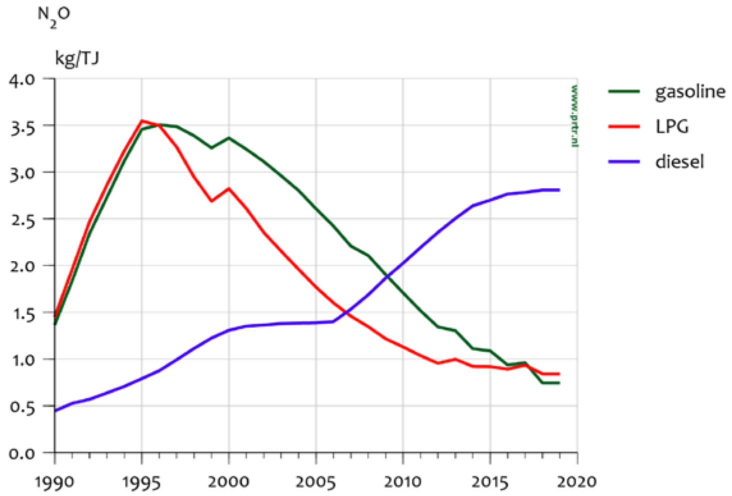


Figure 3.11 IEFs per fuel type for CH_4 and N_2O emissions by road transport, 1990–2019.

Railways (1A3c)

Fuel deliveries to railways are derived from the Energy Balance. Since 2010, the CBS 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, which was 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, as derived from the Energy Balance, are corrected accordingly (as shown in Table 2.1 of Geilenkirchen et al., 2021).
The fuel consumption from the Energy Balance is apportioned between international bunkers and inland navigation as follows: Each fuel supplier has to report its total fuel sales to the CBS, 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 the CBS, 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 that are used and underlying methodology is provided in Geilenkirchen et al. (2021); the EFs are included in Table 2.2.

Other transportation (1A3e)
The methodology used for calculating emissions from other transportation 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. Following methodology is used:
1. Deriving the total amount of biogasoline and biodiesel used for transport in the Netherlands from the Energy Balance, as reported annually by the CBS.
2. Determining the share of different types of biogasoline and biodiesel used in the Dutch market, as reported annually by the Dutch Emission Authority (NEa, 2019).
3. Applying the fossil fraction of the carbon content per type of biofuel as provided by Sempos (2018).

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 2011–2018 period, as reported by NEa (2020[5]), and the fossil part of the carbon content per fuel type.

[5] https://www.emissieautoriteit.nl/documenten/publicatie/2020/06/29/rapportage-energie-voor-vervoer-in-nederland-2019

Table 3.14 Share (in %, rounded) of different types of biofuels in total biofuel consumption for transport in the Netherlands (NEa, 2020).

	Biofuel type	Fossil part of CC	2011	2012	2013	2014	2015	2016	2017	2018	2019
Bio Gas-oline	bio-ethanol	0	92	91	95	99	100	99	99	77	75
	bio-ETBE	63	0	1	2	0	0	1	1	11	0
	bio-MTBE	78	7	7	2	0	0	0	0	0	0
	bio-methanol	0	1	1	2	0	0	0	0	0	0
	bionafta	0	0	0	0	0	0	0	0	11	24
			100	100	100	100	100	100	100	100	100
Bio diesel	FAME	5.4	100	98	99	96	98	98	99	97	78
	HVO	0	0	2	1	4	2	2	1	3	22
	FAEE	0	0	0	1	0	1	0	0	0	0
			100	100	100	100	100	100	100	100	100

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 2.6 of Geilenkirchen et al. (2021), which also shows the sources used to estimate uncertainties. Table 3.15 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 the CBS.
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, which were determined in workshops. Information on uncertainties will be reviewed and, if necessary, the uncertainty analysis of the NIR 2021will be updated accordingly

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.

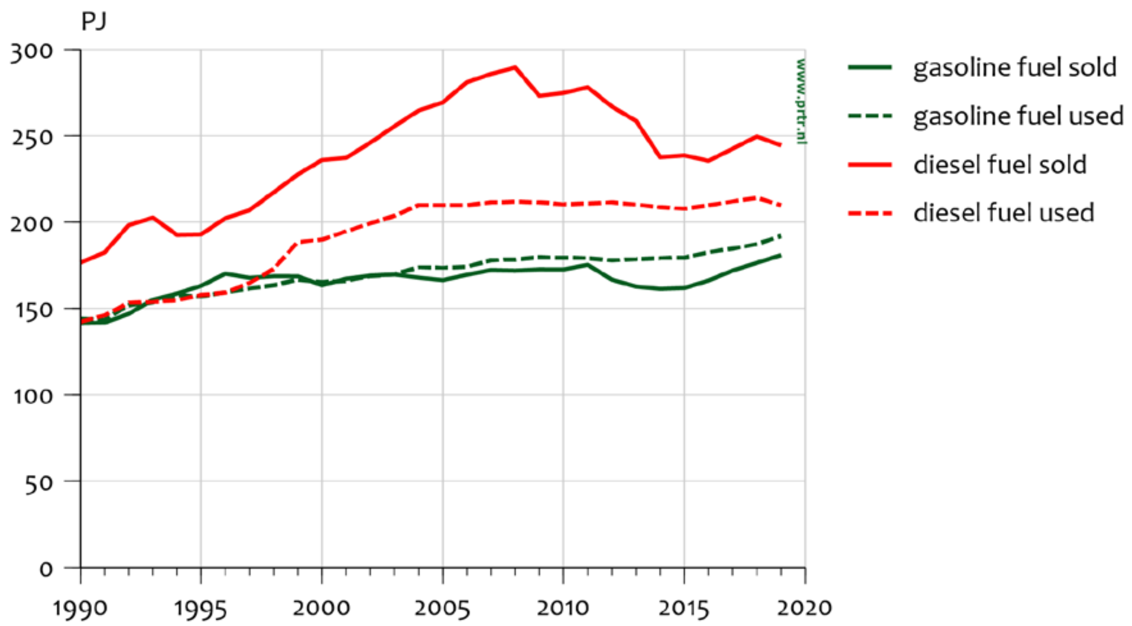


Figure 3.12 Fuel sold and fuel used for road transport in the Netherlands, 1990-2019.

The bottom-up calculation of gasoline consumption in road transport closely corresponds with the (adjusted) sales data from the Energy Balance for the 1990–2011 period; differences between the two figures are small throughout the time series. As of 2011, fuel sold had decreased compared with 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 a less extent- 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 comparable for the most part, 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 with trends in transport volumes. Trends in energy use for waterborne navigation show rather close correspondence with trends in transport volumes, although this does not necessarily hold true 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, as described above. 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 (<0.5%) were made in the activity data for road transport, railways and inland navigation. New data were derived from the Energy Balance. GHG emissions changed accordingly.
This year, no major recalculations have been performed

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 3.16 shows the subcategories under sector 1A4, as well as the key categories.

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 trade.

Table 3.16 Overview of emissions in the Other sectors (1A4) in the base year and the last two years of the inventory (in Tg CO_2 eq.).

Sector/category	Gas	Key	1990	2018	2019	2019 vs 1990	Contribution to total in 2019 (%) by		
			Emissions in Tg CO_2 eq			%	sector	total gas	total CO_2 eq
1A4. Other sectors	CO_2		38.9	33.0	31.8	-18.2%	21.2%	20.7%	17.6%
	CH_4		0.6	1.4	1.5	159.4%	1.0%	8.6%	0.8%
	N_2O	non key	0.0	0.1	0.1	2.1%	0.0%	0.0%	0.0%
	All		39.5	34.5	33.3	-15.6%	22.2%		18.4%
1A4a. Commercial/Institutional	CO_2		8.3	7.5	7.2	-13.4%	4.8%	4.7%	4.0%
	CH4	non key	0.0	0.0	0.0	-13.1%	0.0%	0.2%	0.0%
1A4a Natural gas	CO_2	L,T	7.8	7.1	6.8	-12.6%	4.5%	4.4%	3.8%
1A4b. Residential	CO_2		20.7	16.3	15.4	-25.6%	10.3%	10.0%	8.5%
	CH4	L	0.4	0.3	0.3	-25.4%	0.2%	0.2%	0.2%
1A4b Natural gas	CO_2	L,T	19.9	16.2	15.2	-23.4%	10.2%	9.9%	8.4%
1A4c. Agriculture/Forestry/Fisheries	CO_2		9.8	9.2	9.2	-6.7%	6.1%	6.0%	5.1%
	CH4	L,T	0.1	0.9	1.1	1400.5%	0.7%	0.7%	0.6%
1A4c liquids	CO_2	L,T	2.5	1.7	1.7	-31.1%	1.2%	1.1%	1.0%
1A4c Natural gas	CO_2	L,T	7.3	7.5	7.4	1.6%	5.0%	4.8%	4.1%

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

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

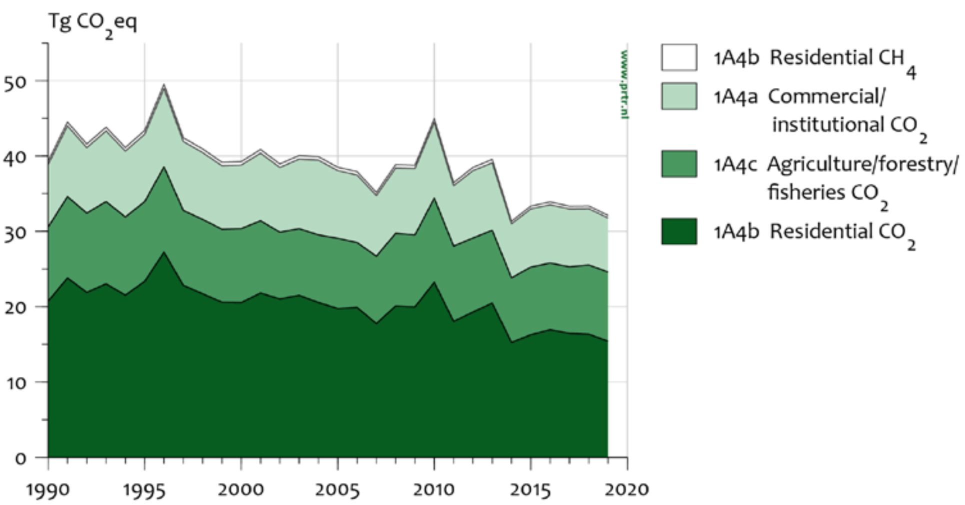


Figure 3.13 1A4 (Other sectors) – trend and emissions levels of source sub-categories, 1990–2019.

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 3.1 PJ in 1990 to 5.6 PJ in 2019, with CO_2 emissions increasing accordingly. Energy use consists mostly of diesel fuel, although some gasoline is also used and in recent years biofuels have also been applied.

Residential (1A4b)
When corrected for the interannual variation in temperature, the trend in total CO_2 emissions (i.e. in gas consumption) becomes quite steady, with interannual variations of less than 5%. The variations are much larger for liquid and solid fuels because of the much smaller figures. Biomass consumption relates almost entirely to wood.

The IEF for CH_4 emissions from national gas combustion 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, which 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.

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 residential increased from 0.5 PJ in 1990 to 1.0 PJ in 2019, with CO_2 emissions increasing accordingly. Energy use consists mostly of diesel fuel, although some gasoline is also used 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 in the sub-category is natural gas. Almost no solid fuels are used in this sub-category. NRMM used in agriculture mostly uses diesel oil, although some biofuel and gasoline is used as well. 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 (e.g. 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 may also provide electricity to the national grid. It should also be noted that 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.

In addition, since the autumn of 2005, CO_2 emissions from two plants have been used for crop fertilisation in greenhouse horticulture, thereby reducing the net CO_2 emissions generated by CHP facilities. Total annual amounts are approximately 0.4 Tg CO_2.
GHG emissions from agricultural NRMM (1A4cii) have been constant throughout the time series at between 1.0 and 1.3 Tg CO_2 eq.

CO_2 emissions from fisheries have significantly decreased, from 1.3 Tg in 2000 to 0.5 Tg in 2019. This has been caused by a decrease 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., (2021), paragraph 2.1: Stationary combustion;
- Visschedijk et al. (2021), chapters 21 and 25: Residential wood combustion and charcoal use;
- Geilenkirchen et al., (2021), chapter 9: Non-road mobile machinery.

This section provides a brief description of the methodology applied for 1A4c.

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 the CBS. For the following emission sources, other activity data are used:

- The activity data for charcoal consumption in barbecues are based on energy statistics from the CBS, and corrected for annual meat consumption.
- Fuel consumption by off-road agricultural machinery is derived from the EMMA model (Hulskotte and Verbeek, 2009). This model is based on sales data for different types of mobile machinery and assumptions made about average use (hours per year) and fuel consumption (kilograms per hour) for different machine types.
- The consumption of diesel oil and heavy fuel oil by fisheries is derived from the Energy Balance.
- The activity data for residential wood combustion are based on surveys by the CBS (every 6 years), and the results of these surveys are used to prepare a complete time series. See Visschedijk et al. (2021) for more details on these wood combustion statistics.

Emission factors
For stationary combustion, the following EFs are used: For CO_2, IPCC default EFs are used (see Annex 5) for all fuels except natural gas,

gas/diesel oil, LPG and gaseous biomass, for which country-specific EFs are used. The Netherlands' list of fuels (Zijlema, 2021) 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, and diesel in the fisheries sector. For natural gas in gas engines, a different EF is used (see Honig et al., 2021). 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.

Mobile combustion

- Emissions from fisheries (1A4c iii) 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. (2021).
- 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. 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 derived from the EMMA model. CH_4 EFs are presented in table 9.6. of Geilenkirchen et al. (2021).

Table 3.17 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 2019, over 99% of the CO_2 emissions in 1A4 were calculated using country-specific EFs (mainly natural gas). The remaining <1% of CO_2 emissions were calculated with default IPCC EFs. These mainly consist of emissions from residual fuel oil, 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 3.18.

Table 3.18 Overview of IEFs used (for the year 2019) in Other sectors (1A4).

Fuel	Amount of fuel used in 2019 (TJ NCV)	IEFs (g/GJ)		
		CO_2 (x 1000)	N_2O	CH_4
Natural gas	520,595	56.6	0.1	104.3
Gas / Diesel oil	27,654	72.5	0.9	2.5
Solid biomass	22,176	111.3	4.0	187.9

Explanations of the IEFs
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 is used in stationary and mobile combustion, for which different EFs for CH_4 and N_2O are used. The implied CO_2 EF for solid biomass consist 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.

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 that is used for natural gas combusted in gas engines (varying between 250 and 450 g/GJ) and the CH_4 EF that is used for natural gas combusted in other plants (5.7 g/GJ). Figure 3.14 shows the trend in natural gas combusted in gas engines and in other plants, as well as the trend in the IEF.

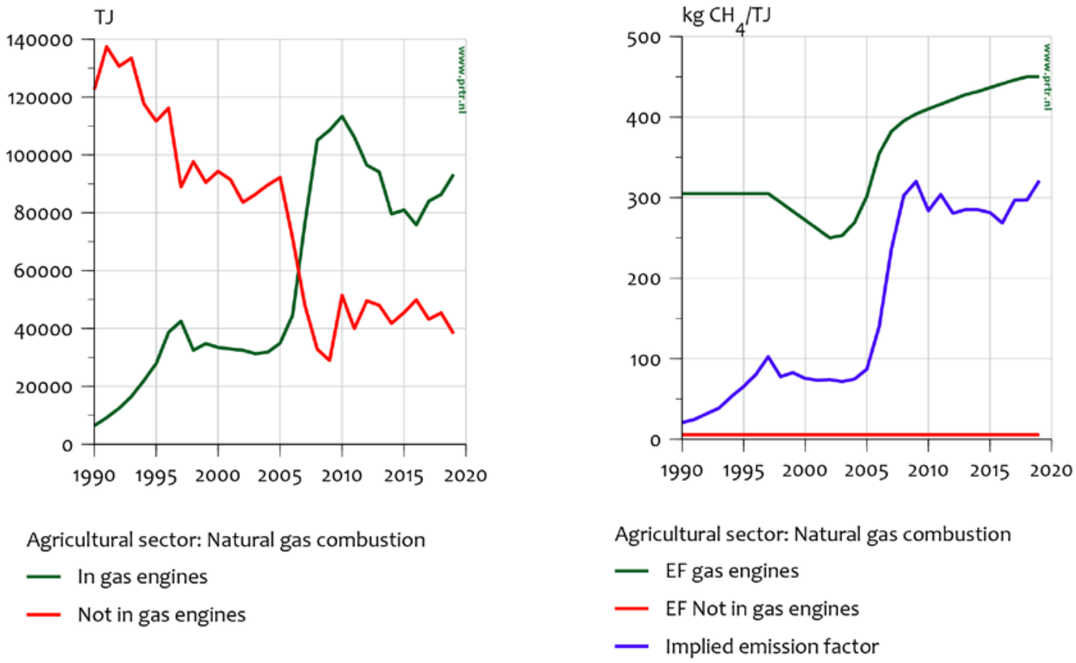


Figure 3.14 Trend in natural gas consumption in gas engines (with a relatively high emission factor) and other engines (with a relatively low emission factor) in the agricultural sector (left) compared with the implied CH_4 emission factor from natural gas combustion in the agricultural sector (right), 1990–2019.

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 10% for the Services category. An uncertainty of 20% is assumed for liquid fuel use for the Services category. Since the uncertainty in small figures in national statistics is generally greater than it is with large figures, as indicated by the high interannual variability of the data, the uncertainty in solid fuel consumption is estimated to be even higher, i.e. 50%. However, the uncertainty in the fuel statistics for the total of Other sectors is somewhat smaller than the uncertainty in the data for the underlying sub-sectors: consumption per fuel type is defined as the remainder of total national supply after subtraction of the amount used in Energy, Industry and Transport. Consequently, energy consumption by the Residential and Agricultural sub-categories is estimated separately using a trend analysis of sectoral data ('HOME' survey of the Residential category and Wageningen Economic Research data for Agriculture).

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 further 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 (about 50%).

Since most of the fuel consumption in this source category is for space heating, consumption has varied considerably across the years 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 2% for gasoline and diesel and 5% for LPG, as reported in Geilenkirchen et al. (2021). 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 few 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 (CBS).

3.2.7.4 Category-specific QA/QC and verification

Trends in CO_2 emissions from the three sub-categories were compared with trends in related activity data: number of households, number of people employed in the services sector and 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. More details on the validation of the energy data can be found in Honig et al., (2021).

3.2.7.5 Category-specific recalculations

Natural gas activity data has been split in a fossil and a biogenic part. The fossil natural gas is mixed with a small amount of biogas (0.008% in 1990 and 0.26% in 2018). Previously, this was all included in the reporting as natural gas (allocated to gaseous fuels). In this submission, the emissions have been split between natural gas (allocated to gaseous fuels) and biogas (allocated to biomass). This results in an increase in biomass CO2 emissions of 2.8 kton CO2 in 1990 and 81.2 kton in 2018 in 1A4.

The energy statistics for 2015-2018 have been improved (some minor corrections).

The changes mentioned above, result in the following changes in fossil CO_2 emissions (in Gg CO_2):

	1990	**2015**	**2016**	**2017**	**2018**
1A4ai	-0.6	-15.4	335.9	-17.5	-42.2
1A4bi	-1.6	-33.5	-34.8	-38.9	-42.8
1A4ci	-0.6	-14.9	-23.1	-17.2	364.2

CH_4 and N_2O emissions have also been recalculated using the improved energy statistics.

The CH_4 emission factor of residential wood combustion has been improved. Previously, a CH_4 emission factor of 300 g/GJ was used for all types of wood stoves (from the IPCC 2006 Guidelines). This has been changed to 10 g/GJ for pellet stoves, 100 g/GJ for improved stoves and 300 g/GJ for open fireplaces and conventional stoves. The CH4 emissions decreased with 0.17 kton CH_4 in 1990 and 2.42 kton CH_4 in 2018.

For NRMM, recalculations have been described in 3.2.5.5.

3.2.7.6 Category-specific planned improvements

There are no source-specific improvements envisaged.

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 3.19.

Table 3.19 Overview of emissions in the sector Other (1A5) in the base year and the last two years of the inventory (in Tg CO_2 equivalents).

Sector/category	Gas	Key	1990	2018	2019	2019 vs 1990	Contribution to total in 2019 (%) by		
			Emissions in Tg CO_2 eq			%	sector	total gas	total CO_2 eq
1A5 Other	CO_2	non key	0.3	0.2	0.2	-49.3%	0.1%	0.1%	0.1%
	CH_4	non key	0.0	0.0	0.0	-55.5%	0.0%	0.0%	0.0%
	N_2O	non key	0.0	0.0	0.0	-54.9%	0.0%	0.0%	0.0%
	All		0.3	0.2	0.2	-49.4%	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 Energy Balance, 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 3.20. 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 3.20 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 2018 (Gg)	152	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%, mainly determined by uncertainty in the activity data (20%). Uncertainties for CH_4 and N_2O emissions from this category are substantially higher: up to around 80% in the EF for N_2O.

3.2.8.4 Category-specific QA/QC and verification

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

3.2.8.5 Category-specific recalculations

The energy statistics for 2015-2018 have been improved (minor corrections).

This results in the following changes in CO_2 emissions (in Gg CO_2):

	2015	2016	2017	2018
1A5b	-0.013	-0.003	-0.000	-0.001

3.2.8.6 Category-specific planned improvements

No 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, transport, distribution).

Table 3.21 shows that total GHG emissions in 1B decreased from 2.8 Tg CO_2 eq. to 1.5 Tg CO_2 eq. between 1990 and 2019.

Table 3.21 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	Key	1990	2018	2019	2019 vs 1990	Contribution to total in 2019 (%) by		
			Emissions in Tg CO_2 eq			%	sector	total gas	total CO_2 eq
1B Fugitive emissions from fuels	CO_2		0.9	1.1	1.1	19.9%	0.7%	0.7%	0.6%
	CH_4		1.9	0.5	0.5	-76.3%	0.3%	2.7%	0.3%
	All		2.8	1.6	1.5	-46.2%	1.0%		0.8%
1B1. Solid fuels transformation	CO_2	non key	0.1	0.1	0.1	-34.1%	0.0%	0.0%	0.0%
1B2. Fugitive emissions from oil and gas operations	CO_2	L,T	0.8	0.0	0.0	-95.4%	0.0%	0.0%	0.0%
1B2. venting/flaring	CH_4	T	1.5	0.2	0.2	-86.8%	0.1%	1.1%	0.1%

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 small. CH_4 emissions from 1B1 are therefore not shown in Table 3.21. Fugitive emissions of CH_4 from this category relate to coke manufacture. The Netherlands currently has only one coke production facility at the iron and steel plant of Tata Steel. A second independent coke producer in Sluiskil discontinued its activities in 1999.
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 also had a large share of the market in neighbouring countries. Production at this location stopped in 2010.

3.3.1.2 Methodological issues

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). After the production of charcoal stopped, the emissions in this category were solely from 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 are only a 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 very 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 AER's and only a limited set of activity data is published by the CBS.
For category 1B1, the production of coke oven coke as registered by the CBS 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., (2021).

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 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, which are discussed in Chapter 1.

3.3.1.5 Category-specific recalculations

There are no category-specific recalculations.

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 transport (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.
- 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; refineries, distributors, filling stations) are equipped with abatement measures to capture any fugitive emissions. Therefore, emissions are considered as 'not applicable' (NA) and activity data 'not estimated' (NE).
- There are also no relevant emissions expected in the Netherlands in categories 1B2a6 Other (NE) and 1B2d Other 'not occurring' (NO).

Gas production and gas transmission vary according to demand: in cold winters, more gas is produced. The gas distribution network is still gradually expanding as new housing estates are being built. PVC and PE are mostly used for this expansion. Besides, PVC and PE are also used to replace cast iron pipelines (see Honig et al., 2021).
The IEF for gas distribution gradually decreases as the proportion of cast iron pipelines decreases due to their gradual replacement and the expansion of the network. Their present share of the total is less than 3.5%; in 1990 it was 10%.

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

3.3.2.2 Methodological issues

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, 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.

Since 2004, the gas distribution sector has annually recorded the number of leaks found per material and detailed information on pipeline length per material. A yearly survey of leakages per length, material and pressure range is also carried out, covering the entire length of the grid every five years. 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).

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 18 measurements at three pressure levels for other materials (PVC, steel, nodular cast iron and PE) and subsequently aggregated to EFs for the pipeline material mix in 2004. As a result of a total of 40 additional leakage measurements, an improved set of EFs could be derived. Based on the (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.

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 1A1c3ei (gaseous). Additionally, to give a complete overview of emissions, the amount of fugitive CO_2 emissions from gas transportation is calculated using the Tier 1 method with the new default IPCC EF of 8.8E-7 Gg/106 m^3 of marketable gas, taken from the 2006 IPCC Guidelines, chapter 4,

Table 4.2.4. This figure is 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.

Fugitive emissions of CH_4 from refineries in category 1B2a4 are based on a 4% share in total VOC emissions reported in the AERs of the refineries (Spakman et al., 2003) and in recent years have been directly reported in those 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 the years. (For more information, see Honig et al., 2021). 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 can be found in paragraph 2.4 of the annex ‘Methodology Report on the Calculation of Emissions to Air from the Sectors Energy, Industry and Waste’ to Honig et al., (2021).

3.3.2.3 Uncertainty and time series consistency

The uncertainty in CO_2 emissions from gas flaring and venting is estimated to be about 50%. The uncertainty in CH_4 emissions from oil and gas production (venting) and gas transport and distribution (leakage) is also estimated to be 50%.

The uncertainty in the EF of CO_2 from gas flaring and venting (1B2) is estimated at 2%. 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 a few locations.

For CH_4 from fossil fuel production (gas venting) and distribution, the uncertainty in the EFs is estimated to be 25% and 50%, respectively. This uncertainty refers to the changes in reported venting emissions by the oil and gas production industry over the years and 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.

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, which are 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 CO2 transport and storage (1C)
Storage of CO_2 (CCS) is implemented in waste combustion facilities from 2019 onwards. See chapter 7 for more information.
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.

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 2020

Emissions:	The total GHG emissions of the IPPU sector show a slight decrease (rounded from 10.4 Tg CO_2 eq. in 2018 to 10.2 Tg CO_2 eq. in 2019). This was the net result of a decrease in CO_2 emissions (c. -0.2 Tg) and a slight increase of emissions of the other greenhouse gases.
Key categories:	New: 2B10, Other (N_2O) 2A1 cement production (CO_2)
Methodologies:	• 2B1: CO_2 storage in urea now is accounted for, timeseries 1990-2019 has been recalculated • 2B10: recalculation CO_2 from industrial gas production, now based on ETS-reports • 2F1: Overlap splicing technique used to create a consistent time series, emissions for the period 1990–2012 recalculated

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 2019, IPPU contributed 5.7% to the total national GHG emissions (without LULUCF) in comparison with 10.5% in 1990. The sector is a major source of N_2O emissions in the Netherlands, accounting for 18.2% of total national N_2O emissions in 2019. Category 2B (Chemical industry) contributes most to the emissions from this sector with 1.4 Tg CO_2 eq. in 2019.

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	Key	1990	2018	2019	2019 vs 1990	Contribution to total in 2019 (%) by		
			Emissions in Tg CO2 eq			%	sector	total gas	total CO2 eq
2. Total Industrial Processes	CO_2		7.2	6.6	6.4	-10.9%	62.5%	4.2%	3.5%
	CH_4		0.3	0.3	0.3	9.4%	3.4%	2.0%	0.2%
	N_2O		7.3	1.4	1.4	-80.3%	14.1%	18.2%	0.8%
	HFC		5.6	1.7	1.8	-67.6%	17.8%	100.0%	1.0%
	PFC		2.7	0.2	0.1	-95.6%	1.1%	100.0%	0.1%
	SF_6		0.3	0.1	0.1	-57.4%	1.1%	100.0%	0.1%
	All		23.3	10.4	10.2	-56.1%	100.0%		5.7%
2A. Mineral industry	CO_2		1.4	1.5	1.15	-18.3%	11.3%	0.8%	0.6%
2B. Chemical industry	CO_2		4.1	4.3	4.4	7.6%	43.5%	2.9%	2.5%
	CH_4		0.3	0.3	0.3	12.8%	3.0%	1.8%	0.2%
	N_2O		7.1	1.4	1.4	-80.9%	13.2%	17.1%	0.7%
	HFC	T	5.6	0.2	0.4	-93.2%	3.7%	21.0%	0.2%
	PFC		0.0	0.1	0.0		0.5%	39.6%	0.0%
	All		17.1	6.3	6.5	-61.7%	63.9%		3.6%
2C. Metal Production	CO_2		0.5	0.0	0.0	-96.0%	0.2%	0.0%	0.0%
	PFC		2.6	0.0	0.0	-99.0%	0.3%	23.3%	0.0%
	All		3.1	0.0	0.0	-98.5%	0.4%		0.0%
2D. Non-energy products from fuels and solvent use	CO_2		0.2	0.3	0.3	72.6%	3.2%	0.2%	0.2%
	CH_4		0.0	0.0	0.0	105.7%	0.0%	0.0%	0.0%
	All		0.2	0.3	0.3	72.6%	3.2%		0.2%
2E. Integrated circuit or semiconductor	PFC	non key	0.0	0.0	0.0	73.2%	0.4%	37.2%	0.0%
2F. Product uses as substitutes for ODS	HFC		0.0	1.4	1.4		14.0%	79.0%	0.8%
2G. Other	CO_2	non key	0.0	0.0	0.0	225.5%	0.0%	0.0%	0.0%
	CH_4	non key	0.1	0.0	0.0	-9.1%	0.4%	0.3%	0.0%
	N_2O	non key	0.2	0.1	0.1	-61.6%	0.8%	1.1%	0.0%
	All		0.5	0.3	0.2	-54.5%	1.3%		0.1%
2H. Other process emissions	CO_2	non key	0.1	0.0	0.0	-77.4%	0.2%	0.0%	0.0%
Indirect CO2 emissions	CO_2	T	0.9	0.4	0.4	-53.0%	4.2%	0.3%	0.2%
National Total GHG emissions (excl. CO2 LULUCF)	CO_2		162.7	159.5	153.6				
	CH_4		31.8	17.3	17.2				
	N_2O		17.5	8.0	7.9				
	HFCs		5.6	1.7	1.8				
	PFCs		2.7	0.2	0.1				
	SF_6		0.2	0.1	0.1				
	All		220.5	186.8	180.7				

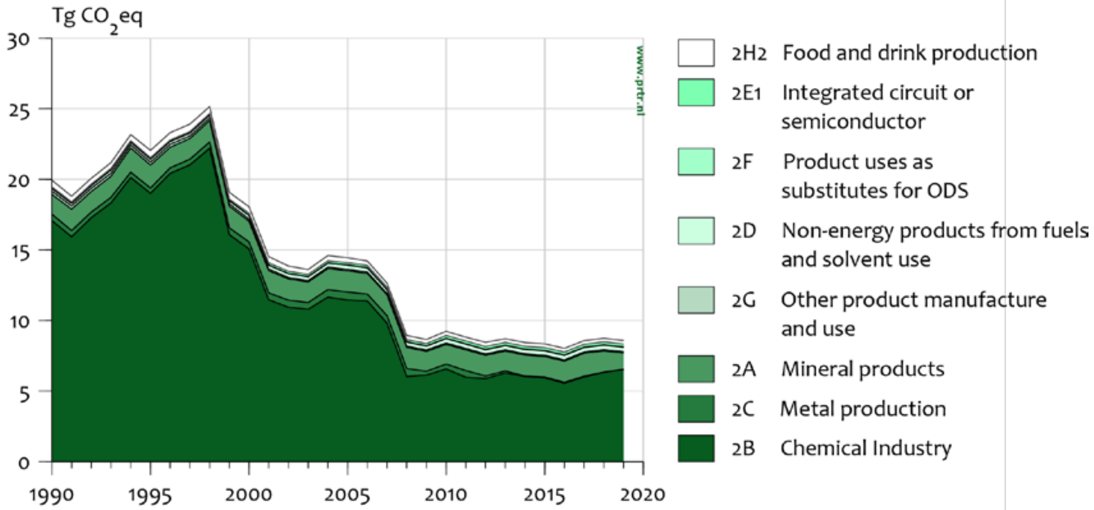


Figure 4.1 Sector 2 Industrial processes and product use – trend and emissions levels of source categories, 1990–2019.

As figure 4.1 shows, there were 2 large decreases in emissions in the chemical industry (2B). One was around 1999, due to a reduction in HFC-23 emissions from HCFC-22 production, the other was in 2008 as a result of the bringing under EU-ETS of the production of nitric acid, resulting in a sharp reduction in N_2O emissions.

In the Netherlands, many industrial processes take place in only one or two companies. Because of the sensitivity of data from these companies, only 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.

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

4.2 Mineral products (2A)

4.2.1 Source 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: bricks and roof tiles, vitrified clay pipes and refractory products.

Process-related CO_2 emissions from ceramics result 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	Key	1990	2018	2019	2019 vs 1990	Contribution to total in 2019 (%) by		
			Emissions in Tg CO2 eq			%	sector	total gas	total CO2 eq
2A. Mineral industry	CO_2		1.41	1.50	1.15	-18.3%	11.3%	0.8%	0.6%
2A1. Cement production	CO_2	T	0.42	0.22	0.01	-98.5%	0.1%	0.0%	0.0%
2A2. Lime production	CO_2	non key	0.16	0.18	0.18	11.1%	1.8%	0.1%	0.1%
2A3. Glass production	CO_2	non key	0.14	0.07	0.07	-51.4%	0.7%	0.0%	0.0%
2A4a Ceramics	CO_2	non key	0.14	0.12	0.12	-11.1%	1.2%	0.1%	0.1%
2A4b Other uses of Soda Ash	CO_2	non key	0.07	0.12	0.12	69.0%	1.1%	0.1%	0.1%
2A4d Other	CO_2	L,T	0.48	0.78	0.66	36.3%	6.4%	0.4%	0.4%

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., (2021).

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 (closed since June 2020) has chosen to base the calculation of CO_2 emissions on the carbonate content of the process input. See (Honig et al., 2021). Process emission data therefore can be taken from the AER.

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.
Lime production does not occur in the paper industry in the Netherlands.
Limestone use depends on the level of beet sugar production.
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.

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., 2021).

From the 2015 submission, 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 manufacture 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:

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

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 fractions and EFs (both defaults) are obtained from the 2006 IPCC Guidelines.

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 the years 2001 and 2002, net domestic consumption of soda ash is 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 the years 1990–2000 and 2003 onwards, these figures are estimated by extrapolating from the figures for 2001 and 2002. This extrapolation incorporates the trend in chemicals production, since 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)
CO_2 emissions from this source category are based on figures for the consumption of limestone for FGD in the coal-fired power plants, limestone and dolomite use in crude steel production and apparent dolomite consumption (mostly in road construction).
After comparison of the emissions with the limestone use, the sum of the CO_2 emissions from the AERs of the coal-fired power plants is included in the national inventory.

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 by IPCC source category. Uncertainty estimates used in the Tier 1 analysis are based on expert judgement, since no detailed information is available that might enable the uncertainties in the emissions reported by the facilities (cement clinker production, limestone and dolomite use, and soda ash production) to be assessed.
The uncertainty in CO_2 emissions from cement clinker and limestone production is estimated to be in the range of 10% and is mainly determined by uncertainties in the EFs.
For dolomite and limestone use for FGD, the uncertainty is estimated to be 50%. This is mainly determined by the relatively high uncertainty in the activity data. The activity data for soda ash use and glass production are also assumed to be relatively uncertain (50% and 25%, 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 was not 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 first 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.
For the source categories 2A and 2A4d, the activity and emissions data of the AERs were compared with the EU-ETS monitoring reports. No differences were found. This (annual) comparison is documented in a (confidential) document. This document is available to the ERT upon request and after signature of a confidentiality agreement.
For category 2A4b no such comparison could be made up to now, because of the unavailability of ETS data. However, the contribution to the national total is only 0.1%.

4.2.5 Category-specific recalculations

The 2018 CO_2 emission figure for 2A2 Sugar production has been recalculated (error correction).

4.2.6 Category-specific planned improvements

Although category 2A4b makes only a minor contribution to the national total (0.1%), we still will endeavour to find out in which chemical industries soda ash is used, and to investigate whether EU-ETS data could be used to improve the data in the inventory. Unfortunately we didn't succeed in this for this submission.

4.3 Chemical industry (2B)

4.3.1 Source category description

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

- Ammonia production (2B1): CO_2 emissions: in the Netherlands, 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.
- Nitric acid production (2B2): N_2O emissions: The production of nitric acid (HNO_3) generates N_2O, which is 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 is manufactured (since 1952) by only 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 arise from the oxidation of coke used as a reductant.
- Soda ash production (2B7): CO_2 emissions are related to the non-energy use of coke.
- Petrochemical and carbon black production (2B8):
  - 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 in the Netherlands repackages HFCs from large units (e.g. containers) into smaller units (e.g. cylinders) and trades in HFCs. There are also many companies in the Netherlands that import small units with HFCs and sell them in the trading areas.
- Other (2B10):
    - 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: Carbon electrodes are produced from petroleum coke and coke, used as feedstock. In this process CO_2 is produced.
    - Activated carbon production: Norit is 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.

Adapic acid (2B3), glyoxal (2B4b), glyoxylic acid (2B4c) and calcium carbide (2B5b) are not produced in the Netherlands. So the Netherlands does not report these emissions in the CRF under 2B4, which are covered by the EU-ETS.
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 the splitting into combustion and process.

Many processes related to this source category take place in only one or two companies. Because of the confidentiality of data from these companies, 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 categories. Emissions from this category contributed 7.7% of total national GHG emissions (excluding LULUCF) in 1990 and 3.6% in 2019.

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	Key	1990	2018	2019	2019 vs 1990	Contribution to total in 2019 (%) by		
			Emissions in Tg CO2 eq			%	sector	total gas	total CO2 eq
2B. Chemical industry	CO_2		4.1	4.3	4.4	7.6%	43.5%	2.9%	2.5%
	CH_4		0.3	0.3	0.3	12.8%	3.0%	1.8%	0.2%
	N_2O		7.1	1.4	1.4	-80.9%	13.2%	17.1%	0.7%
	HFC	T	5.6	0.2	0.4	-93.2%	3.7%	21.0%	0.2%
	PFC		0.0	0.1	0.0		0.5%	39.6%	0.0%
	All		17.1	6.3	6.5	-61.7%	63.9%		3.6%
2B1. Ammonia production	CO_2	L	2.7	2.5	2.3	-12.8%	23.0%	1.5%	1.3%

Sector/category	Gas	Key	1990	2018	2019	2019 vs 1990	Contribution to total in 2019 (%) by		
			Emissions in Tg CO2 eq			%	sector	total gas	total CO2 eq
2B2. Nitric acid production	N_2O	T	6.1	0.3	0.3	-95.1%	2.9%	3.8%	0.2%
2B4. Caprolactam production	N_2O	L	0.7	0.7	0.7	-8.8%	6.6%	8.6%	0.4%
2B7. Soda ash production	CO_2	non key	19.0	NO	NO	-100.0%	0.0%	0.0%	0.0%
2B8. Petrochemical and carbon black production	CO_2	L,T	0.3	0.5	0.6	65.1%	5.4%	0.4%	0.3%
	CH_4	L	0.3	0.3	0.3	12.8%	3.0%	1.8%	0.2%
2B9. Fluorochemical production	HFC	T	7.3	0.2	0.4	-94.8%	3.7%	21.0%	0.2%
	PFC	non key	0.0	0.1	0.0		0.5%	39.6%	0.0%
2B10. Other chemical industry	CO_2	L,T	1.0	1.4	1.5	48.8%	15.1%	1.0%	0.9%

Figure 4.2 shows the trend in CO_2-equivalent emissions from 2B (Chemical industry) in the period 1990–2019.

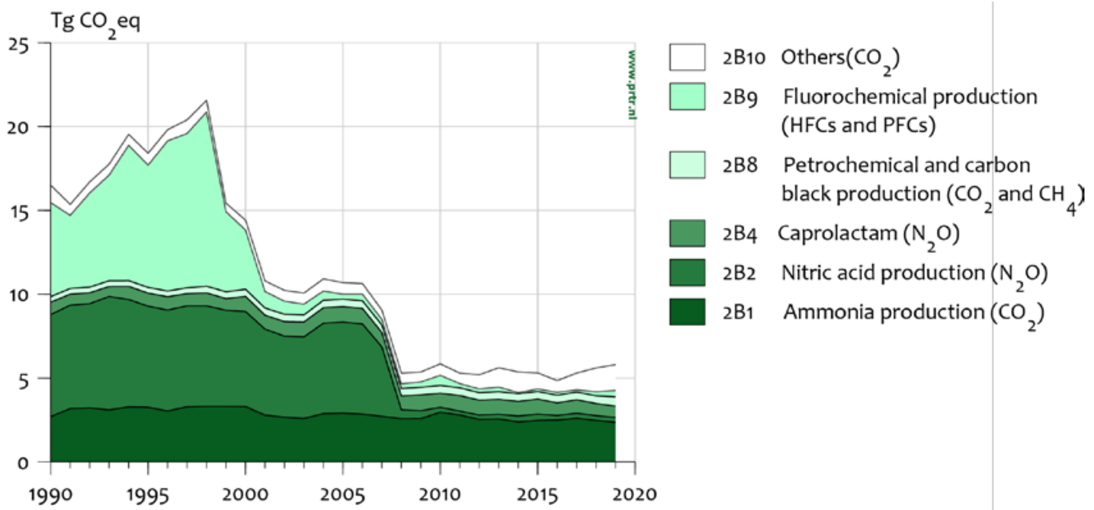


Figure 4.2 2B Chemical industry – trend and emissions levels of source categories, 1990–2019.

Mainly due to a reduction in HFC-23 emissions from HCFC-22 production, total GHG emissions from 2B (Chemical industry) decreased from 1990 to 2001. N_2O emissions remained fairly stable between 1990 and 2000 (when there was no policy aimed at controlling these emissions). Also between 2001 to 2007, total GHG emissions from 2B remained rather stable. As Table 4.4 shows, 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 production process of nitric acid. Since 2008, total GHG emissions from 2B have been relatively stable again.

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	6,085	740	244	7,069
1991	6,169	657	244	7,070
1992	6,228	648	248	7,125
1993	6,765	598	245	7,608
1994	6,407	784	260	7,451
1995	6,035	777	268	7,080
1996	6,020	794	277	7,090
1997	6,020	733	285	7,037
1998	5,990	774	293	7,057
1999	5,731	691	301	6,723
2000	5,670	903	309	6,882
2001	5,134	833	317	6,284
2002	4,837	866	325	6,028
2003	4,864	890	333	6,088
2004	5,400	921	342	6,663
2005	5,440	917	350	6,707
2006	5,380	926	358	6,664
2007	4,138	861	366	5,366
2008	536	822	374	1,733
2009	473	941	382	1,796
2010	290	846	390	1,526
2011	234	926	364	1,524
2012	254	895	388	1,536
2013	274	898	368	1,539
2014	356	874	378	1,607
2015	370	902	336	1,609
2016	270	755	380	1,405
2017	299	802	387	1,489
2018	282	726	344	1,352
2019	297	675	382	1,353

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 the period 2002–2006 the emissions fluctuations were caused by variations in production levels.
Technical measures (as a result of bringing under the EU-ETS) implemented at all nitric acid plants in the third quarter of 2007 resulted in an emissions reduction of 23% compared with 2006. In 2008, the full effect of the measures was reflected in the low 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 NIR's (like the NIR2020), 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)
The emissions fluctuations 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 for the period 1990–2019. Emissions of HFC-23 increased by approximately 35% in the period 1995–1998, due to increased production of HCFC-22. In the period 1998–2000, however, 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 the secondary factor influencing the variation in emission levels during the 2000–2008 period.

Due to the economic crisis, the production level of HCFC-22 was much lower in the last quarter of 2008 and in 2009, resulting in lower HFC-23 emissions in both 2008 and 2009. 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 the fluctuations in the removal efficiency of the TC and to a lesser extent by the production level. The significant emissions fluctuations in sub-category 2B9b3 (Handling activities) during the period 1992–2019 can be explained by the large fluctuations in handling activities, which depend on the demand from customers.

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	5,606	0	5,606
1991	4,366	0	4,366
1992	5,594	27	5,621
1993	6,257	54	6,312
1994	7,941	137	8,078
1995	7,285	13	7,298
1996	8,712	248	8,960
1997	8,486	718	9,204
1998	9,855	544	10,399
1999	4,352	418	4,769
2000	3,062	472	3,534
2001	866	118	983
2002	569	215	784

Year	2B9a: HFC-23	2B9b3: HFCs/PFCs	Total
2003	525	121	645
2004	448	97	546
2005	248	55	303
2006	355	57	412
2007	307	37	344
2008	268	23	291
2009	195	217	411
2010	494	148	642
2011	211	81	292
2012	159	76	235
2013	238	54	291
2014	45	28	73
2015	118	43	161
2016	158	66	224
2017	101	48	149
2018	222	122	344
2019	273	155	427

4.3.2 *Methodological issues*

For all the source categories of the chemical industry, the methodologies used to estimate GHG emissions comply with the 2006 IPCC Guidelines, volume 3, as described in Honig et al. (2021: sections 2.2.3.1 to 2.2.3.6).

Country-specific methodologies are used for CO_2 process emissions from the chemical industry. More detailed descriptions of the methods used and EFs can be found in the methodology report (Honig et al., 2021), as indicated in Section 4.1. 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 information. According to the Guidelines, CO_2 that is stored in the urea should be subtracted from the emissions from the production. Emissions occurring in the sectors where the urea is applied (agriculture, car-SCR, melamine production), should be allocated to those sectors. Up to the 2020 submission, the Netherlands did not subtract this storage, so the stored CO_2 was allocated to Ammonia production (2B1). In this submission this is corrected: the stored CO_2 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 there by application. CO_2 emission from melamine production is allocated to the new CRF category 2B8g. Overall, 2B1 CO_2 emission is roughly 1,000 Gg lower over the whole timeseries 1990-2019 (including a small increase at 2B8g: melamine production). This also lowers the national total, because only a very small part of the ammonia is applied in the Netherlands in the sectors mentioned above.

The 2B1 emissions in the Netherlands are covered by the EU-ETS. For ETS the CO_2-storage should not be subtracted.

- 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 theses EFs have been used to recalculate emissions for the period 1990–1998.
- 2B4a (Caprolactam production): From 2015 onwards, N_2O emissions are based on the updated and improved measurement programme in 2014. For the period 2005–2014 a recalculation was done with the help of the insights provided by the updated and improved N_2O emissions measurement programme.
  The recalculation for the period 1990–2004 was done by using the 'new' average IEF for 2005–2015. Information about the methods used before 2015 can be found in Honig et al.,2021), as indicated in Section 4.1.
- 2B5 (Carbide production): The activity data (petcoke) are confidential, so the IPCC default EF was 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 Netherlands has included the notation code 'NO' in the CRF tables from 2010 onwards, as soda ash production has stopped. See (Honig et al., 2021) for the 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 are calculated with the help of the emission and production levels in 2017 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. As there are no actual activity data available for ethylene production at this moment in the Prodcom database from EUROSTAT, the Netherlands cannot

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. In order to comply with the 2006 IPCC Guidelines, volume 3, an IPCC Tier 2 method is used to estimate emissions from this source category. HFC-23 emissions are calculated using the following formula:
  HFC-23 emissions = HFC-23 load in untreated flow - amount of untreated HFC-23, destroyed in the TC.
  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 TC is registered by the producer.
- 2B9b3 (Handling activities: HFCs): Tier 1 country-specific methodologies are used to estimate emissions of HFCs from handling activities. The estimations are based on emissions data reported by the manufacturing and sales companies. Activity data used to estimate HFC emissions are confidential. The EFs used are plant-specific and confidential, and they are based on 1999 measurement data.
- 2B10 (Other): Because no IPCC methodologies exist for these processes, 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 ETS emission reports to the NEa, from which 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 been re-examined recently, 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 were included in the EU-ETS. So, 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 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 1990–2002 are kept equal to the emissions 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 the CBS.

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 approximately 10%. For all the other sources in this category the uncertainty is estimated to be about 70%.
The uncertainty in the activity data and the EF for CO_2 is estimated at 2% and 10%, respectively, for ammonia production and at 50% for all the other sources in this category.
The uncertainty in the annual emissions of N_2O from caprolactam and acrylonitrile production is estimated to be approximately 30%.
Since N_2O emissions from HNO_3 production in the Netherlands are included in the EU-ETS, all companies have continuous measuring of 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.
The series 2B1 and 2B10 have been recalculated via a methodology consistent over the whole series.

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, N2O emissions from HNO3 production in the Netherlands came under the EU-ETS. For this purpose, the companies developed monitoring plans that were approved by the NEa (the government organisation responsible for EU-ETS in the Netherlands, including emission verification). In 2018, the companies' emissions reports (2017 emissions) were independently verified and submitted to the NEa, where they were checked against 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 calculation quality.
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.
These (annual) comparisons are documented in a (confidential)

document. This document can be made available to the ERT upon request, after signature of a confidentiality agreement.

4.3.5 *Category-specific recalculations*

As described in section 4.3.2, two timeseries have been recalculated: 2B1 and 2B10.
Ammonia production (2B1): As a result of subtracting the CO2 stored in the urea, which is exported for the largest part, 2B1 CO2 emissions are lower.
Industrial gas production (2B10): the timeseries has been recalculated, as a result of not assuming CO2 storage in the product gas anymore. Besides, part of the emissions from chemical waste gas in CRF category 1A2c has been reallocated to 2B10 for the years 2012-2018.

Table 4.6 below reflects these changes; it shows both the old and recalculated timeseries of 2B1 and 2B10.

Table 4.6 recalculations 2B1 and 2B10

Year	NIR 2020 2B1 CO2 [Gg]	NIR 2021 2B1 CO2 [Gg]	Difference CO2 [Gg]	NIR 2020 2B10 CO2 [Gg]	NIR 2021 2B10 CO2 [Gg]	Difference CO2 [Gg]
1990	3730	2695	-1035	583	1038	454
1991	4203	3174	-1029	196	650	454
1992	4273	3207	-1066	201	655	454
1993	4156	3097	-1059	194	648	454
1994	4343	3275	-1069	197	651	454
1995	4303	3249	-1054	302	704	402
1996	4073	3033	-1041	295	662	367
1997	4283	3283	-1000	328	819	491
1998	4351	3309	-1042	307	696	389
1999	4323	3312	-1010	270	516	246
2000	4350	3295	-1056	304	586	282
2001	3655	2780	-875	327	634	307
2002	3502	2659	-843	330	644	313
2003	3463	2586	-877	336	658	322
2004	3718	2873	-845	357	726	369
2005	3741	2898	-843	373	687	314
2006	3700	2845	-855	361	632	271
2007	3634	2712	-922	340	553	213
2008	3434	2571	-864	385	637	252
2009	3442	2576	-866	360	596	236
2010	3803	2956	-847	441	687	246
2011	3801	2790	-1011	414	626	212
2012	3627	2531	-1096	621	849	228
2013	3760	2555	-1205	653	1155	502
2014	3564	2374	-1190	706	1232	526
2015	3921	2470	-1450	610	959	349
2016	3815	2489	-1326	492	698	206
2017	3942	2598	-1344	709	1008	300
2018	3757	2468	-1289	1416	1420	4
2019		2349	-		1544	-

4.3.6 Category-specific planned improvements
No improvements are planned.

4.4 Metal production (2C)
4.4.1 Source category description
General description of the source categories

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 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 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 another 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.

There are some small Ferroalloy trading companies in the Netherlands, which do not produce ferroalloys and so do not have GHG process emissions that would be included in 2C2. Their combustion emissions are included in 1A2.

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

- 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, from the main source categories. 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 4.9). From then on, emissions depended mainly on the number of anode effects and little on production level.

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	Key	1990	2018	2019	2019 vs 1990	Contribution to total in 2019 (%) by		
			Emissions in Tg CO2 eq			%	sector	total gas	total CO2 eq
2C. Metal Production	CO_2		0.5	0.0	0.0	-96.0%	0.2%	0.0%	0.0%
	PFC		2.6	0.0	0.0	-99.0%	0.3%	23.3%	0.0%
	All		3.1	0.0	0.0	-98.5%	0.4%	0.0%	0.0%
2C1. Iron and steel production	CO_2	non key	0.0	0.0	0.0	-58.5%	0.2%	0.0%	0.0%
2C3. Aluminium production	CO_2	T	0.4	0.0	0.0	-100.0%	0.0%	0.0%	0.0%
	PFC	T	2.6	0.0	0.0	-99.0%	0.3%	23.3%	0.0%

Because of the closure of Zalco, PFC emissions decreased after 2011 to 11 Gg CO_2 eq. in 2013. In 2014 PFC emissions decreased to 0.05 Gg CO_2 eq. This was caused by the closure of Aldel at the end of 2013. The restart (under the name Klesch Aluminium Delfzijl, Damco since 2017) at the end of 2014 resulted in increases in PFC emissions in 2015 and 2016.

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	2,049	588	2,638
1991	2,034	577	2,611
1992	1,849	521	2,369
1993	1,876	518	2,394
1994	1,799	498	2,297
1995	1,746	485	2,230
1996	1,946	521	2,467
1997	2,079	549	2,628
1998	1,530	491	2,020
1999	1,134	433	1,567
2000	1,188	454	1,642
2001	1,135	434	1,570
2002	1,744	706	2,450
2003	389	129	518
2004	100	24	124
2005	82	20	102
2006	56	13	69
2007	92	21	113
2008	67	16	84
2009	40	10	50
2010	57	11	67
2011	79	17	96
2012	15	3	18
2013	9	2	11
2014	0.04	0.01	0.05

Year	PFC14 (CF_4)	PFC116 (C_2F_6)	Total
2015	5.4	1.1	6.5
2016	11.3	2.3	13.6
2017	10.8	2.2	13.0
2018	18.7	3.8	22.5
2019	22.7	4.6	27.3

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. (2021: 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 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 obtained from the C mass balance.

From 2000 onwards, data reported in the C mass balance of Tata Steel have been used to calculate CO_2 process emissions. 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 crude steel production.

In former submissions the Netherlands reported fuel-related emissions in this category. During the in-country review this was considered not to be transparent. To improve transparency all fuel-related emissions are now reported in the Energy sector, with the result that emissions in this category have decreased strongly in comparison with previous submissions.

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

Aluminum production (2C3)

A Tier 1a IPCC method (IPCC, 2006) is used to estimate CO_2 emissions from the anodes used in the primary production of aluminium, with aluminium production serving as activity data. Activity and emissions data are based on data reported in the AERs of both companies. In order to calculate the IPCC default EF, the stoichiometric ratio of carbon needed to reduce the aluminium ore to pure aluminium is based on the reaction:

$$Al_2O_3 + 3/2C \rightarrow 2Al + 3/2\ CO_2.$$

This factor is corrected to include additional CO_2 produced by the reaction of the carbon anode with oxygen in the air. A country-specific EF of 0.00145 tons CO_2 per ton of aluminium is used to estimate CO_2 emissions and it has been verified that this value is within the range of the IPCC factor of 0.0015 and the factor of 0.00143 calculated by the World Business Council for Sustainable Development (WBCSD) (WBCSD/WRI, 2004).

Estimations of PFC emissions from primary aluminium production reported by these 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.

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 approximately 6% for iron and steel production and 5% for aluminium production, whereas the uncertainty in PFC emissions from aluminium production is estimated to be 20%. The uncertainty in the activity data is estimated at 2% for aluminium production and 3% for iron and steel production. The uncertainty in the EFs for CO_2 (from all sources in this category) is estimated at 5% and for PFC from aluminium production at 20%.

Time series consistency

A consistent methodology is 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 can be made available to the review team.

4.4.5 Category-specific recalculations

Due to an error in the dolomite figures as delivered by the producer, for 2C1 Iron and steel production the 2018 CO2 emission figure has been recalculated.
Due to an error, for 2C3 Aluminium production the 2018 PFC's emission figures have been recalculated.

4.4.6 Category-specific planned improvements

No improvements are planned.

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 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 are identified as an Approach 2 level and trend key source 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	Key	1990	2018	2019	2019 vs 1990	Contribution to total in 2019 (%) by		
			Emissions in Tg CO2 eq			%	sector	total gas	total CO2 eq
2D. Non-energy products from fuels and solvent use	CO_2		0.2	0.3	0.3	72.6%	3.2%	0.2%	0.2%
	CH_4		0.0	0.0	0.0	105.7%	0.0%	0.0%	0.0%
	All		0.2	0.3	0.3	72.6%	3.2%	0.0%	0.2%
2D1. Lubricant use	CO_2	non key	0.1	0.1	0.1	8.7%	0.9%	0.1%	0.1%
2D2. Paraffin wax use	CO_2	L,T	0.1	0.2	0.2	105.7%	2.1%	0.1%	0.1%
2D3. Other non specified	CO_2	non key	0.0	0.0	0.0		0.2%	0.0%	0.0%

Overview of shares and trends in emissions
The small CO_2 and CH_4 emissions from 2D1 and 2D2 remained fairly constant between 1990 and 2019. CO_2 emissions from Urea use in diesel vehicles (2D3) increased from 0 to 21 kton during the period 2005-2018. Due to the small amounts these are not visible in Table 4.10.

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., (2021), 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, an ODU factor of 20% and for the use of waxes an ODU factor of 100% 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., (2021).

The activity data are based on fuel use data from the CBS.

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 to be approximately 50% in the ODU factor for lubricants. The uncertainty in the activity data (such as domestic consumption of these fuel types) is generally very large, since it is based on production, import and export figures.
These sources do not affect the overall total or the trend in direct GHG emissions.

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*
There were no category specific recalculations.

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 released via the use of these compounds in Semiconductor manufacture (2E1). SF_6 emissions are included in 2G2. PFC and SF_6 emissions from thin-film transistor (TFT) flat panel displays (2E2), Photovoltaics (2E3) and Heat transfer fluid (2E4) manufacturing do not occur in the Netherlands. No Other sources (2E5) are 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 0.3% in 1990 and 2.2% in 2019). The latter figure corresponds to 0.04 Tg CO_2 eq. and accounts for 0.02% of the national total GHG emissions in 2019 (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	Key	1990	2018	2019	2019 vs 1990	Contribution to total in 2019 (%) by		
			Emissions in Tg CO2 eq			%	sector	total gas	total CO2 eq
2E1. Integrated circuit or semiconductor	PFC	non key	0.0	0.0	0.0	73.2%	0.4%	37.2%	0.0%

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	‘16	‘17	‘18	‘19
PFCs	25	50	261	254	305	241	168	205	85	92	43	44	44

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., (2021), see 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 confidential information. Detailed information on the activity data and EFs can be found in the methodology report (Honig et al., 2021).

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 to be 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*

No recalculations have been made.

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. Because of the sensitivity of data from these companies, only the sum of the HFC emissions of 2F2–2F5 is reported (included in 2F6).
Because of data limitations it is not possible to include all information on individual sub-categories of 2F1 in CRF Table 2(II)B-Hs2. Therefore, the sum of all emissions is included in the field ‘emissions from stocks’ for

commercial, industrial and transport refrigeration, stationary air-conditioning and mobile air-conditioning.
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 70% in 2019 (and 79% of total HFC emissions in 2019). This corresponds to 1.4 Tg CO_2 eq. and accounts for 0.8% of the national total GHG emissions in 2018 (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	Key	1990	2018	2019	2019 vs 1990	Contribution to total in 2019 (%) by		
			Emissions in Tg CO2 eq			%	sector	total gas	total CO2 eq
2F. Product uses as substitutes for ODS	HFC		0	1.4	1.4		14.0%	79.0%	0.8%
2F1. Stationary refrigeration and Mobile air-conditioning	HFC	L,T	0	1.2	1.3		12.3%	69.4%	0.7%
2F6. Other	HFC	T	0	0.2	0.2		1.7%	9.6%	0.1%

Starting in the previous submission (NIR 2019), the calculation method (via a stock model) for Stationary refrigeration (2F1) was replaced by a new method. The new method uses the Refrigerants Registration System to estimate emissions from 2013 onwards. This system is the result of a European obligation, whereby building owners are required to register refrigerants.

Emissions for 2F1 have been calculated for 2017 because this is the most recent year for which emissions data are available on account of the delay in reporting. Due to the phasing-out of refrigerants with a high GWP, emissions decreased from 1.053 Mton in 2015 to 0.839 Mton in 2016 (see Table 4.13). In 2017 the emission increased very slightly. Emission data for 2018 and 2019 were kept the same as in 2016.

With the new method, emission figures are available for:
- 4 sectors: Commercial, Industrial, Stationary airco's 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	*10*	3	62	75
1995	*38*	9	201	248
1996	*88*	17	474	579
1997	*135*	31	746	911
1998	*166*	54	849	1,069
1999	*194*	84	849	1,126
2000	*263*	122	689	1,074
2001	*337*	163	386	886
2002	*405*	204	181	790
2003	*479*	244	167	890
2004	*548*	282	214	1,044
2005	*615*	314	152	1,081
2006	*680*	343	171	1,193
2007	*751*	367	238	1,356
2008	*825*	387	261	1,473
2009	*884*	404	226	1,514
2010	*915*	409	205	1,528
2011	*936*	415	287	1,639
2012	*969*	420	222	1,611
2013	1,160	422	186	1,768
2014	955	424	175	1,554
2015	1,053	425	175	1,653
2016	839	425	175	1,440
2017	882	416	175	1,473
2018	882	398	175	1,455
2019	882	379	175	1,436

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. (2021: sections 2.2.3.9–2.2.3.11).

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

- Stationary refrigeration (2F1): Until the 2016 submission, consumption data of HFCs were obtained from the annual reports by PriceWaterhouseCoopers. From 2015 onwards no consumption data of HFCs are available.
- From the 2019 submission onwards the figures from the Refrigerants Registration System, which includes information about leakages, the filling of (new) installations and dismantling, are used.
  The collection of data within the Refrigerants Registration System takes place as follows:
  - Data at plant level 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 getting the data available. This means that in this submission, final figures are provided up to and including 2017. The 2018 and 2019 figures are kept equal to last year for which figures are available (2017). In the 2022 submission, the 2018 figures from the current submission will be replaced by the final figures for 2018.

  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, because the mix of high- and lower-GWP refrigerants is very random throughout the years: a trend cannot be detected. Also the Surrogate Data technique is not appropriate, because no data can be found that has any correlation with the random-like use of refrigerants with different GWP's. So the overall conclusion is the an extrapolation cannot be performed, therefore the emissions from the last 2 years are kept at the same level.
- 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 the CBS. The amounts of recycled and destroyed refrigerants were obtained from ARN, a waste-processing organisation (personal communication).
- Other applications (2F6): HFC emissions from 2F2, 2F3, 2F4 and 2F5:
  Until the 2016 submission, consumption data of HFCs were obtained from the annual reports by PriceWaterhouseCoopers. From 2015 onwards no consumption data of HFCs are available. Therefore, emissions from these sources are kept equal to the emissions of 2014.

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. From this submission onwards figures from the Refrigerants Registration System are used. These include information about leakages, the filling of (new) installations and dismantling.
- 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., 2021), as indicated in Section 4.1. For reasons of confidentiality, the detailed figures for Mobile air-conditioning (2F1) are not included in this submission, but can be made available for review purposes.

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 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 have been used to estimate emissions. The stock model method has been used for the period 1990–2012 and the method using the Refrigerants Registration System 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 figures. To determine the different figures, 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 uses figures from the Refrigerants Registration System to calculate emissions. 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 makes it the best source we have and as complete as possible. In addition, the emissions calculated with the new method are lower than those calculated with the old stock model method. That the stock model gave higher emissions was 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, while according to the new method the average leakage rate during the period 2013–2017 was approximately 4%.

Figures from the Refrigerants Registration System are available from 2013 onwards.

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, for this submission the Overlap splicing technique from the IPCC Guidelines is used to create a consistent time series for the whole period 1990–2019. The formula that is 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, 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, and with the Overlap splicing technique the emissions from 1990 tot 2012 are lowered to fit on the 2013-2019 series. The result is shown in *italics* in table 4.13, and in figure 4.3 below.

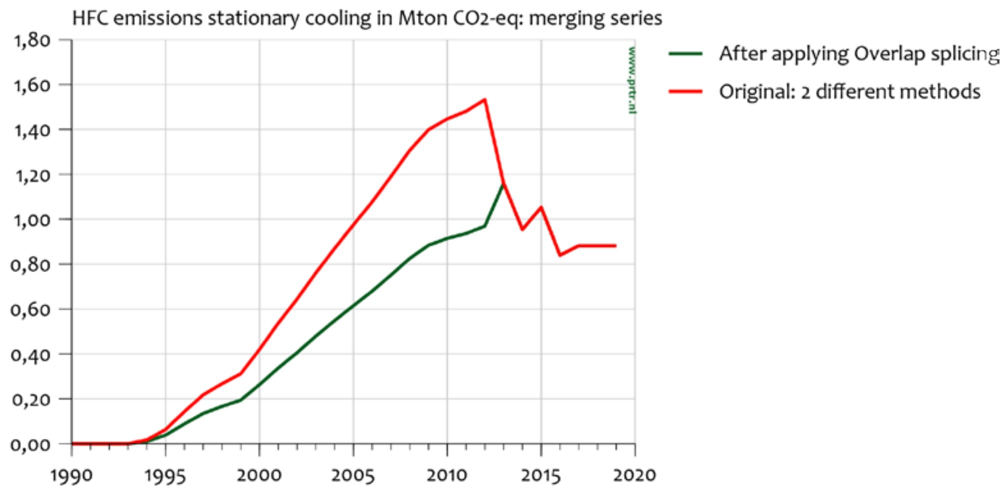


Figure 4.3 overlap splicing method for HFC stationary cooling

4.7.4 *Category-specific QA/QC and verification*

The source categories are covered by the general QA/QC procedures discussed in Chapter 1. For the method used to estimate HFC emissions from Stationary refrigeration (2F1): HFC emissions, a quality control procedure is included in volume 3, paragraph 7.5.4.1 of the 2006 IPCC Guidelines. This control procedure compares the annual national HFC refrigerant market declared by the refrigerant distributors with annual HFC refrigerant needs. However, because the annual reports by PriceWaterhouseCoopers are no longer available, the data needed to estimate HFC refrigerant use are not available, so the Netherlands cannot conduct this quality control.

4.7.5 *Category-specific recalculations*

As described in 4.7.3, the Overlap splicing technique from the IPCC Guidelines has been used to create a consistent time series for 2F1 Stationary cooling. On that basis, emissions for the period 1990–2012 have been recalculated, as shown in italics in table 4.14.
For 2F1 Mobile airconditioning, the 2018 CO2 emission figure has been recalculated (error correction).

4.7.6 *Category-specific planned improvements*

The Netherlands is working on a new method for Other applications (2F6), as well as an update of the uncertainty estimates for HFC emissions from HFC consumption (2F1).

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 Tg CO_2 eq.).

Sector / category	Gas	Key	1990	2018	2019	2019 vs 1990	Contribution to total in 2019 (%) by		
			Emissions in Tg CO2 eq			%	sector	total gas	total CO2 eq
2G. Other	CO_2	non key	0.000	0.001	0.001	225.5%	0.0%	0.0%	0.0%
	CH_4	non key	0.05	0.05	0.05	-9.1%	0.4%	0.3%	0.0%
	N_2O	non key	0.22	0.09	0.09	-61.6%	0.8%	1.1%	0.0%
	All		0.54	0.26	0.24	-54.5%	1.3%	0.0%	0.1%
2G2. SF6 and PFCs from other product use	SF6	non key	0.3	0.1	0.1	-57.4%	1.1%	100.0%	0.1%
2G3. N2O from product uses	N_2O		0.2	0.1	0.1	-65.4%	0.7%	1.0%	0.0%

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 1990–2018.

Table 4.15 Emissions from the use of SF_6, 1990–2017 (Gg CO_2 eq.).

	'90	'95	'00	'05	'10	'11	'12	'13	'14	'15	'16	'17	'18	'19
SF_6	207	261	259	204	154	125	173	120	135	139	134	126	111	111

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 61.3% during the period 1990–2019. 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 2019. For this reason, emissions of N_2O from food aerosol cans also increased sharply.
The small CO_2 and CH_4 emissions remained fairly constant between 1990 and 2019. 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 EnergieNed, the federation of energy companies in the Netherlands, and the emissions from testing were obtained from the single test laboratory that uses the gas. The methodology is described in Honig et al., (2021), see sections 2.2.3.12 and 2.2.3.13.

In 2006 (2008 submission), the method of estimating SF_6 emissions from electrical equipment changed. Before 2006, the method complied with the Tier 2 method (lifecycle EF approach, with a country-specific EF and total banked amounts of SF_6 as activity data).
For the 2006–2008 period, the country-specific method for this source is equivalent to the IPCC Tier 3b method and from 2009 onwards to the IPCC Tier 3a method. So, from 2006 onwards the country-specific method is based on the annual input and output of SF_6.

Furthermore, based on the new emissions data for 2006 and existing emissions data from 1999, SF_6 emissions from electrical equipment have been recalculated by interpolation for the period 2000–2005 to achieve a consistent time series.

For the period 1990–1998, the amounts of SF_6 banked are estimated by EnergieNed. These are used to estimate emissions prior to 1999, using the same methodology as for the emissions estimates for 1999.
The Netherlands considers these estimates to be preferable to an extrapolation of emissions figures backwards from 1999, as the estimates reported are in line with the trend in volume of the energy production sector in that period.
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. Since 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 derives from the following sources:

- fireworks: data on annual sales from the trade organisation;
- production of drinking water: volume and fuel use from the CBS.

The EFs used in 2G4 are based on the following:

- fireworks: CO_2: 43 kg/t; CH_4: 0.78 kg/t; N_2O: 1.96 kg/t (Visschedijk et al., 2021);
- production of drinking water: 2.47 tons CH_4/106 m^3 (Visschedijk et al., 2021).

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 2G1 is estimated to be 34% (IPCC Tier 3a method). For the activity data and the EFs for 2G1 the uncertainty is estimated to be approximately 30% and 15%, respectively.
Uncertainties for the other source categories under 2G vary from 50% to 70%.

Time series consistency

Consistent methodologies have been applied to all source categories. The quality of the N_2O activity data needed was not uniform for the complete time series, requiring some extrapolation from the data. This is not expected to significantly compromise the accuracy of the estimates, which is still expected to be sufficient.

4.8.4 *Category-specific QA/QC and verification*

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

4.8.5 *Category-specific recalculations*

No recalculations have been made.

4.8.6 *Category-specific planned improvements*

No improvements are planned.

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. CO_2 emissions in this source category are related to the non-energy use of fuels. 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 2019 are about 23% of 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	Key	1990	2018	2019	2019 vs 1990	Contribution to total in 2019 (%) by		
			Emissions in Tg CO2 eq			%	sector	total gas	total CO2 eq
2H. Other process emissions	CO_2	non key	0.1	0.0	0.0	-77.4%	0.2%	0.0%	0.0%

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., (2021), see 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 as recorded by the CBS 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 6% (3% 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, which are 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 2020

Emissions:	Total emissions from the Agriculture sector decreased from 18.5 Tg CO_2 eq. in 2018 to 17.9 Tg CO_2 eq. in 2019.
Key categories:	No key category: 3G Liming (CO_2)
Methodologies:	• Nitrous oxide emissions from organic soils and mineral soils were split up. The change was implemented for the years 2000 to 2019 and causes no changes to the emissions. • A new model has been used to distribute manure and artificial fertilizers applied over the different land types. This change resulted in a decrease of 1.4 Gg N_2O in 2000 and 0.8 Gg N_2O in 2018 compared to the N2O emissions reported in the NIR 2020. The splicing overlap technique has been applied to prevent a time series inconsistency for the years 1990-1999. • Carbon dioxide emissions from the application of urea were added to the inventory (source category 3H). Tier 1 from the IPCC guidelines was followed to calculate the CO_2 emissions. This change was implemented to the entire time series. This change resulted in an increase of the CO_2 emissions from the agriculture sector by 1.5 Gg in 1990 and 50.8 Gg in 2019, respectively.

5.1 Overview of sector

Emissions of GHGs from Agriculture include all anthropogenic emissions from the agricultural sector, with the exception of emissions from fuel combustion (these emissions are included in 1A2g Manufacturing industries and construction – Other and 1A4c Other sectors – Agriculture/Forestry/Fisheries) and carbon dioxide 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 sector Agriculture, subdivided in the relevant subcategories, to the total greenhouse gas emissions in the Netherlands.

Emissions of GHGs in this sector include the following:
- 3A Enteric fermentation (CH4);
- 3B Manure management (CH4 and N2O);
- 3D Crop production and agricultural soils (N2O);
- 3G Liming (CO2).
- 3H Urea application.

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 whole period 1990-2018, 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. The methods used to calculate the emissions are described in van der Zee *et al.* (2021). The activity data that was used to calculate the emissions are summarized in Van Bruggen *et al.* (2021), the activity data that could not be included into the CRF is included in this report. The calculation method of the VS and N excretion used in the Netherlands are described in Bannink *et al.* (2018) and CBS (2012), respectively.

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	Key	1990	2018	2019	2019 vs 1990	Contribution to total in 2019 (%) by		
			Emissions in Tg CO2 eq			%	sector	total gas	total CO2 eq
3. Agriculture	CO_2		0.2	0.1	0.1	-56.6%	0.4%	0.1%	0.0%
	CH_4		14.7	12.1	12.0	-18.5%	66.7%	69.5%	6.6%
	N2O		9.7	5.8	5.6	-42.0%	31.3%	71.0%	3.1%
	All		24.5	18.5	17.9	-26.9%	98.4%		9.8%
3A. Enteric fermentation	CH_4		9.2	8.3	8.1	-11.9%	45.4%	47.3%	4.5%
3B. Manure management	CH_4		5.4	3.8	3.8	-29.7%	21.3%	22.2%	2.1%
	N_2O		0.9	0.8	0.8	-16.4%	4.4%	10.0%	0.4%
	All		6.4	4.7	4.6	-27.6%	25.7%		2.6%
3D. Agriculture soils	N_2O		8.7	5.0	4.8	-44.8%	26.9%	61.1%	2.7%
3G. Liming	CO_2	non key	0.2	0.03	0.03	-80.9%	0.2%	0.0%	0.0%
3H. Urea application	CO_2	non key	0.0	0.1	0.05	2882.3%			
National Total GHG emissions (excl. CO2 LULUCF)	CO_2		162.7	159.5	153.6	-5.6%			
	CH_4		31.8	17.3	17.2	-45.9%			
	N_2O		17.5	8.0	7.9	-54.9%			
	total*		220.5	186.8	180.7	-18.0%			

* total incl. F-gases.

5.1.1 *Overview of shares and trends in emissions*

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

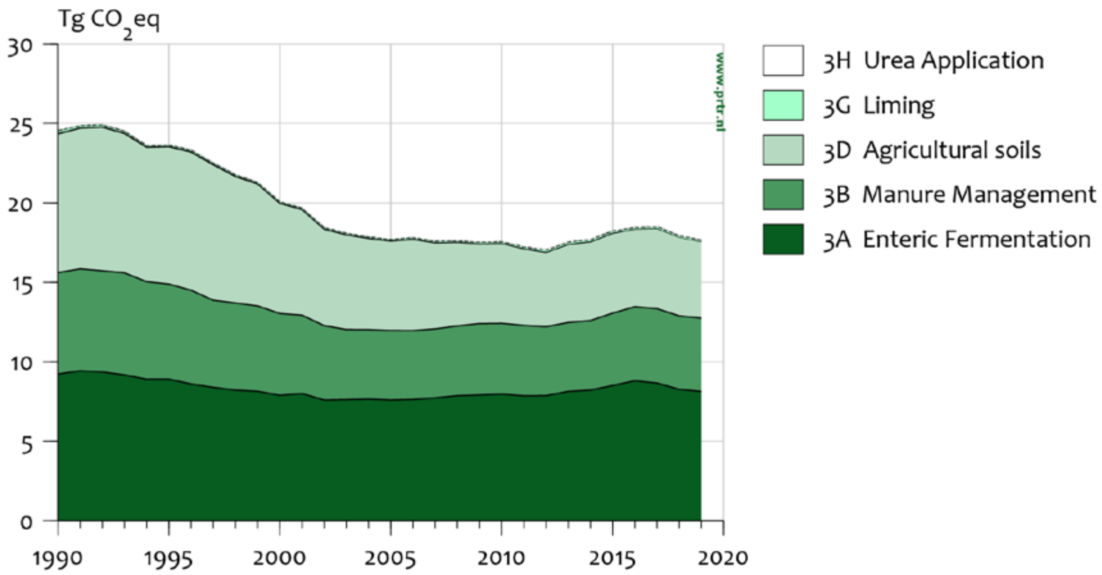


Figure 5.1 Sector 3 Agriculture – trend and emission levels of source categories, 1990–2019.

In 2019, agriculture contributed 9.7% of the national GHG emissions in comparison with 11.1% in 1990. However, this sector is a major contributor to both national total CH_4 and N_2O emissions. In 2019 agriculture accounts for 69.5% of the total CH_4 emissions and for 71.0% of the total N_2O emissions (Table 5.1).

Trend in carbon dioxide emissions

The CO_2 emissions from agriculture decreased between 1990 and 2008, which is caused by a decrease in application of liming products in the Netherlands. Between 2009 and 2015 CO_2 emissions increased as more urea was applied as an artificial fertilizer. Between 2016 and 2019 the CO_2 emissions decreased again.

Trend in methane emissions

The methane emissions from agriculture show a decline from 1990 to 2005, after which the emissions stabilize. From 2007 onwards an increase is shown, which continued to 2016. The last three years the CH_4 emissions of enteric fermentation and manure management decreased again. This trend in methane emissions is mainly explained by the decrease of mature dairy cattle.

Trend in nitrous oxide emissions

From 1990 onwards a decline in N_2O emissions can be seen, caused by a decrease of organic and inorganic N fertilizer application, a decrease in animal numbers and a decrease in animal production on pasture. From 2010 onwards, the decline of N_2O emissions stabilized.

5.1.2 *Overview of trends in activity data*

Animal numbers are the primary activity data used in all emission calculations for Agriculture. Animal numbers come from the annual Agricultural census, performed by Statistics Netherlands. Table 5.2 presents an overview of the different animal categories. The animal numbers decreased between 1990 and 2019 for total cattle, swine as well as sheep by 24%. For poultry, horses and goats the animal numbers increased by 1%, 10% and 1020%, respectively. The number of goats increased drastically due to an increased demand for goat milk and goat cheese. The increase was only reversed in 2010, when goats were culled due to the outbreak of Q fever. The increase resumed in the next year. The number of rabbits decreased by 55%, due to a decrease in demand for rabbit meat. The number of fur-bearing animals increased by 46%. Higher production rates per animal and restrictions via quotas (pig and poultry production rights and phosphate rights for dairy cattle) decreased the animal numbers of cattle, sheep and swine.

The phosphate quota introduced in 2018 limits the amount of cattle (all categories) that can be kept in the Netherlands and resulted in a decrease of cattle numbers from 2017 to 2019.

The increased production rates per animal resulted in a decrease of swine numbers until 2004, after which more animals were kept. The increase leveled off after 2011 and has been stable since.

An increase in the number of poultry was observed between 1990 and 2002. As a direct result of the avian flu outbreak in 2003 the 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. However, a decrease is shown between 2017 and 2018, which can be explained by a change in the way the number of poultry is collected. Before 2018 the poultry numbers where based on the Agricultural census filled in by farmers, with the number of animals present on a reference date of 1 April. From 2018 onward the poultry numbers in the Agricultural census are based on the Identification and Registration system for poultry (I&R pluimvee; data from the Netherlands Enterprise Agency), in which animals must be registered year-round. This results in lower poultry numbers. The difference is mainly caused by farmers who did not report their animal numbers as zero in the agricultural census when their stable was empty on the reference date, but instead gave the average of the number of chickens present. With the data from I&R this overestimation is minimized (Van Os *et al.*, 2019). In the NIR 2022 it will be assessed how to reduce the time series inconsistency caused by the change in the census. In 2019 the number of poultry decreased.

Table 5.2 Animal numbers in 1990–2019 (x 1,000) (www.cbs.nl)

Animal category	1990	1995	2000	2005	2010	2015	2018	2019
Cattle	4,926	4,654	4,069	3,797	3,975	4,134	3,844	3,750
Mature dairy cattle	1,878	1,708	1,504	1,433	1,479	1,622	1,591	1,578
Other mature cattle	120	146	163	151	115	80	69	63
Growing cattle	2,929	2,800	2,402	2,213	2,381	2,432	2,183	2,109
Sheep	790	771	680	647	558	523	563	598
Young stock and males	913	903	625	714	571	423	385	392
Swine	8,724	8,801	8,015	6,749	7,131	7,005	6,738	6,665
Young stock	5,191	5,596	5,102	4,563	5,124	5,598	5,653	5,549
Goats	37	43	98	172	222	292	387	420
Young stock and males	23	33	80	120	131	178	201	195
Horses	370	400	417	433	441	417	409	408
Mules and asses	NO	NO	NO	NO	1	1	1	1
Poultry	94,902	91,637	106,517	95,190	103,371	108,558	99,220	95,415
Other livestock								
Rabbits	105	64	52	48	39	48	41	48
Young stock	681	424	340	312	260	333	291	288
Furbearing animals	554	463	589	697	962	1,023	913	807

The methodology to calculate the CH_4 and N_2O emissions are based on different activity data (see Section 5.2 and 5.3). This includes sometimes different animal numbers, since for N_2O the N excretion data for female swine, sheep and goats and their young offspring/male animals is estimated based on the number of female animals.
The N excretion is estimated by the Working group on Uniformity of calculations of Manure and mineral data (WUM). Whereas for CH_4 calculations, default IPCC emission factors for average animals present are used. These calculations are therefore based on the total number of animals, including young and male animals. For cattle, the same animal numbers are used for the calculation of both CH_4 and N_2O emissions. Detailed information on data sources can be found in chapter 2 of the methodology report (van der Zee *et al.*, 2021).

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 also do not provide a default EF for enteric CH_4 emissions from poultry.

The CH_4 emissions from enteric fermentation have decreased from 9.2 Tg CO_2 eq to 8.1 Tg CO_2 eq (-11.9%) between 1990 and 2019 (Table 5.3), which is almost entirely explained by the decrease in CH_4 emissions from cattle. Cattle accounted for the majority (89%) of CH_4 emissions from enteric fermentation in 2019. Swine contributed 6% and the animal categories sheep, goats, horses and mules and asses accounted for the remaining 5%. The reduction of CH_4 emissions from cattle is caused by a decrease in animal numbers, partly mitigated by an increase in EF for mature dairy cattle (higher production/animal) 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	Key	1990	2018	2019	2019 vs 1990	Contribution to total in 2019 (%) by		
			Emissions in Tg CO2 eq			%	sector	total gas	total CO2 eq
3A. Enteric fermentation	CH_4		9.2	8.3	8.1	-11.9%	45.4%	47.3%	4.5%
3A1. Cattle	CH_4		8.2	7.4	7.2	-11.9%	40.3%	41.9%	4.0%
3A1. Mature dairy cattle	CH_4	L.T	5.2	5.4	5.3	3.0%	29.8%	31.0%	3.0%
3A1. Other mature cattle	CH_4	non key	0.2	0.1	0.1	-42.4%	0.7%	0.7%	0.1%
3A1. Growing cattle	CH_4	L.T	2.8	1.9	1.8	-37.2%	9.8%	10.2%	1.0%
3A2. Sheep	CH_4		0.3	0.2	0.2	-41.8%	1.1%	1.2%	0.1%
3A3. Swine	CH_4	L	0.5	0.5	0.5	-12.2%	2.6%	2.7%	0.3%
3A4. Other livestock	CH_4	non key	0.2	0.3	0.3	49.8%	1.5%	1.5%	0.1%

5.2.2 *Methodological issues*

For all the sub-source categories, the methodologies used to estimate emissions comply with the 2006 IPCC Guidelines. Detailed information on calculation methods and EFs can be found in chapter 3 of the methodology report (van der Zee *et al.*, 2021). An overview of the activity data can be found in CBS (2011 through 2019); Van Bruggen *et al.* (2020).

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. The north-west (NW) has a diet that contains mainly grass and the south-east (SE) has 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 the diets of cattle is published by CBS, (2014 through 2019). Table 5.4 shows the IEFs of the different cattle categories that are 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 (CBS, 2020).

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	2018	2019
Mature dairy cattle	110.4	114.4	120.0	125.0	128.0	129.0	134.6	135.3
Of which NW region	111.0	115.4	121.7	126.4	129.9	131.2	135.5	136.0
Of which SE region	109.9	113.5	118.4	123.6	126.7	127.5	134.0	134.8
Other mature cattle	70.3	71.3	72.1	76.7	78.1	79.1	77.6	77.4
Growing cattle	38.3	38.6	35.4	34.4	35.0	36.4	34.2	33.4

For both mature dairy cattle and other mature cattle, EFs increased primarily as a result of an increase in total feed intake during the period

1990–2019. For mature dairy cattle, a change in the feed nutrient composition partly counteracted this effect. Also the average weight of mature dairy cattle and the average milk production has increased, while the animal numbers decreased (CBS, 2019). Both increased the gross energy intake of mature dairy cattle in 2019 compared to 1990.

For growing cattle, the decrease of EF between 1990 and 2019 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 softened however by an increase in EF for white veal calves, as increasing amounts of roughage are fed because of 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 ca. 12%. 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 vary between 15% and 56%, mostly determined by the uncertainties in the emission factors (e.g. uncertainty in the EF for 3A3 Swine estimated at 40% whereas for 3A1a Mature dairy cattle at 15%). Uncertainties for the activity data are estimated between 2 and 36%.

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 the CBS. 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.

5.2.4 *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*

No category-specific recalculations were made.

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 2.1% to national total GHG emissions and 21.3% 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 11% and 9.8%, respectively, to the total GHG emissions of the Agriculture sector in 2019. Based on the trend, CH_4 emissions from manure management of poultry is a minor key source, which has decreased drastically over time(-83.1% from 1990 to 2019).

In 2019, N_2O emissions from manure management contributed 0.4% to the national total GHG emissions and 4.4% to the agriculture sector. Nitrous oxide emissions from manure management from cattle contribute 1.9% 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	Key	1990	2018	2019	2019 vs 1990	Contribution to total in 2019 (%) by		
			Emissions in Tg CO2 eq			%	sector	total gas	total CO2 eq
3B. Manure management	CH_4		5.4	3.8	3.8	-29.7%	21.3%	22.2%	2.1%
	N_2O		0.9	0.8	0.8	-16.4%	4.4%	10.0%	0.4%
	All		6.4	4.7	4.6	-27.6%	25.7%		2.6%
3B1. Cattle (total)	CH4		1.6	2.0	2.0	22.3%	11.0%	11.4%	1.1%
3B2. Sheep	CH4	non key	0.0	0.0	0.0	-41.8%	0.0%	0.0%	0.0%
3B3. Swine	CH4	L.T	3.4	1.7	1.8	-48.0%	9.8%	10.2%	1.0%
3B4. Poultry	CH4	T	0.4	0.1	0.1	-83.1%	0.4%	0.4%	0.0%
3B4. Other livestock	CH4	non key	0.0	0.0	0.0	26.2%	0.2%	0.2%	0.0%
3B1. Cattle (total)	N_2O		0.3	0.4	0.3	0.4%	1.9%	4.3%	0.2%
3B2. Sheep	N_2O	non key	0.0	0.0	0.0	-72.8%	0.0%	0.0%	0.0%
3B3. Swine	N_2O	non key	0.1	0.1	0.1	-28.8%	0.6%	1.3%	0.1%
3B4. Poultry	N_2O	non key	0.0	0.0	0.0	-13.7%	0.1%	0.3%	0.0%
3B4. Other livestock	N_2O	non key	0.0	0.1	0.1	137.3%	0.4%	0.9%	0.0%
3B5. Indirect emissions	N_2O	L.T	0.4	0.3	0.2	-38.1%	1.3%	3.1%	0.1%

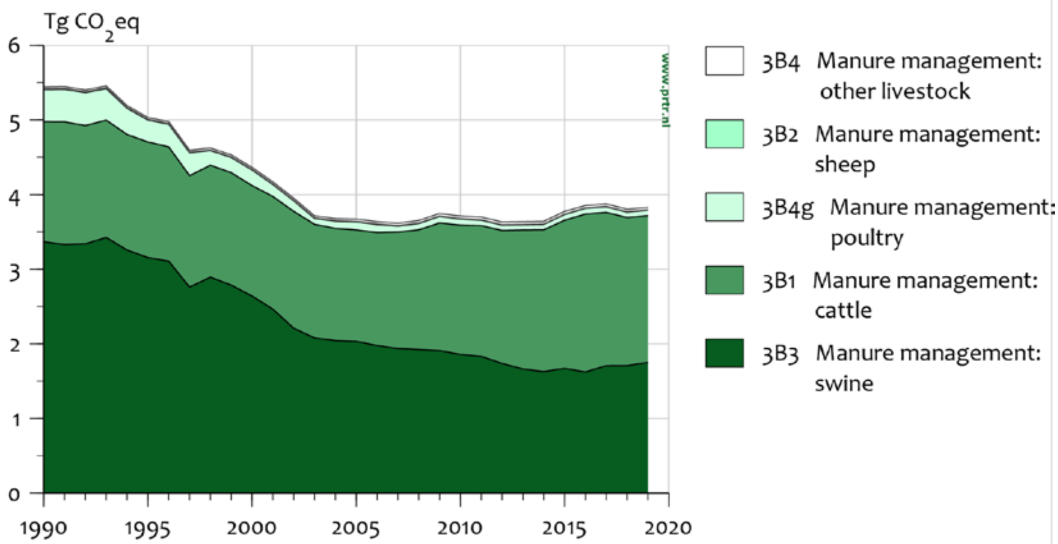


Figure 5.2 Category 3B Manure management – trend and emissions levels of source categories CH_4, 1990–2019.

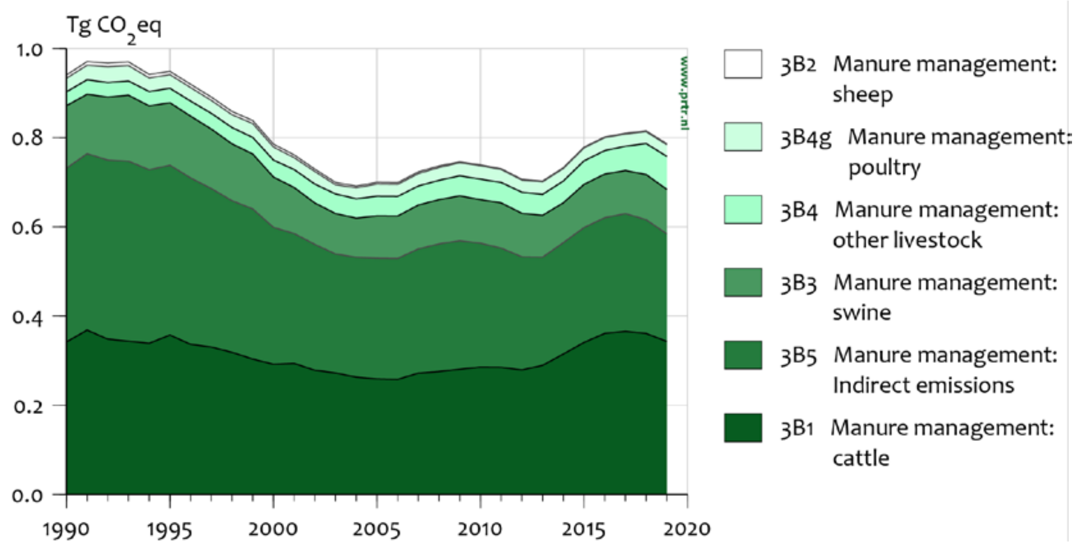


Figure 5.3 Category 3B Manure management – trend and emissions levels of source categories N_2O, 1990–2019.

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 over 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 taken into account in source category 3B Manure management, but are included in source category 3D Agricultural soils (see Section 5.4). The methodology of the calculation of N excretion for the different livestock categories is described in CBS (2012).

CH_4 from manure management
Between 1990 and 2019, emissions of CH_4 from manure management decreased by 30.1% (Figure 5.2). Emissions from cattle increased by 23.4%, while swine and poultry emissions decreased by 49.3% and 83.4% respectively during this period (Table 5.5). With an increasing percentage of cattle kept indoors, a larger proportion of the manure is excreted inside animal housing facilities, with higher EF than manure excreted on pasture, thus increasing the overall emissions during the time period. In growing cattle emissions decreased due to lower livestock numbers; this outweighs the small increase in EF (van Bruggen *et al.*, 2020).

In 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. This lowered the CH_4 emissions, since the solid manure systems have a lower EF. Also the increase of manure treatment had an effect, by shortening the storage time of the manure.

The decreasing trend in CH_4 emissions from swine is directly related to the decrease of VS excretions by swine (CBS, 2020). The VS excretion has decreased due to changes in the feed composition (Zom and Groenestein, 2015). The decrease of CH_4 emissions was somewhat softened by an increase in livestock numbers in the first part of the time series (up to 1997).

N_2O from manure management
Nitrous oxide emissions are calculated using an N-flow model (van der Zee *et al.*, 2021). 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, minus 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 in order to yield the remaining N available for application.

The direct N_2O emissions from cattle and other livestock have increased between 1990 and 2019 with 5.5% and 123%, respectively. Sheep, swine and poultry emissions have decreased 74.4%, 27.7% and 12.5% between 1990 and 2019 (Table 5.5). Decreasing livestock numbers and N excretions per animal influence this trend. Between 1990 and 2013 the N excretion decreased, due to an optimization of the 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 (RVO, 2018).

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 also led to a decrease in manure management emissions.

Indirect N_2O emissions following atmospheric deposition of NH_3 and NO_x emitted during the handling of animal manure decreased 34.5% from 1990 to 2019 (Table 5.5). This decrease is explained by reduction measures for NH_3 and NO_x emissions from animal housing systems and manure storages over the years.

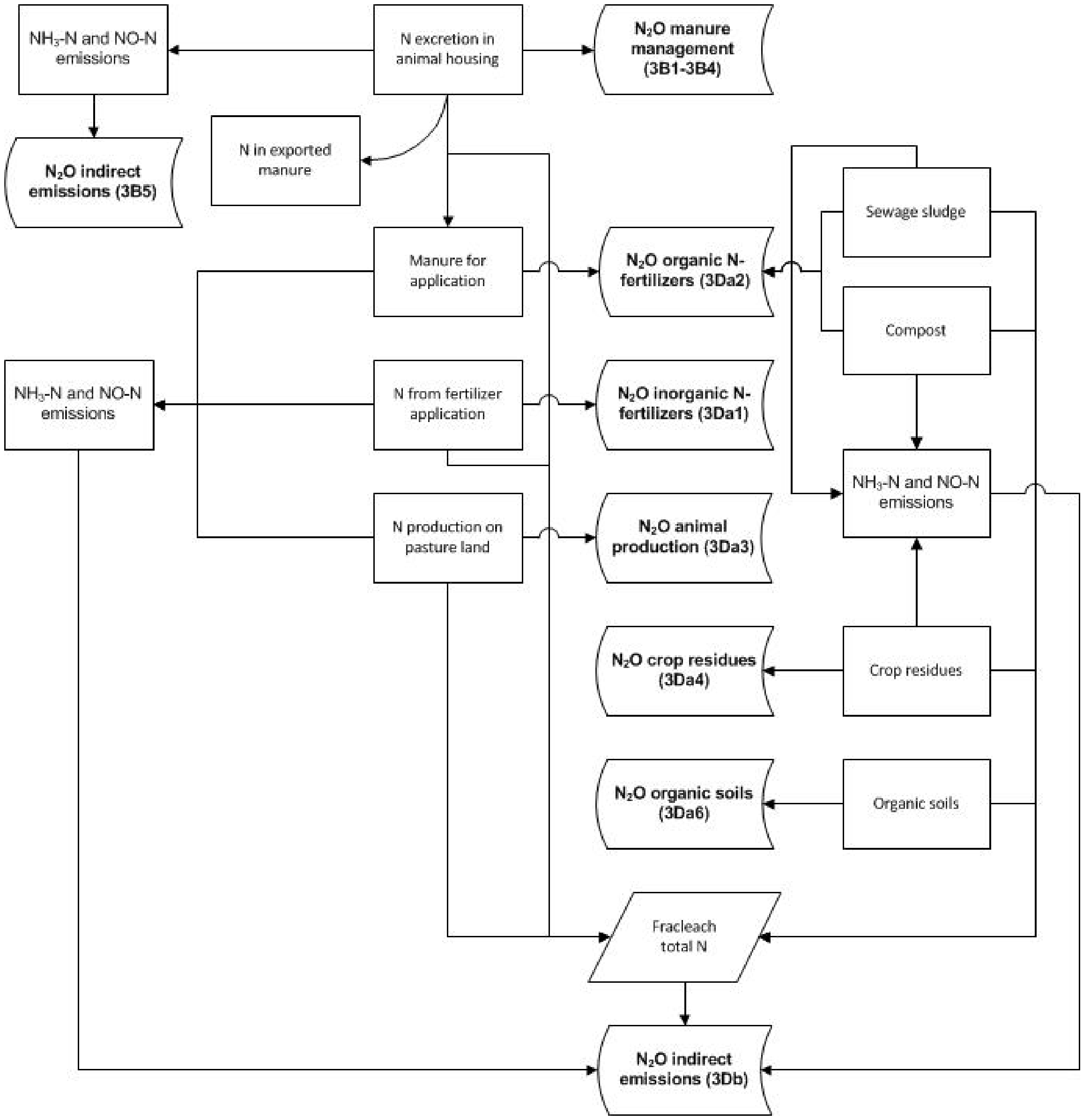


Figure 5.4 Schematic representation of N flows in agriculture and the allocation of emissions to source categories.

5.3.2 *Methodological issues*

For all the sub-source categories, the methodologies used to estimate emissions comply with the 2006 IPCC Guidelines. Detailed information on calculation methods and EFs can be found in chapters 4 and 7 of the methodology report (Lagerwerf et al., 2019). An overview of the activity data can be found in CBS, (2011–2019); Van Bruggen et al., (2020). More information on housing systems used in the Netherlands can be found at https://www.infomil.nl/onderwerpen/landbouw/stalsystemen/stalbeschrijvingen/ (in Dutch).

A description of and 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

A country-specific Tier 2 approach is used to calculate CH_4 EFs for manure management annually. 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 CH4 producing potential (B0, in m3 CH4/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, liquid manure is pumped into outside storage facilities or applied to the land. Given this practice, country-specific MCF values were 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 spent on pasture is calculated yearly by the Working group on Uniformity of calculations of Manure and mineral data (CBS, 2011 through 2020).

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 a given category.

Table 5.6 CH_4 implied emission factors (kg/animal/year) for manure management specified by animal category, 1990–2019.

Animal category	1990	1995	2000	2005	2010	2015	2018	2019
Cattle								
Mature dairy cattle	23.07	24.10	27.97	31.07	34.87	36.72	38.80	38.99
Other mature cattle	7.42	7.53	7.50	7.84	8.04	8.01	6.88	6.77
Growing cattle	6.87	7.04	6.62	6.30	7.05	7.88	7.85	7.93
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	NE	NE	NE	NE	0.76	0.76	0.76	0.76
Swine*	9.68	8.77	8.05	7.19	6.07	5.31	5.52	5.73
Swine excl. piglets	15.44	14.34	13.18	12.06	10.43	9.55	10.14	10.51
Fattening pigs	12.87	11.81	10.76	9.70	8.40	7.53	8.02	8.48
Breeding swine	26.09	25.08	23.60	22.47	20.18	19.27	20.52	20.74
Poultry	0.18	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	0.52	0.50

* The IEF is calculated on total animal numbers, including young stock. Manure production by young stock is accounted for in manure production by adult breeding swine.

Cattle (3B1)
The IEF for the manure management of mature dairy cattle increased between 1990 and 2018 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 liquid manure, compared with the amount of manure produced on pasture, increased between 1990 and 2019 (CBS, 2020).

Swine (3B3)
Between 1990 and 2018, the IEF of swine manure management (based on total swine numbers, including piglets) decreased in line with lower VS excretions 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 changes over the years, increasing the overall digestibility.

Poultry (3B4)
In 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 increase in poultry numbers by 4% since 1990 is counteracted by the shift towards solid manure management systems with a lower EF. This led to an overall decrease in CH_4 emissions of poultry.

Other animals (3B2 and 3B4)
Sheep, goats, horses, and mules and asses produce only 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 in a given year. As rabbit numbers decreased and mink

numbers increased over the entire time period, the CH_4 IEF increased because a larger proportion of the manure consisted of liquid manure, with a higher EF.

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. For the key categories cattle, swine and poultry a Tier 2 approach is used to calculate CH_4 emissions from manure management. For all other animal categories emissions are estimated using a Tier 1 approach. Detailed descriptions of the methods are given in the methodology report (Van der Zee et al., 2021). 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 CBS, (2019) for the period from 2006 onwards.

N_2O from manure management
Emissions of N_2O from manure management are calculated using the 2006 IPCC default EFs. An increase in IEF between 2010 and 2018 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 (CBS, (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 has increased in 2018 (Bikker *et al.*, 2019).

Table 5.7 N_2O IEFs for manure management per animal category, 1990–2019 (mln kg/year and kg N_2O/kg manure-N).

Animal category	1990	1995	2000	2005	2010	2015	2018	2019
Cattle								
Mature dairy cattle	0.34	0.36	0.32	0.34	0.34	0.35	0.40	0.40
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	0.13	0.12
Sheep	0.03	0.03	0.03	0.02	0.01	0.01	0.01	0.01
Goats	0.31	0.34	0.30	0.28	0.28	0.29	0.31	0.32
Horses	0.21	0.21	0.21	0.21	0.19	0.19	0.25	0.26
Mules and asses	NO	NO	NO	NO	0.10	0.10	0.13	0.13
Swine	0.05	0.05	0.05	0.05	0.04	0.03	0.03	0.02
Poultry	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rabbits	0.07	0.06	0.06	0.06	0.06	0.07	0.06	0.07
Fur-bearing animals	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01

For indirect emissions from manure management, the atmospheric N deposition is calculated as described in section 7.4.1 of Lagerwerf *et al.,* (2019). 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 outside 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 was 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 CH4 varies between 21% and 68%, mostly determined by the estimated uncertainties in the EF (21% for 3B1c Growing cattle; 44% for 3B4 Poultry). Uncertainties in activity data vary between 1% and 36%. The uncertainty in the annual N2O emissions from manure management is much higher; estimated at 144% - 225%, attributable to the uncertainties in the EFs. A complete overview of the new method can be found in section 4.4./ annex 11 of van der Zee *et al.,* (2021).

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, as 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*

No category-specific recalculations were made.

5.3.6 *Category-specific planned improvements*

It will be investigated 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 2019 agricultural soils were responsible for 26.9% of total GHG emissions in the Agriculture sector. Total N_2O emissions from agricultural soils decreased by 44.8% between 1990 and 2019 (Table 5.8). In 2019, N_2O emissions from grazing decreased by about 2.9% compared to 2018. Emissions from both organic and inorganic N fertilizers decreased by 6.0% respectively 2.9% in 2019 compared to 2018, due to a decrease in application. Emissions from crop residues in 2019 were similar to those of 2018.

The decrease in total N_2O emissions from 1990 was caused by a relatively large decrease in N input into soil (from inorganic fertilizer and organic N fertilizer application and production of animal manure on pasture during grazing; Figure 5.6). 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 are not occurring in the Netherlands, as is described in chapter 11.4 of the methodology report of LULUCF (Arets *et al.*, 2021), since it is assumed that there is no change in soil C in cropland remaining cropland, also resulting in no associated N losses.

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**	**Key**	**1990**	**2018**	**2019**	**2019 vs 1990**	**Contribution to total in 2019 (%) by**		
			Emissions in Tg CO2 eq			**%**	**sector**	**total gas**	**total CO2 eq**
3D. Agriculture soils	N_2O		8.7	5.0	4.8	-44.8%	26.9%	61.1%	2.7%
3Da. Direct N2O emissions from agricultural soils	N_2O	L,T	7.1	4.4	4.2	-40.4%	23.6%	53.7%	2.3%
3Da1. Inorganic ferilizers	N_2O		2.0	1.2	1.1	-43.6%	6.2%	14.2%	0.6%
3Da2. Organic N fertilizers	N_2O		0.8	1.3	1.2	57.3%	6.8%	15.4%	0.7%
3Da3. Urine and dung from grazing animals	N_2O		3.0	0.9	0.9	-70.3%	5.0%	11.4%	0.5%
3Da4. Crop residues	N_2O		0.5	0.3	0.3	-29.3%	1.8%	4.2%	0.2%
3Da6. Cultivation of organic soils	N_2O		0.9	0.7	0.7	-22.3%	3.8%	8.6%	0.4%
3Db. Indirect N2O Emissions from managed soils	N_2O	L,T	1.6	0.6	0.6	-63.9%	3.2%	7.3%	0.3%

Figure 5.5 shows the trend in total agricultural soils emissions.

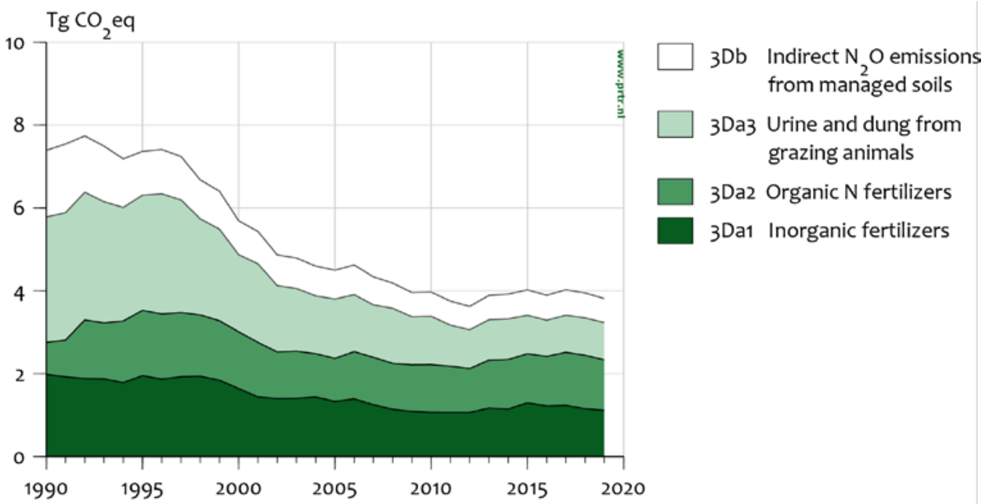


Figure 5.5 Category 3D Agricultural soils – trend and emissions levels of source categories, 1990–2019.

Between circa 70% and 80% of the N excreted in animal housing is available for application to soils. The remaining part of the N excreted in animal houses is lost during storage or exported. The export of manure increased in the last decade, but this increasing trend 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 taken into account for calculating leaching and run-off. This supply consists of N in: manure production in animal housing and on pasture (including treated manure, corrected for manure export) and the application of inorganic N fertilizer, sewage sludge and compost. In accordance with the IPCC 2006 Guidelines, the calculation includes atmospheric N deposition, because also the N deposited to soil is subject to leaching and run-off. Total N supply to the soil decreased by 36% between 1990 and 2019. 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 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. Since the leaching fraction has also decreased over time, the amount of N leached or run off has been reduced by 44% since 1990.

The emissions of crop residues decreased between 1990 and 2019 by 28%, 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.

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 comply with the 2006 IPCC Guidelines. A description of the methodologies used and data sources is presented in Lagerwerf *et al.,* (2019).

Calculations of N_2O emissions from agricultural soils are based on a variety of activity data, including manure production (calculated as described in Section 5.3) and statistics on inorganic N fertilizer application, compost and sewage sludge use, crop area, grassland renewal area and cultivated organic soil area. For an overview of data sources, see chapter 12 of the methodology report (Van der Zee et al., 2021) or the background document by Van der Hoek *et al.,* (2007). The activity data and characteristics for crops are presented in Van Bruggen *et al.,* (2020).

Direct N_2O emissions (3Da)

An IPCC Tier 1b/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 pasture land 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 2019 separate EFs have been quantified for organic soils and mineral soils. Also a distinction has been made between arable land and grassland. This results in three different EFs for inorganic fertiliser application, surface spreading of manure and incorporation into soil. The EFs of organic soil grassland and arable land are the same as their carbon content is similar, furthermore organic soils are hardly used for arable crops in the Netherlands. For the years 2000 to 2019 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		**2.7***	**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
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.

For compost no experimental data of emissions are available. The emission factor for compost was set equal to that of surface-applied manure, because compost is also surface-applied. The EF used for urine and dung deposited by grazing animals is based on Velthof *et al.,* (1996), in which the results of experiments were published. In Annex 10.1 and 10.7 of the methodology report by van der Zee *et al.,* (2021) it is described 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 with 105% in the period 1990–2019 (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, 1990–2019.

	'90	**'95**	**'00**	**'05**	**'10**	**'15**	**'18**	**'19**
Nitrogen input from manure applied to soils	0.004	0.008	0.009	0.008	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 & 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.

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 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 to be 45%, 66% and 67%, respectively. The uncertainty in indirect N_2O emissions from N used in agriculture is estimated to be 267% (leaching and run-off) and 414% (atmospheric deposition).

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*

Organic and mineral soils emit different quantities of N_2O when fertilised. To calculate these emissions a weighted average based on the number of ha of both soil types was used. This has been changed to two separate EF. This change is applied from 2000 to 2019 and has a negligible effect on the N_2O emissions.

The distribution of different manure types (liquid or solid, from which animal) and artificial fertilisers over the land types (organic or mineral soils and grassland or cropland) is modelled using the INITIATOR model. This model replaces the MAMBO model. The change is implemented for the N_2O emissions from 2000 to 2019. This resulted in a decrease of 1.4 Gg N_2O from the application of artificial fertilizers in 2000 and 0.8 Gg N_2O in 2018. Due to time constraints, the change of N_2O emissions resulting from the application of other N inputs were not recalculated for the years 1990-1999. To prevent a time series inconsistency for the years 1990-1999, it was decided to apply the splicing overlap technique as described in IPCC (2006). A complete overview of the recalculations can be found in van der Zee *et al.,* (2021).

5.4.6 *Category-specific planned improvements*

For the NIR of 2022 it will be investigated whether the separate EFs of organic and mineral soils can be applied to the years 1990 to 1999. Change of N2O emissions resulting from the application of other N inputs will be recalculated for the years 1990-1999 in the NIR 2022.

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 have decreased by c. 81% between 1990 to 2019 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	Key	1990	2018	2019	2019 vs 1990	Contribution to total in 2019 (%) by		
			Emissions in Tg CO2 eq			%	sector	total gas	total CO2 eq
3G. Liming	CO_2	non key	0.18	0.03	0.03	-80.9%	0.2%	0.0%	0.0%

Limestone and dolomite make up 40–60% of the 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 the methodology report (Van der Zee et al., 2021).

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 to be 100%. The uncertainty in the activity data is estimated to be 100% and the uncertainty in the EFs is 10%. When considered over a longer time span, all carbon applied through liming is emitted.
New insights into uncertainties for this source category will be further elaborated and taken into account in the NIR 2021.

Time series consistency

The methodology used to calculate CO_2 emissions from limestone and dolomite application for the period 1990–2019 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*
Updated activity data for liming became available, increasing 2017 emissions by 1.9 kton CO_2.

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 entrapped from the atmosphere. During the application of urea this CO_2 is subsequently released. The entrapment and subsequent release used to be attributed to the production of urea. However this has been changed. The entrapment is now attributed to the production. The CO_2 emissions resulting from the application of urea on Dutch farmland are attributed to the agriculture sector. As the majority of the produced urea is exported, the CO_2 emissions from the Netherlands decrease. However, the CO_2 emission from the agriculture sector increases due to this new source. This change is applied to the entire time series. The use of urea increased from 2003 to 2015 after which it decreased again. Carbon dioxide emissions from urea application have increased by 2882% from 1990 to 2019 (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	Key	1990	2018	2019	2019 vs 1990	Contribution to total in 2019 (%) by		
			Emissions in Tg CO2 eq			%	sector	total gas	total CO2 eq
3H. Urea Application	CO_2	non key	0.002	0.051	0.045	2882.3%	0.2%	0.0%	0.0%

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 complies with the IPCC Tier 1 methodology. More detailed descriptions of the methodology and EF used can be found in the methodology report (van der Zee *et al.*, 2021).

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 to be 26%. The uncertainty in the activity data is estimated to be in the range of 26% 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
This category was included for the first time.

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 2021

Emissions:	Total LULUCF emissions in 2019 decreased by 2.4% compared with 2018. Compared with the base year, there is a reduction of 25.5%. As a result of methodological changes described in this NIR 2021, emissions in the LULUCF sector for the year 1990 decreased by c. 7.5% compared with the NIR2020. For 2018 they decreased by 5.8% compared with the NIR2020.
Key categories:	New: 4B Cropland (CO_2)
Methodologies:	This year, one methodological changes has been implemented. In response to the recommendation L.4 in the review of the NIR2019 (ARR 2019) to include the pre 1990 land use changes to correctly represent the "land converted to" categories from 1990 onwards, in the NIR 2021 a land-use map for 1970 has been included. The effect plays a role until 2010 in most land-use categories. However, due to the approach of the Netherlands for calculating carbon stock changes from newly established forests (see chapter 4.2.2. in Arets et al., 2021), the effect in forest land remaining forest land and forest land converted to other land use categories lasts until 2020. Additionally updated data for fruit orchards, which are reported under grassland, is included, an error in the allocation of Harvested Wood Products was corrected and also an error observed in the litter data used in the NIR2020 was corrected.

6.1 Overview of sector

6.1.1 General overview of shares and trends in sources and sinks

This chapter describes the 2021 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 souls are included in the Agriculture sector (category 3D), except for N_2O emissions from forest land, which are reported in CRF Table 4(II). Emissions of CH_4 from wetland are not estimated due to the lack of data.

Land use in the Netherlands is dominated by agriculture (approximately 55%), followed by settlements (15%) and forestry (9%); 3% comprises dunes, nature reserves, wildlife areas, heather and reed swamp. The remaining area (18%) is open water.

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 or hayfields, 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. A total of 78% of grassland is permanent grassland (of which 11% is high-nature-value grassland); the remaining 22% is temporary grassland, on which grass and fodder maize are cultivated in rotation (CBS, 2021[6]). Since 1990, the agricultural land area has decreased by about 5%, mainly because of conversion to settlements/infrastructure and nature.

Table 6.1 shows the sources and sinks in the LULUCF sector in 1990, 2018 and 2019. For 1990 and 2019, total net emissions are estimated to be approximately 6.1 Tg CO_2 eq. and 4.5 Tg CO_2 eq., respectively. The results for 2018 have been added to give insight into annual changes.

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)

Sector/category	**Gas**	**Key**	**1990**	**2018**	**2019**	**2019 vs 1990**	**Contribution to total in 2019 (%) by**		
			Emissions in Tg CO2 eq			**%**	**sector**	**total gas**	**total CO2 eq**
4. Total Land use Categories	CO_2		6.0	4.5	4.4	-26.3%	97.7%	2.7%	2.3%
	CH_4	non key	0.0	0.0	0.0	33.5%	0.0%	0.0%	0.0%
	N_2O		0.1	0.1	0.1	30.5%	2.2%	0.1%	0.1%
	All		6.1	4.6	4.5	-25.5%	100.0%		2.4%
4A. Forest land	CO_2	L	-2.0	-1.9	-1.8	-9.9%	-40.8%	-1.1%	-1.0%
4A1. Forest land remaining Forest Land	CO_2		-1.5	-1.4	-1.4	-10.5%	-30.3%	-0.8%	-0.7%
4A2. Land converted to Forest Land	CO_2		-0.5	-0.5	-0.5	-8.3%	-10.5%	-0.3%	-0.2%
	All		-2.0	-1.9	-1.8	-9.9%	-40.8%	-1.1%	-1.0%
4B. Cropland	CO_2	L,T	2.6	1.6	1.6	-38.6%	34.8%	1.0%	0.8%
4B1. Cropland remaining Cropland	CO_2		1.2	0.5	0.4	-64.3%	9.4%	0.3%	0.2%
4B2. Land converted to Cropland	CO_2		1.4	1.1	1.2	-16.5%	25.5%	0.7%	0.6%
	All		2.6	1.6	1.6	-38.6%	34.8%	1.0%	0.8%

[6] 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 26 Februari 2021.

Sector/category	Gas	Key	1990	2018	2019	2019 vs 1990	Contribution to total in 2019 (%) by		
			Emissions in Tg CO2 eq			%	sector	total gas	total CO2 eq
4C. Grassland	CO_2	L,T	4.7	3.0	2.9	-38.2%	64.1%	1.8%	1.5%
4C1. Grassland remaining Grassland	CO_2		5.0	3.3	3.2	-36.6%	70.1%	1.9%	1.7%
4C2. Land converted to Grassland	CO_2		-0.3	-0.2	-0.3	-12.7%	-6.0%	-0.2%	-0.1%
	All		4.7	3.0	2.9	-38.2%	64.1%	1.8%	1.5%
4D. Wetlands	CO_2	non key	0.1	0.0	0.0	-68.4%	0.6%	0.0%	0.0%
4D1. Wetlands remaining Wetlands	CO_2		NO,IE,NA	0.0	0.0		0.0%	0.0%	0.0%
4D2. Land converted to Wetlands	CO_2		0.1	0.0	0.0	-66.0%	0.6%	0.0%	0.0%
	All		0.1	0.0	0.0	-68.4%	0.6%	0.0%	0.0%
4E. Settlements	CO_2	L,T	0.8	1.5	1.5	74.4%	32.7%	0.9%	0.8%
4E1. Settlements remaining Settlements	CO_2		0.4	0.4	0.4	-11.2%	8.2%	0.2%	0.2%
4E2. Land converted to Settlements	CO2		0.4	1.1	1.1	157.1%	24.5%	0.7%	0.6%
	All		0.8	1.5	1.5	74.4%	32.7%	0.9%	0.8%
4F. Other land	CO_2	non key	0.0	0.2	0.2	710.7%	3.9%	0.1%	0.1%
4F1. Other land remaing other Land	CO_2								
4F2. Land converted to Other Land	CO_2		0.0	0.2	0.2	710.7%	3.9%	0.1%	0.1%
	All		0.0	0.2	0.2	710.7%	3.9%	0.1%	0.1%
4G. Harvested wood products	CO_2	non key	-0.2	0.1	0.1	-168.4%	2.5%	0.1%	0.1%
National Total GHG emissions (incl. CO2 LULUCF)	CO_2		167.8	167.2	163.6	-2.5%			
	N_2O		17.6	8.1	8.3	-52.5%			
	total*		226.6	195.8	191.4	-15.5%			
National Total GHG emissions (excl. CO2 LULUCF)	CO_2		162.7	159.5	153.6	-5.6%			
	CH_4		31.8	17.3	17.2	-45.9%			
	N_2O		17.5	8.0	7.9	-54.9%			
	total*		220.5	186.8	180.7	-18.0%			

* including f-gases

Sector 4 (LULUCF) accounted for about 2.3% of total national CO_2-equivalent emissions in 2019.
CO_2 emissions from the drainage of peat soils and peaty soils were the major source in the LULUCF sector and total 5.5 Tg CO_2 in 2019 (7.6 Tg CO_2 in 1990). This drainage leads to peat oxidation and is due to agricultural and urban water management and is the major contributor to the results of Cropland (4B), Grassland (4C) and Settlements (4E).
The major sink is the storage of carbon in forests: -1.8 Tg CO_2 in 2019, which includes Forest land remaining forest land (4A1) and Land converted to forest land (4A2).

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., 2021).

The methodology of the Netherlands for assessing emissions from LULUCF is 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.

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.
Emissions from land use-related activities such as liming, are reported under the Agriculture sector (3G; see Section 5.5). Changes in land use (‘remaining’ or ‘land converted to’) are presented in a matrix (see Chapter 6.3), which is in accordance with the approach described in 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., 2021). 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.

Trees outside forests 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 (see also Chapter 11). 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., 2021).

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.

From **To↓**		**FL**	**CL**	**GL**	**WL**	**Sett**	**OL**
FL		**BG** (T2) **BL** (T2) **DW** (T2) **Litt** (T2) **MS** (NO) **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** (NO) **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** (NO) **OS** (T2) WF (IE)	**BG** (T2) **BL** (T1, T2) **DM** (NO, NA, n.s 6.6.1) **MS** (T2) **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** (T2) **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** (NO) **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. (2021).

Forest land, Cropland, Grassland and Settlements are key categories. The last three are key categories due to their significant emissions from peat soils (see Sections 6.5.1, 6.6.1 and 6.8.1).

Carbon stock changes in mineral soils
The Netherlands has developed a Tier 2 approach for calculating carbon stock changes in mineral and organic soils. For 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 that have been quantified for each land use and soil type combination (see section 3.5 in Arets et al., 2021).

For the Netherlands, the basis for quantifying carbon emissions from land use changes on mineral soils is the LSK national sample survey of soil map units (Finke et al., 2001), 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., (2005a). 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 only 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 wetland 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. Such a 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. From the NIR 2021 onwards these pre 1990 land use changes are correctly 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
On the basis of the definition of organic soils in the 2006 IPCC Guidelines, two types of organic soils are considered. These are peat soils, which have a peat layer of at least 40 cm within the first 120 cm, and, peaty soils (Dutch: *moerige gronden*), which have a peat layer of 5–40 cm within the first 80 cm. Based on overlays of two soil maps – the initial map with the average year of sampling dated at 1977 and a 2014 update on the spatial extent of organic soils – the development of organic soil area between 1990 and 2014 was assessed (see Arets et al., 2021 for details). Drainage of cultivated organic soils results in oxidation and thus loss of peat in the Netherlands. As a result the total area of organic soils decreases from 528 kha in 1977 to 500 kha in 1990 and 437 kha in 2014. The total area of organic soils for the intermediate years is interpolated between 1977 and 2014. After 2014 the loss of

organic soil area is extrapolated on the basis of the trend between 1977 and 2014.

Changes in organic soil area are not yet monitored on a regular basis, but currently receive a lot of policy attention. Once new information on the extent of organic soils is available, the trend from 2014 will be recalculated.

Overlays with the land use maps provide information on areas of organic soils under the different land use categories. Detailed information is provided in Arets et al. (2021).

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., 2021). 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 results in an average EF for peat of 19 tons CO_2 ha^{-1} for the period 1990–2004. Using the updated 2014 land use map Arets et al., 2021), the approach results in an EF of 17.7 tons CO_2 ha^{-1}. The EF decreases because relatively more of the deepest drained peat areas have disappeared and hence draining is on average currently less deep than in the past, resulting in reduced emissions per ha of peat. Through interpolation the EF gradually decreases from 19 tons CO_2 ha^{-1} in 2004 to 17.7 tons CO_2 ha^{-1} in 2014. This decreasing trend of the EF is then extrapolated after 2014. Analyses are under way to also establish an EF based on the 1977 soil map. This will be included in future submissions, and will change the EFs in the period 1990–2004.

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. Again two EFs were assessed on the basis of the areas of peaty soils present on the 2004 map or the 2014 map. For 2004 the average EF for peaty soils was 13 tons CO_2 ha^{-1}, which is applied to the period 1990–2004 and an average EF of 12 tons CO_2 ha^{-1} in 2014 Arets et al., 2021). Through interpolation the EF gradually decreases from 13 tons CO_2 ha^{-1} in 2004 to 12 tons CO_2 ha^{-1} in 2014. This decreasing trend of the EF then is extrapolated after 2014. Analyses are under way to also establish an EF based on the 1977 soil map. This will be included in future submissions, and will change the EFs in the period 1990–2004.
Drainage of organic soils is not usually applied in forestry in the Netherlands. However, since afforestation usually occurs on land with previously 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 that is planted on organic soils that were previously in agricultural use and where drainage systems may still be (partially) functioning was estimated at 24.2% of the total forest area on peat soils and 22.0% of

the total forest area on peaty soils. The same country-specific EFs are then applied to these areas as are used for drained peat and peaty soils under Grassland, Cropland and Settlements. Additionally, the associated emissions of N_2O are calculated. For this a Tier 1 approach is used using 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 over 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., 2021), and 100% of the forests on peaty soils were on nutrient-rich peaty soils. These ratios were then 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., (2021).

Emissions and removals from drainage and rewetting and other management of organic soils
Carbon stock changes resulting from drainage are included in organic soils under the various land use categories. Rewetting and other management does not occur in the Netherlands.

Direct nitrous oxide emissions from disturbance associated with land-use conversions
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., 2021). 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 Arets et al., 2021), were used. For all other aggregated soil types, we used the default C:N ratio of 15 (IPCC, 2006: section 11.16). For aggregated soil types where conversion of land use led to a net gain of carbon, N_2O emissions were set to zero.

Controlled biomass burning
Controlled biomass burning is 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).

6.1.3 *Changes this year and recalculations for years previously reported*
This year, one methodological change has been implemented, resulting in modifications to the carbon stock changes and associated emissions and removals along the whole time series.

Additionally, an error in the allocation of Harvested Wood Products (HWP) has been corrected, as well as an error in the input files for forest litter used in deforestation.
In the land-use category grasslands, updated data for fruit orchards were introduced, and in forest land and HWP updated forest data were

used. Because these changes may interact with each other, the effects of these changes cannot be separated.

Addition of pre 1990 land-use changes

In order to improve the representation of the “land converted to” categories from 1990 onwards, in the NIR 2021 a land-use map for 1970 has been included. Based on this a land-use change matrix 1970-1990 was included. As a result the “converted to” land-use categories do no longer start at zero in 1990 but instead include changes to the land-use starting from 1971. This effect plays a role along the whole time series covered. This is the case for instance for lands that, for example, before the inclusion of the 1970 map in 1990 would start in the “remaining” category, but now are in the “converted to” category. If such lands change again to yet another land-use type before the 20 year transition period has passed, carbon content in the biomass or soil pools may not yet have reached the content of the “remaining category”. This will then result in different carbon stock changes when converted to another land-use type than the changes that would occur from the “remaining” land category. Due to the approach of the Netherlands for calculating carbon stock changes from newly established forests (see chapter 4.2.2. in Arets et al, (2021) presenting a 30 year period for forest biomass to grow from zero to the biomass of the average Dutch forest), this effect is particularly strong in the forest land remaining forest land and forest land converted to land categories.

Due to the heavy computational burden of including the full 1970 map, a number of simplifications were introduced. These simplifications aim at;

1) reducing the number of small area transitions in 1970-1990, mostly due to uncertainty caused by a lower map quality in 1970,
2) ignoring land-use transitions where the exact area and emissions of the ‘converted to’ category is not relevant for calculating emissions after 1990 (wetlands, settlements, and other land, where the T1 assumptions are no changes in carbon stocks),
3) exclusion of trajectories with a high computational burden in relation to their area, and
4) simplification of trajectories exceeding a threshold of 1 million resulting trajectories when expanded to all underlying possible combinations, regardless of the area.

This methodological change is in line with the provisional recommendation L.4 of the ERT in the review report of the NIR 2019 (ARR2019). See section 6.3 for the updated information. In the recalculations the effect of including the 1970 map dominates the effect of the error corrections and updated data provided below. Figure 6.1 shows how the new methodology affects the area development. The figure shows, as an example, the development for the category Forest Land.

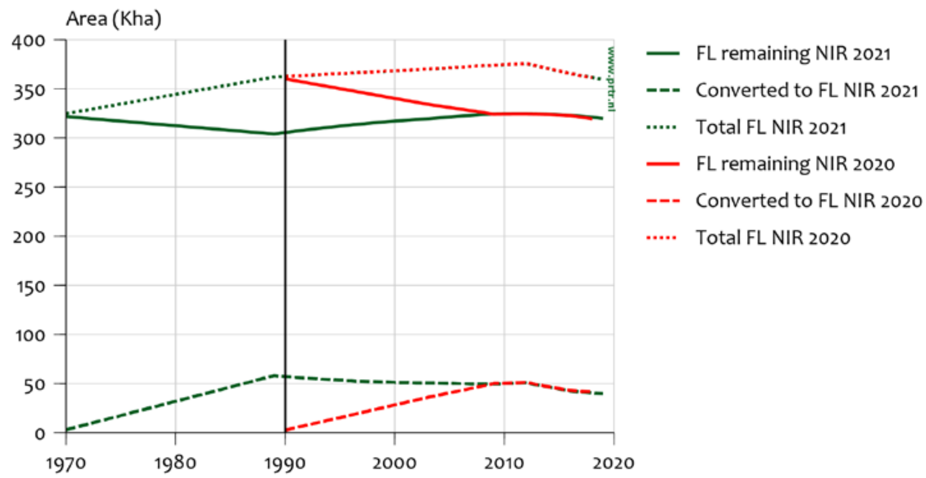


Figure 6.1 impact methodological change for Forest Land development

Error correction HWP
During an internal code review of the HWP module in the bookkeeping model used for the LULUCF calculations, two mistakes were detected and corrected. In the NIR2020, the methodology of allocating round wood harvest to Forest land remaining forest was changed, but this was not updated in the HWP module itself, only in the preceding calculations. Furthermore, the fraction of wood that is exported for each of the product categories (sawnwood, panels, other industrial wood and paper) were inadvertently all calculated based on data for sawnwood. Both mistakes have been corrected and will result in recalculations of emissions and removals from HWP during the whole time series from 1990 to 2018.

Error correction forest litter
As a result of an additional quality check applied to explain the differences in emissions resulting from loss of litter as part of the dead organic matter (DOM) pool under the categories forest land converted to other lands, an error in the information for litter for the years 2017 and 2018 as used in the NIR2020 was found. This now has been corrected and will result in changes in carbon stock changes for DOM in the years 2017 and 2018. It should be noted that this information will be updated again in the NIR 2022 with new information from the 7th National Forest Inventory which was finalized in 2020 and which information will be processed in 2021.

Updated data
In the calculations of emissions and removals for this NIR a number of activity data and emission factors have been updated on the basis of new and updated data that have become available:

1) Because the FAO sometimes changes its forest statistics without notice or explanation, from this NIR onwards data on production, import and export of wood is directly taken from PROBOS, the

Dutch national correspondent to the Joint Forest Sector Questionnaire (JFSQ), These JFSQ data are also used to report national forestry statistics to the FAO and other international organisations and therefore largely are the same as the data published by FAO. This should improve the transparency and consistency of the data used. The data for national round wood harvest and input values for calculation of the Harvested Wood Products have been updated for the years 2017-2019, based on data provided by Probos (Teeuwen et al., 2020).

2) Using new and updated information the area of fruit orchards after 2016 is updated. This has an effect on the emission factor for Grassland (non-TOF) which is partly determined by the fraction of orchards (see section 6,6) this changes the emission factor in the period 2016-2018. Additionally using new information on the age of fruit orchards in 2017 the carbon stocks in fruit orchards were recalculated and updated for the whole time series from 1990-2018 (see Arets et al 2021, and section 6.6). This affects the emission factor used for land use conversion to and from Grassland (non-TOF) in which the fruit orchards are included (see section 6.6, table 6.10).

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., 2021).

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 is in conformity with FAO reporting standards and 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 and are reported under Grassland. For part of the Netherlands’ agricultural land, rotation between cropland and grassland is frequent, but data on where exactly this is occurring are not available. Currently, the situation on the topographical map is used as the 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 are 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. Until the NIR 2014 these areas were included as a separate category under Forest land. This, however, appeared to be confusing when comparing UNFCCC and KP reporting and accounting and resulted in continuing questions and recommendations during the review process. In the NIRs 2015–2017 these areas were included under Forest land without making a distinction between units of forest land that did comply with the definition and those that did not. Due to new insights and to improve transparency the separate reporting of Trees outside forests has been reinstated. But to prevent the previously observed confusion between emissions and removals as reported under UNFCCC and KP, the category TOF is now included under Grassland.

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., 2021).
  In the calculations orchards are not spatially explicitly included. Instead, statistics on areas of orchards are used. See Arets et al., (2021) for details.

Wetland (4D)
The Netherlands is characterised by wet areas. Many of these areas are covered by a 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, which 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. Because even 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 that are not included in any other category. In the Netherlands, this means mostly 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, which 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 (originally developed to support temporal and spatial development in land use and policy in the field of nature conservation) representing land use on 1 January 1990, 2004, 2009, 2013 and 2017 were used for wall-to-wall map overlays (Arets et al., 2019; 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 1990–2004 (Table 6.4), 2004–2009 (Table 6.5), 2009–2013

(Table 6.6) and 2013–2017 (Table 6.7). 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., (2021).

The classification of forest areas on the underlying topographical maps that are used to compile the LULUCF maps takes into consideration 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.

From the NIR 2021 onwards also a land-use map for 1970 is included (Table 6.3). The basis differs from that of the other land-use maps, but nevertheless it allows for a consistent approach to take into consideration the continuing effects of pre 1990 land-use transitions after 1990. The 1970 map is based on the ("Historisch Grondgebruik Nederland 1970" (HGN 1970) map, and is based on scanned paper topographic maps. It has a resolution of 25 m. The HGN1970 map was cut to the same size and was rastered in the same way as the more recent maps. Pixels with unknown land-use were assigned the land use of the 1990 map. The HGN1970 map was processed in the same way as the other maps to distinguish Trees Outside Forests from Forest land.

An overlay was produced with all land-use and soil maps, resulting in an array of trajectories, showing land-use in the respective maps (1970, 1990, 2009, 2013, 2017), and soil in the respective 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 in 2014, since the new map is considered to be 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 1.5% of the total land area. In addition, if the land-use in 1990 was wetlands, settlements or other land, the 1970 land use was also reclassified to the 1990 land use. For these land-use categories, there are no consequences if the 1990-2010 'converted to' classes are not up-to-date.

Furthermore, after doing the land-use and soil extrapolation to the year 2022, we excluded trajectories that had a ratio of more than 100 underlying trajectories when expanded per 0.0625 ha (the size of 1 pixel). The area of the remaining trajectories were proportionally increased to maintain a full area cover. This affected 0.33% of the total area, while reducing the total number of expanded trajectories by over 95%. Trajectories that changed their soil type were left untouched. Any remaining trajectories that still expanded to more than 1 million combinations were simplified by setting the 2022 extrapolated land-use to the 2017 land-use, and when needed, by additionally changing the 1970 land-use to the 1990 land-use. This concerned about 25 single trajectories. All had small areas (<10 ha) but escaped above rules because they contained a soil transition (peat in 1977, peaty in 2004 and projected to be mineral by 2022).

For trajectories that changed from one mineral soil type to another, we assumed the 1977 value to be the same as the 2014 value, since the new map is considered to be more accurate than the old one. The resulting array of trajectories was then aggregated so that only unique trajectories remained.

Table 6.3 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 1990							
HGN 1970	**FL**	**CL**	**GL (non-TOF)**	**G (TOF)**	**WL**	**Sett**	**OL**	***Total***
FL	297,663	4,642	16,473	1,465	1,103	6,308	783	*328,437*
CL	22,727	681,652	184,983	2,287	11,455	51,607	213	*954,924*
GL-non TOF	29,259	301,149	1,237,874	5,341	22,226	87,157	1,275	*1,684,281*
GL-TOF	1,843	1,420	4,371	9,368	180	2,289	114	*19,586*
WL	1,416	5,141	15,792	171	752,101	4,677	3,803	*783,101*
Sett	7,999	25,199	45,276	2,090	3,767	257,083	515	*341,929*
OL	1,192	149	2,913	84	3,217	335	32,860	*40,751*
Total	*362,100*	*1,019,352*	*1,507,682*	*20,806*	*794,051*	*409,457*	*39,562*	*4,153,009*

Table 6.4 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	334,211	1,218	14,586	2,852	1,503	7,031	699	*362,100*
CL	12,520	739,190	176,797	2,039	6,821	81,782	201	*1,019,352*
GL-non TOF	18,066	196,595	1,190,740	4,474	18,641	78,259	907	*1,507,682*
GL-TOF	2,352	386	3,316	11,336	319	2,988	110	*20,806*
WL	888	596	9,092	328	777,519	2,836	2,791	*794,051*
Sett	1,452	1,623	10,987	1,078	1,390	392,804	122	*409,457*
OL	552	8	2,547	98	2,583	629	33,143	*39,562*
Total	*370,041*	*939,617*	*1,408,064*	*22,207*	*808,777*	*566,330*	*37,973*	*4,153,009*

Note: For comparison with CRF tables, map dates are 1 January 1990 and 2004, i.e. the areas for 2004 correspond to the areas reported in CRF tables for the 2003 inventory year.

Table 6.5 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 2009							
BN 2004	**FL**	**CL**	**GL (non-TOF)**	**GL (TOF)**	**WL**	**Sett**	**OL**	***Total***
FL	357,474	350	5,219	1,516	703	4,571	208	*370,041*
CL	2,007	813,282	108,480	297	1,794	13,729	27	*939,617*
GL-non TOF	7,119	106,547	1,243,329	1,708	10,610	37,705	1,047	*1,408,064*
GL-TOF	1,701	137	1,198	16,893	126	2,122	30	*22,207*
WL	374	177	9,633	92	796,297	1,441	762	*808,777*
Sett	4,597	4,367	23,123	1,558	3,033	529,415	237	*566,330*
OL	209	2	506	29	890	137	36,200	*37,973*
Total	*373,480*	*924,863*	*1,391,488*	*22,092*	*813,453*	*589,121*	*38,512*	*4,153,009*

Table 6.6 Projected land use and land use change matrix for the six UNFCCC land use categories for the period 2009–2013 using the land use data available on 1 January 2013 (ha) with Grassland (GL) divided into GL (non-TOF) and GL (TOF).

	BN 2013							
BN 2009	**FL**	**CL**	**GL (non-TOF)**	**GL (TOF)**	**WL**	**Sett**	**OL**	***Total***
FL	360,211	1,315	6,245	1,483	699	3,324	204	*373,480*
CL	2,480	793,892	116,002	311	1,410	10,740	28	*924,863*
GL-non TOF	8,081	145,410	1,194,126	1,591	10,849	30,915	516	*1,391,488*
GL-TOF	1,347	220	1,534	17,215	164	1,582	31	*22,092*
WL	651	304	6,179	112	803,050	1,311	1,846	*813,453*
Sett	2,530	3,198	20,653	815	4,477	557,312	135	*589,121*
OL	444	1	970	49	1,825	328	34,896	*38,512*
Total	*375,743*	*944,340*	*1,345,709*	*21,575*	*822,474*	*605,512*	*37,656*	*4,153,009*

Table 6.7 Projected land use and land use change matrix for the six UNFCCC land use categories for the period 2013–2017 using the land use data available on 1 January 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	356,631	1,662	9,345	2,012	804	4,886	404	*375,743*
CL	901	762,447	170,184	244	1,674	8,865	24	*944,340*
GL-non TOF	4,816	103,116	1,197,036	1,500	9,185	28,661	1,394	*1,345,709*
GL-TOF	1,143	205	1,658	16,549	146	1,834	41	*21,575*
WL	837	291	6,717	191	807,284	4,417	2,736	*822,474*
Sett	1,034	2,582	21,372	710	1,559	578,065	191	*605,512*
OL	215	7	735	34	1,399	429	34,838	*37,656*
Total	*365,577*	*870,310*	*1,407,046*	*21,240*	*822,052*	*627,156*	*39,628*	*4,153,009*

Annual land use changes are derived from these land use change matrices. The 2013–2017 matrix (Table 6.7) is used for the extrapolation of annual land use changes in later years (until new land use statistics become available).

As can be observed from the land use change matrices above, land use is very dynamic in a densely populated country like the Netherlands. 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. During the last period (between the 2013 and 2017 maps) the earlier observed increase in conversion of Grassland to Cropland was reversed, with more Grassland being converted to Cropland.

When comparing the five land use change matrices, however, the different lengths of time between the available land use maps should be taken into consideration, 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 captured when the land use maps of 1990 and 2004 are used. The more recent maps are closer together timewise and thus are better able to capture short-term rotations between Grassland and Cropland.

Since 2004, deforestation has been increasing in the Netherlands, for two principal reasons. First, deforestation takes place as part of nature development, and specifically Natura 2000 development, under which areas of heathland and shifting sand have especially increased at the cost of Forest land. Second, farmers' contracts under the set-aside forest regulation and other national regulations from the 1980s that were 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 the previous periods, until 2013 the rate of afforestation was higher than that of deforestation. From the most recent matrix, 2013–2017, 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. The exception to this rule is when conversion to priority nature takes place on the basis of ecological arguments, e.g. through Natura 2000 development or management plans. In such cases, forest conversion can take place without compensation. There are also signs that there is a lack of monitoring and enforcement of the compensation rule at local government level. Recently, however, this issue has received more attention and it is currently being addressed. Therefore, it is expected that this trend of net loss of forest cover will be reversed again in the coming years.

A new land use map will be implemented and used in the NIR 2022.

6.4 Forest land (4A)

6.4.1 Source category description

Reported in this category of land use are emissions and sinks of CO_2 caused by changes in forests. All forests in the Netherlands are classified as temperate: 30% of them coniferous, 38% broadleaved and the remainder a mixture of the two. The share of mixed and broadleaved forests has grown in recent decades (Schelhaas et al., 2014[7]). In the Netherlands, with its very 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 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 Reported in this category of land use are emissions and sinks of CO_2 caused by changes in forests. All forests in the Netherlands are classified as temperate: 30% of them coniferous, 38% broadleaved and the remainder a mixture of the two. The share of mixed and broadleaved forests has grown in recent decades (Schelhaas et al., 2014[8]). In the Netherlands, with its very 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 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;

[7] Report on the 6th 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://www.wur.nl/en/Expertise-Services/Research-Institutes/Environmental-Research/Projects/Dutch-Forest-Inventory/Results.htm
[8] Report on the 6th 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://www.wur.nl/en/Expertise-Services/Research-Institutes/Environmental-Research/Projects/Dutch-Forest-Inventory/Results.htm

- forest land converted to other land use categories (4B2, 4C2, 4E2, 4F2): includes emissions related to the conversion of forest land to all other land use categories (deforestation).

6.4.2 *Methodological issues*

Removals and emissions of CO_2 from forestry and changes in woody biomass stock are estimated using a country-specific Tier 2 methodology. The chosen approach follows the 2006 IPCC Guidelines, which suggest a stock difference approach. The basic assumption is that the net flux can be derived by converting the change in growing stock volumes in the forest into volumes of carbon. Detailed descriptions of the methods and EFs used can be found in the methodological background report for the LULUCF sector (Arets et al., 2021). 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 three National Forest Inventories (NFI) carried out during 1988–1992 (HOSP: Schoonderwoerd and Daamen, 1999), 2000–2005 (NFI-5: Daamen and Dirkse, 2005) and 2012–2013 (NFI-6: Schelhaas et al., 2014). 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, representing the state of the forest at three moments in time; 1990 (HOSP), 2003 (NFI-5) and 2012 (NFI-6). Information between 2013 and 2023 was based on an extrapolation with the EFISCEN model using age class-dependent projections and applying five-year time intervals (see Arets et al., 2021). This generates the same information as is taken from the NFIs for the year 2023. Once new information from the NFI-7 is available (by 2021), these extrapolated numbers will be replaced by that information.

From plot-level data from the HOSP, NFI-5 and NFI-6 inventories, changes in carbon stocks in living biomass in forests have been calculated. In addition, changes in activity data have been 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., (2021).

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 and 2003–2012. The annual changes during the years between 1990 and 2003 and between 2003 and 2012 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 dominant tree species, their standing stock (stem volumes) and the forest area they represent. Based on this information the following calculation steps are implemented (for more details see Arets et al., 2021):

1. On the basis of the growing stock information from the three forest inventories and biomass expansion functions (BCEFs) for each plot in the NFIs, total tree biomass per hectare is calculated. Biomass is calculated using the dominant tree species group's specific BCEFs.
2. Average growing stocks (in m^3 ha^{-1}), average BCEFs (tonnes biomass m^{-3}) and average root-to-shoot ratios are calculated (Arets et al., 2021). These are weighted for the representative area of each of the NFI plots for each NFI.
3. On the basis of the distribution of total biomass per hectare between coniferous and broadleaved plots (determined by the dominant tree species), 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 those parameters for all the intermediate years.
5. Combining for each year average growing stock, BCEF and root-to-shoot ratios, the average above-ground and below-ground biomasses (tonnes dry matter ha^{-1}) are estimated for each year (Table 6.8).
6. Using the relative share of coniferous and broadleaved forests and the differentiated T1 carbon fractions for conifers and broad-leaved species, above- and below-ground biomass are converted to carbon amounts.

Losses from wood harvesting are not taken into account, as these are already included in the differences in carbon stocks between the three forest inventories, HOSP, NFI-5 and NFI-6.

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 indeed appears to be higher than in other countries, the volume growth rates are not. However, the very low harvest intensities in the Netherlands, with only about 55% of the increment being harvested (see Schelhaas et al., (2018), and annex 5 in Arets et al., 2021), result in a strong net increase in growing stock over time.

Table 6.8 Annual values for growing stock, above-ground biomass (AGB) and below-ground biomass (BGB), and BCEF based on temporal interpolation between the inventories and/or model projections.

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	0.714	113	20
1991	161	0.716	115	21
1992	164	0.717	117	21
1993	166	0.719	120	22
1994	169	0.721	122	22
1995	172	0.722	124	22
1996	175	0.724	127	23
1997	178	0.726	129	23
1998	181	0.728	131	24
1999	183	0.729	134	24
2000	186	0.731	136	24
2001	189	0.733	138	25
2002	192	0.734	141	25
2003	195	0.736	143	26
2004	197	0.737	145	26
2005	200	0.738	148	27
2006	203	0.738	150	27
2007	206	0.739	152	27
2008	209	0.740	154	28
2009	211	0.741	156	28
2010	214	0.742	159	29
2011	217	0.742	161	29
2012	220	0.743	163	29
2013	222	0.744	165	30
2014	224	0.745	167	30
2015	226	0.747	169	30
2016	228	0.748	171	31
2017	230	0.750	172	31
2018	232	0.751	174	31
2019	234	0.752	176	32

d.m.: dry matter

Dead wood

Dead wood volume is available from the three forest inventory datasets (up to 2013). 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., 2021). From 2013 onwards, carbon stock changes in dead wood are extrapolated from the trend of the last two forest inventories. Once new data are available from the NFI-7 in 2021 (see Section 6.4.6), these carbon stock changes will be recalculated on the basis of the actual data.

Litter
Analysis of carbon stock changes based on collected data has shown that there is probably a 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., 2021).

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., (2021) for more details.

Emissions from forest fires
In the Netherlands no recent statistics are available on the occurrence and intensity of wildfires in forests (forest fires). The area of burned forest is based on a historical series from 1980 to 1992, for which the annual number of forest fires and the total area burned is available (Wijdeven et al., 2006). The average annual area (37.77 ha) from the period 1980–1992 is used for all years from 1990 onwards (Arets et al., 2021).

Emissions of CO_2, CH_4 and N_2O from forest fires are reported at Tier 2 level according 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 (Table 6.9). 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's 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 to be a conservative approach.

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., (2021) for more details).

We have looked into other possible improvements in wildfire statistics in the Netherlands using the EFFIS data that have been reported in its annual fire reports since 2000. Until 2017 the Netherlands did not submit a report to EFFIS, but the EFFIS reports also include independent rapid damage assessments that aim 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., (2021), 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 not much 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 TOF to FL 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., 2021). This sink is not reported, in order to be conservative.

Emissions from forest fires
All emissions from forest fires are included under Forest land remaining forest land and therefore are reported here as IE.

Emissions from fertiliser use in forests
Fertilisers are not much 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 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 the amount of carbon lost depends on the accumulated carbon since establishment of the forest, where for units of land in the land converted to forest land category and forest land remaining forest land that was 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., (2021).

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 FL to TOF it is assumed that no loss of biomass occurs.

Table 6.9 Emission factors for deforestation (Mg C ha^{-1}).

Year		EF dead wood	EF litter
1990		0.84	28.66
1991		0.99	29.22
1992		1.15	29.78
1993		1.30	30.34
1994		1.46	30.90
1995		1.62	31.46
1996		1.77	32.02
1997		1.93	32.59
1998		2.08	33.15
1999		2.24	33.71
2000		2.39	34.27
2001		2.55	34.83
2002		2.70	35.39
2003		2.86	35.95
2004		2.97	35.63
2005		3.09	35.32
2006		3.20	35.00
2007		3.32	34.68
2008		3.43	34.37
2009		3.54	34.05
2010		3.66	33.73
2011		3.77	33.41
2012		3.88	33.10
2013		4.00	32.78
2014		4.11	32.53
2015		4.22	32.27
2016		4.34	32.02
2017		4.45	31.76
2018		4.57	31.51
2019		4.68	31.26

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., (2021) and resulting emission factors in Table 6.9), which includes both standing and lying dead wood)). In the corresponding Table in the NIR2020 inadvertently only carbon in standing dead wood was included.

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 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 could 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 accord 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 changes thereto in litter in Dutch forests was based on extensive datasets on litter thickness and carbon content in litter (see Arets et al., (2021): 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., (2021) and resulting emission factors in Table 6.9)

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., 2021, 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 4A1 (Forest land remaining forest land) is calculated at +10% to -12% and for Land converted to forest land at +26% to -21%. See Arets et al. (2021) for details.

Time series consistency

To ensure time series consistency in Forest land remaining forest land, for all years up to 2019 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, as discussed in Chapter 1. Additional Forest land-specific QA/QC includes:

- During the measurements of the three forest inventories, specific QA/QC measures were implemented to prevent errors in measurements and reporting (see Arets et al., 2021).
- Changes in forest area and mean carbon stocks in Dutch forests were verified by data from the FAO Forest Resources Assessment (FRA).

6.4.5 *Category-specific recalculations*

The data for national round wood harvest and input values for calculation of the Harvested Wood Products have been update. Additionally, the more general methodological change of adding pre 1990 land-use changes (i.e. including the 1970 land use map), has resulted in recalculations in the forest land category for the whole time series 1990-2018. See also Section 6.1.3.

6.4.6 *Category-specific planned improvements*

In 2017 the Netherlands started its 7^{th} National Forest Inventory (NFI-7). This is expected to deliver results by 2021. The results will be used in the NIR 2022 and will then replace the currently extrapolated changes in carbon stocks in dead wood and the extrapolated changes in carbon stocks in living biomass based on the projections with the EFISCEN model.

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., 2021). As a result of these high emissions from mineral 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 needed for it to be a significant pool under the Cropland category.

Because Cropland in the Netherlands mainly consists of annual cropland were annual biomass gains are harvested each year, no net accumulation of carbon stocks in biomass over time is expected to occur 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 usually grassy vegetation between the 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 will depend on the carbon stocks in DOM in the ‘converted from’ land use category. Currently, carbon stocks in DOM are included only under Forest land.

As with living biomass and DOM, no carbon stock changes in mineral soils are expected in Cropland remaining cropland. Therefore, for Cropland remaining cropland no net carbon stock changes in mineral soils are calculated or reported.

6.5.2 *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 CRF Table 4.B, the area associated with the transition period for soil is reported.

Living biomass

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). Net carbon stock changes in both mineral and organic soils for land use changes involving Cropland are calculated using the methodology provided in Arets et al., (2021).

6.5.3 *Uncertainty and time series consistency*

Uncertainties

The Approach 1 analysis in Annex 2, shown in 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., (2021) 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 4B1 (Cropland remaining cropland) is calculated at -60% to +61% and for 4B2 (Land converted to cropland) at -45% to +61%; see Arets et al. (2021) for details.

Time series consistency
To ensure time series consistency, for all years up to 2019 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 correction of an error in the carbon stock losses resulting from loss of litter in the dead organic matter (DOM) pool resulted in recalculations of the category forest land converted to cropland for the years 2017 and 2018. Additionally, the more general methodological change of adding pre 1990 land-use changes (i.e. including the 1970 land use map), also has resulted in recalculations in the cropland category for the time series 1990-2010. See also Section 6.1.3.

6.5.6 Category-specific planned improvements
Currently the 7th National Forest Inventory is being carried out. The results are expected to become available in 2021 and will then be used to update the forest-based information and replace the projections with the EFISCEN model (Section 6.4).

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 calculate 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., 2021). 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 very high, and disturbance effects on litter may prevent accumulation. Therefore, the conservative estimate of no carbon accumulation in these pools is 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 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., 2021).

For carbon stock changes in living biomass in grassland vegetation and nature remaining in those categories, a Tier 1 method is applied, assuming no change in carbon stocks (IPCC, 2006; for details see Arets et al., 2021). In orchards an increase in carbon stocks can be expected as the fruit trees age. However, data on orchards indicate that the average age of trees in orchards remains relatively constant at 10.5 years (see chapter 6 in Arets et al., 2021). Therefore, it is assumed that at the national level average carbon stocks per unit of area of orchard will not change. As a result of changing areas of grassland vegetation and orchards, the average carbon stocks in Grassland remaining grassland (non-TOF) change between years, which is 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 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 are carbon stock gains in DOM included in land use conversions to Grassland (non-TOF), nor are 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 included only under Forest land.

Following the IPCC Guidelines, no carbon stock changes in mineral soils are expected for Grassland (non-TOF) remaining grassland (non-TOF). However, since transitions between nature and grassland vegetation are treated as Grassland (non-TOF) remaining grassland (non-TOF), and land is always reported under its last known use, a unit of land that is converted from another land use to nature (or grassland vegetation) and subsequently to grassland vegetation (or nature) will be reported under Land converted to grassland (non-TOF) until its conversion to grassland vegetation, and as Grassland (non-TOF) remaining grassland (non-TOF) thereafter. However, the soil carbon stock is still in the transition phase, causing a change in the mineral soil carbon stock in the Grassland (non-TOF) remaining grassland (non-TOF) category even if soil carbon under grassland is assumed to be stable.

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, see Arets et al., 2021), from that point in time is reported under Grassland (non-TOF) remaining grassland (non-TOF). Continued carbon stock changes in mineral soils, however, are still being assessed, and are also reported under Grassland (non-TOF) remaining grassland (non-TOF). This results in a minor misallocation of areas and emissions between Land converted to grassland and Grassland remaining grassland, although total emissions for the Grassland category are correct.
Correcting this allocation error in the LULUCF bookkeeping model is not easy. Currently the LULUCF bookkeeping model is reprogrammed in a different programming language. This allocation issue is taken into account in the reprogramming and will be solved once the model is implemented. The model will be tested in 2021 and it is foreseen that it will be used for the NIR 2022.

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 as separate 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.

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
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 6.10).
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., 2021). Carbon stocks in living biomass in orchards are based on an average age of trees in orchards[9] and a Tier 1 biomass accumulation rate of 2.1 ton C ha^{-1} yr^{-1} (IPCC, 2003a). The average age of fruit orchards changes over time from 10.4 years in 1997 to 13 years in 2017[10]. In between the measurement years (1997, 2002, 2007, 2012 and 2017) the age developments are interpolated and before and after they are linearly extrapolated based on the two adjacent measured ages. Subsequently the average ages of fruit orchard are multiplied by the Tier 1 biomass assumulation of 2.1 tonnes ha^{-1} yr^{-1} to calculate the average carbon stock in orchard biomass (tC ha^{-1}) (Table 6.10). Average carbon stocks in living biomass in orchards are thus. Areas of orchards as published by Statistics Netherlands (CBS) between 1992 and 2016[11] and for 2017 onwards[12], are used to assess the area-weighted average carbon stocks in Grassland non-TOF (Table 6.10).

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., (2021).

Table 6.10 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	1476.3	9436.7	1500.6	9986.8	6.66
1991	23.9	22.6	540.6	1469.5	9393.2	1493.5	9933.8	6.65
1992	23.6	22.5	531.6	1462.7	9349.6	1486.3	9881.2	6.65
1993	23.4	22.4	524.3	1455.8	9305.5	1479.2	9829.8	6.65
1994	23.4	22.3	520.8	1448.7	9260.3	1472.1	9781.2	6.64
1995	22.4	22.2	496.4	1442.6	9221.2	1465.0	9717.6	6.63
1996	22.2	22.1	490.1	1435.7	9176.9	1457.9	9667.0	6.63
1997	22.2	22.0	488.6	1428.5	9131.2	1450.8	9619.8	6.63
1998	21.6	21.9	473.5	1422.0	9089.5	1443.6	9563.0	6.62
1999	21.1	21.8	460.4	1415.4	9047.2	1436.5	9507.6	6.62
2000	19.8	21.7	428.4	1409.7	9010.5	1429.4	9438.9	6.60
2001	18.8	21.6	404.7	1403.5	8971.4	1422.3	9376.1	6.59
2002	18.5	21.5	397.4	1396.7	8927.6	1415.2	9324.9	6.59
2003	17.7	21.8	384.7	1390.4	8887.4	1408.1	9272.2	6.59

[9] https://opendata.cbs.nl/statline/#/CBS/nl/dataset/81735NED/table?ts=1517993072950
[10] https://opendata.cbs.nl/statline/#/CBS/nl/dataset/81735NED/table?ts=1517993072950
[11] https://opendata.cbs.nl/statline/#/CBS/nl/dataset/70671NED/table?fromstatweb
[12] 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)
2004	17.6	22.1	388.7	1387.1	8866.6	1404.7	9255.3	6.59
2005	17.4	22.4	388.7	1384.1	8847.0	1401.4	9235.7	6.59
2006	17.4	22.7	395.8	1380.7	8825.3	1398.1	9221.1	6.60
2007	17.7	23.0	407.3	1377.1	8802.3	1394.8	9209.7	6.60
2008	17.9	23.3	415.6	1373.6	8780.3	1391.5	9195.8	6.61
2009	18.1	23.6	425.3	1362.0	8705.8	1380.0	9131.2	6.62
2010	17.8	23.8	424.8	1350.8	8634.2	1368.6	9059.0	6.62
2011	17.6	24.1	423.6	1339.6	8562.7	1357.2	8986.3	6.62
2012	17.2	24.4	419.3	1328.5	8492.0	1345.7	8911.3	6.62
2013	17.5	25.0	436.9	1343.6	8588.1	1361.0	9025.0	6.63
2014	17.5	25.6	449.3	1358.8	8685.7	1376.4	9135.0	6.64
2015	18.5	26.2	485.2	1373.2	8777.5	1391.7	9262.6	6.66
2016	19.1	26.8	512.4	1387.9	8871.6	1407.0	9384.0	6.67
2017	18.6	27.4	508.5	1403.6	8971.7	1422.1	9480.2	6.67
2018	18.4	28.0	515.2	1418.8	9069.2	1437.2	9584.4	6.67
2019	18.4	28.6	525	1434.0	9166.0	1452.3	9690.9	6.67

Trees outside forests
For 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., 2021). The only difference between the two categories is the size of the stand (<0.5 ha for TOF), so this seems to be 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 o 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., 2021). 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 the areas of cultivated organic soils under Grassland (non-TOF) are drained. Areas of nature grasslands are not drained. 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. This also 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 6.11.

Table 6.11 Areas of peat and peaty soil in total Grassland (non-TOF) compared with the part considered to be cultivated grassland reported in CRF Table 3.D

Year	Grassland (non-TOF)			Cultivated grassland		
	Peat	Peaty	Total	Peat	Peaty	Total
	kha					
1990	223,550	96,422	319,972	218,058	93,677	311,735
1991	221,959	95,856	317,816	216,507	93,118	309,625
1992	220,378	95,293	315,670	214,964	92,562	307,526
1993	218,805	94,731	313,536	213,429	92,008	305,437
1994	217,241	94,172	311,413	211,901	91,456	303,358
1995	215,686	93,614	309,301	210,382	90,907	301,289
1996	214,140	93,059	307,199	208,870	90,360	299,230
1997	212,603	92,506	305,109	207,367	89,816	297,182
1998	211,074	91,955	303,029	205,871	89,274	295,144
1999	209,555	91,406	300,961	204,383	88,734	293,117
2000	208,044	90,859	298,903	202,903	88,196	291,099
2001	206,542	90,315	296,857	201,431	87,661	289,092
2002	205,049	89,772	294,821	199,966	87,129	287,095
2003	203,565	89,232	292,796	198,510	86,599	285,109
2004	201,989	88,700	290,689	196,969	86,043	283,012
2005	200,420	88,169	288,589	195,436	85,488	280,923
2006	198,859	87,636	286,495	193,909	84,932	278,842
2007	197,305	87,103	284,408	192,390	84,377	276,767
2008	195,758	86,569	282,327	190,878	83,822	274,700
2009	194,774	85,990	280,764	189,914	83,208	273,122
2010	193,798	85,409	279,207	188,958	82,592	271,550
2011	192,830	84,826	277,656	188,010	81,975	269,985
2012	191,871	84,240	276,110	187,071	81,356	268,427
2013	191,411	84,904	276,315	186,602	82,029	268,631
2014	190,928	85,557	276,485	186,110	82,690	268,800
2015	190,020	86,239	276,259	185,201	83,385	268,586
2016	189,108	86,901	276,008	184,290	84,058	268,348
2017	188,161	87,513	275,674	183,365	84,700	268,065
2018	187,211	88,105	275,316	182,438	85,320	267,758
2019	186,259	88,676	274,936	181,509	85,919	267,428

6.6.3 *Uncertainty and time series consistency*

Uncertainties

The Approach 1 analysis in Annex 2, shown in 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., (2021) for details). The uncertainty range for CO_2 emissions in category 4C1 Grassland (non-TOF) remaining grassland (non-TOF) is calculated at -60% to +68% and for 4C2 Land converted to grassland (non-TOF) at -220% to +340%; see Arets et al., (2021) for details. There is not yet a 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 NIR2022.

Time series consistency

To ensure time series consistency, for all years up to 2019 the same approach is used for activity data, land use area and emissions calculation. 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 that have 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. Therefor, the mix of combinations of land use changes and soil types included, 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 area of fruit orchards after 2016 is updated using new and updated information. This has an effect on the emission factor for Grassland (non-TOF) which is partly determined by the fraction of orchards. This results in recalculations for the period 2016-2018. Additionally using new information on the age of fruit orchards in 2017 the carbon stocks in fruit orchards were recalculated and updated for the whole time series from 1990-2018 (see also section 6.1.3). The correction of an error in the carbon stock losses resulting from loss of litter in the dead organic matter (DOM) pool resulted in recalculations of the category forest land converted to grassland for the years 2017 and 2018. Additionally, the more general methodological change of adding pre 1990 land-use changes (i.e. including the 1970 land use map), has also resulted in recalculations in the grassland category for the time series 1990-2010. See also Section 6.1.3

6.6.6 *Category-specific planned improvements*

A correction of the misallocation of Land converted to grassland that within the 20-year transition period changes from one Grassland (non-TOF) category to another is currently being implemented in a new version of the LULUCF model. After testing in 2021 the model is expected to be used for the NIR 2022.

6.7 Wetland (4D)

6.7.1 *Source category description*

The land use category Wetland mainly comprises open water. Therefore for 4D1 (Wetland remaining wetland) no changes in carbon stocks in living biomass and soil are 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 included only 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 land use category Wetland 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 *Uncertainty and time series consistency*

Uncertainties

The Approach 1 analysis in Annex 2, shown in Table 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., (2021) for details).
The uncertainty range in the CO_2 emissions for 4D2 Wetland converted to wetland is calculated at -67% to +76%; see Arets et al., (2021) for details.

Time series consistency
To ensure time series consistency, for all years up to 2019 the same approach is used for activity data, land use area and emissions calculation. The time series shows a decrease in CO_2 emissions from 87 Gg CO_2 in 1990 to 41 Gg CO_2 in 2019.

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 correction of an error in the carbon stock losses resulting from loss of litter in the dead organic matter (DOM) pool resulted in recalculations of the category forest land converted to wetlands for the years 2017 and 2018.
Additionally, the more general methodological change of adding pre 1990 land-use changes (i.e. including the 1970 land use map), has resulted in recalculations in the forest land category for the time series 1990-2010. See also Section 6.1.3

6.7.6 Category-specific planned improvements
No improvements are planned.

6.8 Settlements (4E)
6.8.1 Source category description
Also in peat soils under Settlements, lowering of the groundwater table 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., 2021).
In other words, the major pools of carbon in urban areas are covered by other land use categories.

Since 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 considered to be 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) provide 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, shown in 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., (2021), for details).

The uncertainty range in CO_2 emissions for 4E1 (Settlements remaining settlements) is calculated at -64% to +53% and for 4E2 (Land converted to settlements) at -17% to +90%; see Arets et al., (2021) for details.

Time series consistency

To ensure time series consistency, for all years up to 2019 the same approach is used for activity data, land use area and emissions calculation. The time series shows a consistent increase from 848 Gg CO_2 in 1990 to 1,479 Gg CO_2 in 2019, which is the result of increasing land use change to Settlements.

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*

There are no category-specific recalculations. The correction of an error in the carbon stock losses resulting from loss of litter in the dead organic matter (DOM) pool resulted in recalculations of the category forest land converted to settlements for the years 2017 and 2018.

Additionally, the more general methodological change of adding pre 1990 land-use changes (i.e. including the 1970 land use map), has resulted in recalculations in the forest land category for the time series 1990-2010. 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 that are 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 developed in the Netherlands as a result of heavy overgrazing. This was for a long time combated 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 will 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, shown in 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., (2021) for details).

The uncertainty range in CO_2 emissions for 4F2 (Land converted to other land) is calculated at -3% to +152%; see Arets et al., (2021) for details.

Time series consistency
To ensure time series consistency, for all years up to 2019 the same approach is used for activity data, land use area and emissions calculation. The time series shows a consistent slow increase from 22 Gg CO_2 in 1990 to 175 Gg CO_2 in 2019.

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*
There are no category-specific recalculations. The correction of an error in the carbon stock losses resulting from loss of litter in the dead organic matter (DOM) pool resulted in recalculations of the category forest land converted to other land for the years 2017 and 2018. Additionally, the more general methodological change of adding pre 1990 land-use changes (i.e. including the 1970 land use map), has resulted in recalculations in the forest land category for the time series 1990-2010. See also Section 6.1.3

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

6.10 Harvested wood products (4G)

6.10.1 *Source category description*
The Netherlands calculates sources and sinks from Harvested wood products (HWP) on the basis of the change of the pool, as suggested in the 2013 IPCC KP guidance (IPCC, 2014). For greater transparency, and following footnote 12 in the Convention CRF Table 4.G s1, both the HWP changes reported under the convention and those reported under the KP are calculated using the same methodology (see Arets et al., 2021). Under the convention, 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 the guidance in chapter 2.8 of the 2013 IPCC KP guidance (IPCC, 2014). As required by the guidelines, carbon from HWP allocated to Deforestation is reported using instantaneous oxidation (Tier 1) as the calculation method. The remainder of the carbon is allocated to Forest management and is subsequently 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., 2021).

Four categories of HWP are taken into account: Sawn wood, Wood-based 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 management, 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 1990 onwards to the FAO for its statistics on

imports, production and exports of the different wood product categories (see Table 6.12), 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 Sawn wood, Wood-based panels, and Paper and paperboard from the 2013 IPCC KP guidance (see Table 6.13) have been used. For the category Other industrial round wood, the values for Sawn wood 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 gives a negative value. In line with the instructions in the 2013 IPCC KP guidance (IPCC, 2014) these negative values are set to zero, indicating that there is no inflow of domestically produced pulp.

Table 6.12 Annual production, import and export statistics for Sawn wood, Wood-based panels, Other industrial round wood (only production, no import or export) and Paper and paperboard

	Sawn wood			**Wood-based panels**			**Other**	**Paper and paperboard**		
	Prod.	**Im.**	**Ex.**	**Prod.**	**Im.**	**Ex.**	**Prod.**	**Prod.**	**Im.**	**Ex.**
Year	1000 m^3							metric kt		
1990	455	3,450	413	97	1,621	141	115	2,770	2,420	2,099
1991	425	3,149	461	105	1,589	154	132	2,862	2,547	2,135
1992	405	3,222	440	111	1,532	167	95	2,835	2,579	2,224
1993	389	3,564	427	107	1,456	237	77	2,855	2,429	2,050
1994	383	3,771	426	110	1,593	312	100	3,011	2,366	2,204
1995	426	3,277	458	114	1,599	305	75	2,967	2,522	2,250
1996	359	3,322	389	96	1,531	318	70	2,987	2,798	2,438
1997	401	3,431	377	101	1,765	313	59	3,159	3,178	2,844
1998	349	3,534	415	59	1,813	299	39	3,180	3,523	2,810
1999	362	3,606	427	61	2,089	288	92	3,256	3,496	2,588
2000	390	3,705	380	61	1,727	275	110	3,332	3,210	3,001
2001	268	3,294	305	20	1,816	257	84	3,174	3,211	2,558
2002	258	3,022	356	23	1,631	254	116	3,346	3,306	2,819
2003	269	3,163	400	10	1,630	247	126	3,339	3,264	3,044
2004	273	3,175	388	8	1,597	308	33	3,459	3,055	2,957
2005	279	3,100	488	11	1,643	327	44	3,471	3,386	3,151
2006	265	3,399	555	10	1,871	363	32	3,367	3,367	3,169
2007	273	3,434	601	18	1,886	405	20	3,224	3,519	3,106
2008	243	3,101	423	33	1,894	411	31	2,977	3,413	2,374
2009	210	2,575	292	46	1,495	301	48	2,609	2,923	2,007

	Sawn wood			Wood-based panels			Other	Paper and paperboard		
	Prod.	Im.	Ex.	Prod.	Im.	Ex.	Prod.	Prod.	Im.	Ex.
Year	1000 m^3							metric kt		
2010	231	2,750	314	51	1,483	274	52	2,859	3,036	2,270
2011	238	2,710	322	46	1,680	295	61	2,748	2,874	2,484
2012	190	2,557	432	58	1,431	329	20	2,761	2,570	1,941
2013	216	2,477	446	33	1,371	288	14	2,792	2,758	2,279
2014	228	2,506	508	29	1,404	290	14	2,767	2,789	2,268
2015	185	2,757	526	29	1,568	314	13	2,643	2,592	2,217
2016	184	2,821	468	29	1,608	326	21	2,671	2,424	2,289
2017	171	3,165	587	29	1,815	335	20	2,983	2,439	2,508
2018	140	3,515	686	29	1,935	388	23	2,980	2,563	2,529
2019	141	3355	767	29	1757	357	52	2,489	2.332	2,556

Table 6.13 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., (2021) for details).

The uncertainty range in the CO_2 emissions for 4G (Harvested wood products) is calculated at -8% to +1%; see Arets et al., (2021) 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*

An error correction in the HWP pool has resulted in recalculations for the whole time series (see Section 6.2.1 for more details). Input values for calculation of the HWP emissions and removals have been updated for the years 2017-2019 based on data provided by Teeuwen et al., (2020).

6.10.6 *Category-specific planned improvements*

No improvements are planned.

7 Waste (CRF sector 5)

Major changes in the Waste sector compared with the National Inventory Report 2020	
Emissions:	In 2019, total GHG emissions from the Waste sector further reduced by 3.4% compared with 2018; and by 80% compared with 1990.
Key categories:	New: 5D Wastewater treatment and discharge (CH_4)
Methodologies:	No changes.

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 communal 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 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.

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	Key	1990	2018	2019	2019 vs 1990	Contribution to total in 2019 (%) by		
			Emissions in Tg CO2 eq			%	sector	total gas	total CO2 eq
5 Waste	CH_4		14.0	2.8	2.7	-80.6%	94.2%	15.8%	1.5%
	N_2O		0.2	0.2	0.2	-7.0%	5.8%	2.1%	0.1%
	All		14.2	3.0	2.9	-79.6%	100.0%		1.6%
5A. Solid Waste Disposal	CH_4		13.7	2.5	2.4	-82.7%	82.1%	13.8%	1.3%
5A1. Managed Waste Disposal on Land	CH_4	L,T	13.7	2.5	2.4	-82.7%	82.1%	13.8%	1.3%
5B. Biological treatment of solid waste	CH_4	non key	0.0	0.1	0.1	2577.3%	4.0%	0.7%	0.1%
	N_2O	non key	0.0	0.1	0.1	1295.7%	3.2%	1.2%	0.1%
	All		0.0	0.2	0.2	1803.1%	7.1%		0.1%
5D. Wastewater treatment and discharge	N_2O	non key	0.2	0.1	0.1	-56.1%	2.6%	1.0%	0.0%
	CH_4	L	0.3	0.2	0.2	-25.3%	8.0%	1.3%	0.1%
	All		0.5	0.3	0.3	-36.3%	10.6%		0.2%
Total national emissions	CO2		162.7	159.5	153.6	-5.6%			
(excl LULUCF)	CH4		31.8	17.3	17.2	-45.9%			
	N2O		17.5	8.0	7.9	-54.9%			
	total*		220.5	186.8	180.7	-18.0%			

* including f-gases

CO_2 emissions from the anaerobic decay of waste in landfill sites are not included, since 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 in the Waste sector either, because these facilities also produce electricity and/or heat used for energy purposes; these emissions are therefore included in category 1A1a (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., 2021), see also the reference in Annex 7.

The Waste sector accounted for 1.5% of total national emissions (without LULUCF) in 2019, compared with 6.4% in 1990. Emissions of CH_4 and N_2O accounted for about 94% and 6% of CO_2-equivalent emissions from the sector, respectively. Emissions of CH_4 from waste – almost all of which (98%) originates from landfills (5A1 Managed waste disposal on land) – accounted for 13.8% of total CH_4 emissions in 2019. 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), since all large-scale incinerators also produce electricity and/or heat for energy purposes.
Emissions from the Waste sector decreased by almost 80.0% between 1990 and 2018 (from 14.2 Tg CO_2 eq. in 1990 to 2.9 Tg CO_2 eq.; see Figure 7.1), mainly due to an 82.7% reduction in CH_4 from landfills (5A1). Between 2018 and 2019, CH_4 emissions from landfills decreased by 4.7%.
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 2019).

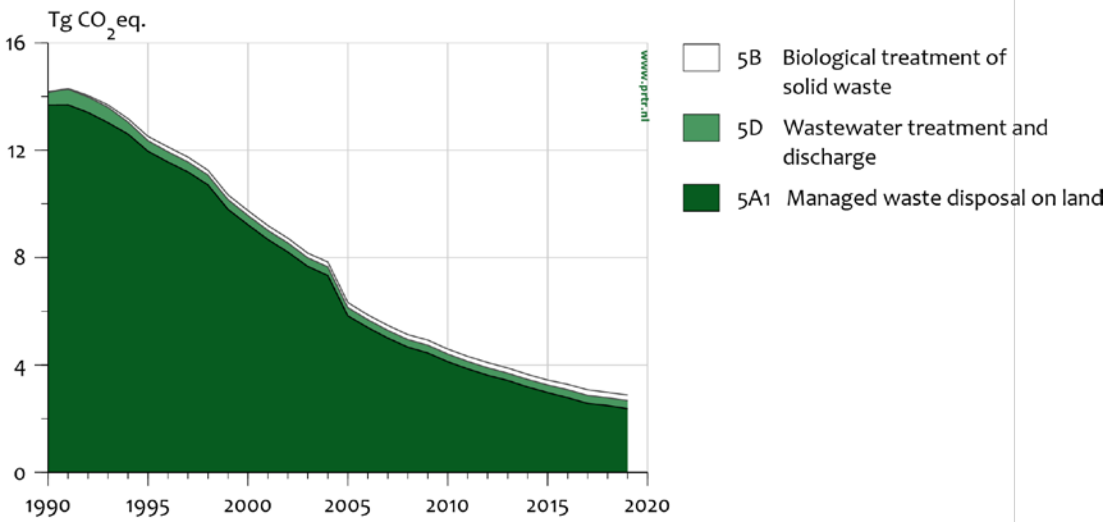


Figure 7.1 Sector 5 Waste – trend and emissions levels of source categories, 1990–2019.

As indicated above, emissions from waste incineration (5C) are included in category 1A1ai Other fossil fuels (see Section 3.2.4.1). Emissions from waste incineration accounted for c. 0.6 Tg CO_2 eq. in 1990 (601 Gg CO_2 and 0.03 Gg N_2O emissions). In 2019, emissions accounted for approximately 2.8 Tg CO_2 eq. (2,723 Gg CO_2 and 0.41 Gg N_2O); see also Table 7.8.

7.2 Solid waste disposal on land (5A)

7.2.1 Category description

In 2019 there were 19 operating landfill sites, as well as a few thousand old sites that were used. As a result of the anaerobic degradation of the organic material within the landfill body, all of these 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 takes place at 54 sites in the Netherlands. The gas is extracted before it emits into the atmosphere and is subsequently used as an energy source or flared off. In both of these 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 may take many decades. Some of the factors influencing this process are known; some are not. Each landfill site has unique characteristics: 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 6.2% in 1990 and 1.3% in 2019.
This decrease is partly due to the increase in recovered CH_4, from about 4% in 1990 to 13% in 2019 as indicated above. A second cause is the decrease in methane produced at solid waste disposal sites (SWDS) and the decrease in the relative amount of methane in landfill gas from 57% to 50%.

In 2019, solid waste disposal on land accounted for 82.1% of total emissions from the Waste sector and 1.3% of total national CO_2-equivalent emissions (see Table 7.1).

Dutch policies directly aim at reducing the amount of waste sent to landfill sites. This requires 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.[13] As a result of this policy, the amount of waste sent to landfills decreased from 14 million tons in 1990 to 2.8 million tons in 2019, thereby reducing emissions from this source category.

7.2.2 *Methodological issues*

A more detailed description of the method and EFs used can be found in paragraph 2.3.2.2 of Honig et al., (2021) and Annex 7.
Data on the amount of waste disposed of 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, (2021), which also gives the annual amount of CH_4 recovered from landfill sites.

In order to calculate CH_4 emissions from all the landfill sites in the Netherlands, for modelling purposes it is assumed that all waste is disposed of at one landfill site. As stated above, however, characteristics of individual sites 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).

[13] 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'.

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): 0.094 up to and including 1989, decreasing to 0.0693 in 1995, further 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, 2021);
- Time delay from deposit of waste to start of 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 few of the above parameters are discussed in the sub-sections below.

Amount of waste landfilled

Table 7.2 shows an overview of waste landfilled 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

Year	Amount landfilled (Mton)	Degradable organic carbon (kg/ton)
2014	2.2	34
2015	2.3	43
2016	2.8	52
2017	2.9	56
2018	3.2	51
2019	2.8	50

Between 1945 and 1970 a number of municipalities kept detailed records of the collection of waste. 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); CBS, (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, assuming 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) are linearly extrapolated.

From 1970 on, accurate data on production and waste treatment are available (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 the way in which 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 that the WAR has a complete overview of the waste that is landfilled 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 declines 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, 2021). 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 waste that is landfilled is included in the figures. This includes waste streams that have very low DOC content (contaminated soil, dredging spoils) or no DOC at all (inert waste). The result is that the average DOC value of a ton of landfilled waste is low compared with the IPCC default values.

For each EWL code an amount of degradable carbon is determined (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 of this approach, Table 7.3 shows the waste stream groups, with their DOC values and the amount landfilled in 2019 (where permitted).

Table 7.3 Amount of waste landfilled in 2019 and DOC value of each group.

Waste stream group	Amount landfilled (ton)	DOC value (kg/ton)	Total DOC landfilled (ton)
Waste from households	82,730	182	15,057
Bulky household waste		192	
Commercial waste		182	
Cleansing waste	12,228	43.4	531
Fresh organic waste	77,681	112	8,700
Stabilised organic waste	570,716	130	74,193
Little organic waste	752,051	44	33,090
Contamined soil	299,874	11.5	3,449
Dredging spoils	23,112	42.4	980
Inert waste	986,661	0	0
Wood waste	2,714	430	1,167
Total	**2,807,767**	**50**	**137,167**

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 that is 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.

Materials never decompose completely. For waste streams considered to be ‘biodegradable’, like the ‘organic wet fraction’ (OWF), a conversion of about 70% seems to be the maximum achievable. Under landfill

conditions the 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 assume 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 a value for slowly degrading waste (wood, paper, textiles) in a wet and temperate climate zone. The IPCC default value is between 0.03 and 0.06; a k-value of 0.05 is used in the Dutch model.
Degradable waste is not landfilled in large quantities in the Netherlands. There is still a quantity of mixed municipal waste landfilled (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.
The problem with commercial waste is that an accurate composition of this waste stream is not available. Waste incinerator operators do not accept this stream, so an exemption of the landfill ban is permitted by the regional authorities. Waste incinerator operators must give an explanation why waste cannot be incinerated at their plants. In most cases the operators state that the waste stream is not combustible or not suitable for their processes and therefore has to be landfilled.
The same problem applies to residues from waste treatment. If residues have to be landfilled, it is in most cases because they are not combustible or recyclable. In some cases waste incinerator operators argue that the caloric value is also too high, mainly due a high content of plastics in the residues. Residues do not contain rapidly degrading waste such as food waste or sewage sludge.
Other waste streams that are 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 contain only slowly degrading waste, because the organic content is stabilised.

Methane correction factor (MCF)

All sites that were 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 placement of waste (i.e. waste is directed to specific deposition areas, and there is a degree of control over scavenging and over the outbreak of fire) and feature at least one of the following: (i) cover material; (ii) mechanical compacting; or (iii) levelling of the waste.

Many landfill sites are situated near urban areas. In order to prevent odour and scavenging animals (birds, rats) the management of landfill sites has attracted close attention since the beginning 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 managed during the whole 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 since then Dutch waste policy has changed. 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 nowadays mostly incinerated and or recycled. As a result, existing models are 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 from e.g. 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 that is 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 was 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 is 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. At all landfill sites the amount of recovered landfill gas is measured. Only the percentage of methane in older landfill sites is sometimes estimated. In 2018, the methane content of recovered landfill gas at 12 landfill sites was estimated. Table 7.4 gives an overview of the amounts of recovered landfill gas, the average methane content and the amount flared or used for energy purposes. Amounts for the whole time series are also available in an Excel file.

Table 7.4 Amount of landfill gas recovery .

Parameter	1990	1995	2000	2005	2010	2015	2018	2019
Amount landfill gas recovered (million m³)	63.7	181.5	161.5	130.4	101.5	60.4	55.4	49.3
Amount combusted in flares (%)	25	25	27	25	22	28	48	50
Amount used for energy purposes (%)	75	75	73	75	78	72	52	50
Average percentage methane (%)	57.4	57.4	57.4	53.2	51.3	49.6	44.9	45.3

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 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 undertaken 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 uses 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 till 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 7.5 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	2018	2019
Fraction DOC in landfilled waste	0.13	0.13	0.11	0.06	0.03	0.04	0.05	0.05
CH_4 generation rate constant (k)	0.09	0.07	0.07	0.05	0.05	0.05	0.05	0.05

Parameter	1990	1995	2000	2005	2010	2015	2018	2019
Number of SWDS recovering CH_4	45	50	55	50	53	54	55	54
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 shown in Annex 2 provides estimates of uncertainties by IPCC source category and gas. The uncertainty in CH_4 emissions from SWDS is estimated to be approximately 24%. The uncertainty in the activity data and the EF is estimated to be less than 0.5% 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 (Wever, 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.

7.2.5 *Category-specific recalculations*

Compared with the previous submission, minor errors 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 and green waste from gardens and horticulture; and emissions from manure from agriculture.
Emissions from the small-scale composting of garden waste and food waste by households are not estimated, as these are assumed to be negligible.

The amount of composted and digested organic waste increased from almost nothing in 1990 to 3.8 million ton in 2019. In 2019, this treatment accounted for 7.1% of the emissions in the Waste sector (see Table 7.1). The biological treatment of solid waste is not a key source of CH_4 or N_2O emissions.

7.3.2 *Methodological issues*

Detailed information on activity data and EFs can be found in paragraph 2.3.2.3 in Honig et al., (2021).

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, 2021). 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.
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), as described in Chapter 5 and the methodology report for agricultural emissions (van der Zee et al., 2021).

Table 7.6 Total amount of treated collected organic waste from households and green waste from gardens and companies.

Year	organic waste from households (Mton)		Green waste from gardens and enterprises (Mton)	
	Composted	**Digested**	**Composted**	**Digested**
	(5B1a)	(5B2a)	(5B1b)	(5B2b)
1990	228	-	-	-
1995	1,409	44	2,057	-
2000	1,498	70	2,473	2
2005	1,326	41	2,770	14
2009	1,178	81	2,648	0
2010	1,066	154	2,424	13
2011	1,091	182	2,384	25
2012	1,009	292	2,417	30
2013	942	331	2,299	42
2014	911	445	2,086	59
2015	882	475	1,992	85
2016	966	465	2,321	78
2017	1,027	465	2,335	107
2018	1,044	448	2,376	94
2019	1,072	476	2,189	95

In 2010 an independent study on the EFs was carried out (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 that were 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 that has been obtained from the literature. The uncertainty in annual CH_4 and N_2O emissions is estimated at 63% and 50%. The uncertainty is mainly determined by uncertainties in the EF (63% and 50%, respectively); whereas to uncertainty in the activity data is about 5%. For a more detailed analysis of these uncertainties, see Rijkswaterstaat, (2014).

Time series consistency

The time series consistency of the activity data is very good, due to the continuity in the data provided.

7.3.4 *Category-specific QA/QC and verification*

The source categories are covered by the general QA/QC procedures, which are discussed in Chapter 1, and the specific QA/QC described in the document for the QA/QC of outside agencies (Wanders, 2020).
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, minor errors in the data have been corrected in this submission.
Additionally, CH_4 emissions from the digesting of manure (category 5B2) have been added from the starting year 2006 (4 Gg CO_2 eq.) up to 44 Gg CO_2 eq. in 2019.

7.3.6 *Category-specific planned improvements*

No planned improvements.

7.4 Waste incineration (5C)

7.4.1 *Category description*

This category comprises mostly emissions from activities of the waste incineration facilities that process municipal solid waste and other waste streams.
In general, the 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 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 it is known where they occur. The permits often specify how much biomass waste may be burned in the open air. 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), since all 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.

7.4.2 *Methodological issues*

Detailed information on activity data and EFs (waste incineration in WIPs) can be found in paragraph 2.3.2.1 in Honig et al., (2021).

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 on the website http://english.rvo.nl/nie and in a background document (Rijkswaterstaat, 2021).

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 on a yearly basis, on the basis of analyses of household residual waste. Table 7.7 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 7.7 Composition of incinerated waste.

	1990	**1995**	**2000**	**2005**	**2010**	**2015**	**2018**	**2019**
Total waste incinerated (Gg)	2,780	2,913	4,896	5,503	6,459	7,564	7,434	7,386
Total waste incinerated (TJ)	22,746	27,903	51,904	55,058	63,818	75,299	74,650	72,588
Energy content (MJ/kg)	8.2	9.6	10.6	10.0	9.9	10.0	10.0	9.8
Fraction biomass (energy %)	58.2	55.2	50.4	47.8	53.1	54.2	52.4	53.1
Amount of fossil carbon (Gg)	164	221	433	561	675	780	779	743
Amount of bio-genic carbon (Gg)	544	561	938	909	1,172	1,381	1,346	1,337

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.

Starting in this inventory 2021 (reporting year 2019), carbon capture is taken into account in the CO_2 emissions of WIPs. In earlier years the amount of carbon capture was insignificant. The amount in 2019 is still small; 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 take usage of captured CO_2 into account in the inventory. The Netherlands deals with it along two lines of potential application of the carbon captured:

- *use as growth medium in agriculture*. As most of the CO_2 will in the end be emitted to the atmosphere, this amount is not subtracted from the produced CO_2;
- *the captured CO_2 is used 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 comes from the annual survey of WIPs (Rijkswaterstaat,2021). Detailed information can be found in Honig et al., (2021).

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 the methodology report (Honig et al., 2021). A comparison between the country-specific EFs and the IPCC defaults can also be found in this report. Table 7.8 shows the emissions from the waste incinerations plants. The emission trend is directly related to the trend in the amount of waste processed.

Table 7.8 Emissions of incinerated waste.

	1990	**1995**	**2000**	**2005**	**2010**	**2015**	**2018**	**2019**
Total CO_2 emission (Gg)	2,596	2,867	5,025	5,392	6,770	7,924	7,791	7,624
Fossil CO_2 emissions (Gg)	601	810	1,586	2,058	2,473	2,861	2,857	2,723
N_2O emissions (Gg)	0	0.1	0.1	0.1	0.1	0.2	0.4	0.4
Total GHG emissions (Gg CO_2 eq.)	622	843	1,655	2,138	2,573	2,989	2,980	2,846

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 emissions for 2019 from waste incineration is estimated at 8%.
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 in the amounts of incinerated fossil waste and the uncertainty in the corresponding EF are estimated to be 3% and 7%, respectively.
The uncertainty in annual N_2O emissions from waste incineration is estimated at 71%. The uncertainty in the activity data and the uncertainty in the corresponding EF for N_2O are estimated to be less than 0.5% and 71%, respectively. For a more detailed analysis of these uncertainties, see Rijkswaterstaat, (2014).

Bonfires

Uncertainties in the bonfire related emissions (both CH_4 and N_2O) are high: over 300%. This relates to uncertainties in activity data as well as in EFs: estimated at 100% and 300%, respectively, for both gases.

Time series consistency

Consistent methodologies have been used throughout the time series for this source category. Time series consistency of the activity data is considered to be very good, due to the continuity of the data provided by the WAR.

7.4.4 *Category-specific QA/QC and verification*

The source categories are covered by the general QA/QC procedures, which are discussed in Chapter 1, and the specific QA/QC described in the document for the QA/QC of outside agencies (Wanders, 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 and septic tanks. In 2019, 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).

In 2019, urban wastewater (the mixture of domestic, industrial and commercial wastewater, including urban run-off) was treated aerobically in 318 public wastewater treatment plants (WWTPs). The treatment of the resulting wastewater sludges is accomplished mainly by anaerobic digesters. During wastewater treatment, the biological breakdown of degradable organic compounds (DOC) and nitrogen compounds can result in CH_4 and N_2O emissions. Incidental venting of biogas also leads to CH_4 emissions. 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 discharge of effluents, as well as other direct discharges from households and companies, result in indirect N_2O emissions from surface water due to the natural breakdown of residual nitrogen compounds. The source category also includes CH_4 emissions from the operational anaerobic industrial WWTPs (IWWTPs) (2019: 50 plants).

N_2O emissions from the wastewater treatment (see Tables 7.1 and 7.9) contributed about 1.0% of total N_2O emissions in 2019 and 0.04% in total CO_2-equivalent emissions. During the period 1990–2019, N_2O emissions from wastewater handling and effluents decreased by 56.1%. This decrease is mainly the result of lower untreated discharges, resulting in lower effluent loads (see Table 7.10) and a subsequent decrease in (indirect) N_2O emissions from domestic and industrial effluents.

The contribution of wastewater handling to the national total of CH_4 emissions in 2019 was 1.3%, or 0.1% of total CO_2 equivalents. Since 1994, CH_4 emissions from public WWTPs have decreased due to the introduction in 1990 of a new sludge stabilisation system in one of the largest WWTPs. As the operation of the plant took a few years to optimise, venting emissions were higher in the introductory period (1991–1994) than under subsequent normal operating conditions. During the period 1990–2019 CH_4 emissions from category 5.D wastewater handling decreased by 25.3%. The amount of wastewater and sludge being treated does not change 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	2018	2019
CH_4 domestic wastewater[1)]	8.13	6.88	7.40	7.36	7.76	8.25
CH_4 industrial wastewater	0.29	0.39	0.38	0.38	0.42	0.41
CH_4 septic tanks	3.93	1.99	0.68	0.63	0.57	0.57
Net CH_4 emissions	12.35	9.25	8.46	8.37	8.74	9.23
CH_4 recovered[2)] and/or flared	33.0	40.6	40.0	44.4	47.1	48.5
N_2O domestic WWTP	0.076	0.076	0.079	0.082	0.084	0.084
N_2O effluents	0.501	0.302	0.174	0.168	0.167	0.169
Total N_2O emissions	0.577	0.378	0.253	0.250	0.251	0.253

1) Including emissions caused by venting of biogas at public WWTPs.
2) Used for energy purposes on site at public WWTPs and/or flared, so excludes CH_4 in external delivered biogas and vented amounts.

7.5.2 *Methodological issues*

Activity data and EFs

Most of the activity data on wastewater treatment is collected by the CBS via yearly questionnaires that cover all public WWTPs as well as all anaerobic IWWTPs, and is presented in StatLine (CBS, 2020a); see also www.statline.nl for detailed statistics on wastewater treatment. Table 7.10 shows the development in the main activity data with respect to domestic wastewater treatment as well as industrial wastewater treatment and septic tanks.

Due to varying weather conditions, the volumes of treated wastewater and of the total load of DOC 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, 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. These data are inventoried by the CBS.
From Table 7.10 it can be concluded that the DOC of treated domestic wastewater and sludge increases slightly over time. In 2019, methane emissions increased with 6% compared to 2018. This is caused by an increased influent TOW as well as an increase in the total amount of recovered biogas, because a larger fraction of sludge is digested.

Inter-annual changes in CH_4 emissions can also 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 paragraph 2.3.2.4 of Honig et al., (2021). In general, emissions are calculated according to the 2006 IPCC Guidelines, with country-specific activity data.

Table 7.10 Activity data of domestic and industrial wastewater handling.

	Unit	1990	2000	2010	2015	2018	2019
Domestic (urban) WWTPs:							
Treated volume	Mm^3/yr	1,711	2,034	1,934	1,957	1,771	1,904
TOW as COD[1)]	Gg/year	933	921	953	999	1,017	1,051
Sludge organic dry solids[2)]	Gg/year	260	308	340	360	368	366
Sludge DOC as COD[1)2)]	Gg/year	365	431	476	505	514	512
Biogas recovered [3)]	mio m^3/yr	74	87.9	98.5	107.0	116.1	124.8
Biogas flared	1,000 m^3/yr	8,961	6,150	7,360	7,405	11,278	12,061
Biogas vented	1,000 m^3/yr	2,524	284	1,066	82.3	238.0	76.3
Actual PE load WWTP[4)]	1,000	23,798	23,854	24,745	25,686	26,394	26,144
IWWTPs:							
TOW as COD[1)]	Gg/year	144	194	192	190	209	206
Biogas recovered[3)]	Mio m^3/year	[9)]	[9)]	[9)]	[9)]	[9)]	80.5 [5)]
Septic tanks:							
Resident population [6)]	1,000	14,952	15,926	16,615	16,940	17,233	17,345
inhabitants with septic tank	% of pop.	4	1.9	0.62	0.57	0.50	0.50
Direct discharges of nitrogen:							
Nitrogen in effluents[7)], total	Gg/yr	63.79	38.45	22.13	21.35	21.20	21.56
Via effluents from UWWTP[8)]	Gg/yr	42.68	30.44	17.69	17.05	16.55	16.90
Via industrial discharges	Gg/yr	12.71	4.51	2.36	2.29	2.27	2.27
Via other direct discharges	Gg/yr	8.40	3.51	2.07	2.01	2.39	2.39

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 in 2019; 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) Data on the years 2003-2018 will become available next submission. Data for 1990-2002 are not available.

CH_4 emissions from domestic wastewater treatment (5D1)
In 2019, 99.5% of the population was connected to closed sewer systems, which were in turn connected to 318 public WWTPs. All public WWTPs in the Netherlands are of the advanced aerobic treatment type. In addition, in larger plants sludge digestion is carried out.

For the category 5D1 (Domestic wastewater treatment), CH_4 emissions from three types of processes are calculated:

1. Wastewater treatment process emissions: Although according to IPCC (2006) methane emissions from advanced aerobic WWTPs are zero, small amounts of methane can be formed during certain wastewater treatment process steps and there can be small emissions from the influent cellars, anaerobic zones created for phosphorus removal and anaerobic pockets in zones with poor aeration, for example.
2. Anaerobic sludge digestion emissions: In addition to the methane that is recovered and used for energy processes, uncontrolled CH_4 emissions can arise from sludge (post-)thickeners, sludge silos and the digesters.
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 paragraphs 2.3.2.4.2 and 2.3.2.4.3 in Honig et al., (2021). The calculation of emissions from these processes is described below.

1. Wastewater treatment process emissions
Methane emissions from the wastewater treatment process are calculated using the B0 from the 2006 IPCC Guidelines, a country-specific MCF and country-specific data for the TOW and sludge produced. 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 the CBS among the Water Boards. Data on influent COD are available for the years 1990 until the present for every treatment plant.

Data on sludge produced are available on an annual basis for the years 1990 until 2016. Due to a re-evaluation of the statistical programme these data in future will only be inventoried for the even years. For odd years (starting 2017) the data of the previous year will be used as a best estimate; see also paragraph 2.3.2.4.2 in Honig et al., (2021).

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 sludge digesters and related process steps (e.g. post-thickening) are calculated using a country-specific method based on an EF per m^3 biogas recovered in the sludge digesters. The emissions are calculated per WWTP with sludge digestion facilities. In 2019, 72 urban WWTPs (UWWTPs) were equipped with sludge digesters. See also paragraph 2.3.2.4.2 in Honig et al., (2021).

Country-specific activity data on the volume of recovered biogas in all public WWTPs with sludge digesters are derived from the yearly survey conducted by the CBS among the Water Boards. Data are available for the years 1990 until the present for every treatment plant.

3. Emissions from incidental venting of biogas
Incidental venting of biogas at public WWTPs is recorded by the plant operators and subsequently reported to the CBS. In 2019, the amount of CH_4 emitted by the venting of biogas was 0.035 Gg CH_4, equalling 0.4% of total CH_4 emissions from the category Domestic wastewater. During the last decade, this value varied between 0.3% and 9%, which means that the venting of biogas in 2019 was low.

Recovered biogas is largely used for energy generation purposes, but a small amount is flared, vented or delivered to third parties. Table 7.9 provides data on the recovery of CH_4 (total) and CH_4 combusted via flaring. See also paragraph 2.3.2.4.3 in Honig et al., (2021).

CH_4 emissions from industrial wastewater treatment (5D2)
In the calculation of methane emissions from anaerobic industrial wastewater treatment, the Netherlands uses the default IPCC parameters for the EF and 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 EFs used can be found in paragraph 2.3.2.4.5 of Honig et al., (2021).

In the Netherlands no information is available on the actual load of COD that is treated in the IWWTPs. The TOW thus has to be determined in an alternative way. The TOW is estimated by using statistics on the design capacity of the IWWTPs and an assumed average loading rate of 80% of the design capacity (Oonk, 2004). The design capacity is expressed in terms of a standardised value for quantifying organic pollution in industrial wastewater: Pollution Equivalents (PE). One PE equals an amount of 40 kg COD per year. Data on the design capacity is available from the CBS, (2018). Table 7.10 provides the time series of total TOW for IWWTPs.
In 2019, 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%).

Since 2017, the inventory on industrial wastewater treatment is no longer continued. Information on existing anaerobic WWTPs is no longer updated on a regular basis.
Therefore, the activity data and resulting CH_4 emissions for 2019 are mainly a copy of the 2018 values but have been corrected using information on closed and/or newly started anaerobic WWTPs.

Numerical estimate of the recovered CH4 in anaerobic industrial wastewater treatment plants available for 2019 (response to review question)
In response to a review question it is investigated whether 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. In this submission this is elaborated for 2019 only (see also table 7.10). Data on 2003-2018 will be added in the next submission, because this could not be elaborated very easy within the available time. Data on 1990-2002 are not available from the ePRTR reports.

The total amount of IWWTP biogas recovered in 2019 equals 66.8 million m^3, but this only includes data from 39 out of total 50 anaerobic IWWTPs, equalling 83% of total TOW treated. For the remaining 11 plants, no data are available, but based on the amount of TOW this missing volume can be estimated at an extra 13.7 million m^3. Total recovery can then be estimated at 80.5 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 digesting (0.44 kg CH_4/m^3 biogas, see Honig et al, 2021) a total recovery of 35.4 Gg CH_4 can be calculated for 2019. Applying a loss by leakage of 1% of total CH_4 recovered (Honig et al., 2021), this results in an emission of 0.354 Gg CH_4. This figure can be compared with the current CS method resulting in an emission of 0.411 Gg CH_4 (+16% higher). Given all uncertain factors in both methods this difference seems quite 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 paragraph 2.3.2.4.4 of Honig et al., (2021).

Table 7.10 shows the time series of the percentage of the population connected to septic tanks. The percentage of the population connected to septic tanks decreased from 4% in 1990 to 0.5% in 2019. These data derive from surveys and estimates by various organisations in the Netherlands, such as Rioned, (2009, 2016) and the National Water Authorities.

N_2O emissions from centralized wastewater treatment (5D1)
N_2O emissions from domestic wastewater handling are determined on the basis of the IPCC default EF of 3.2 g N_2O/person/year and country-specific activity data for the number of people connected, including the

extra fraction of industrial and commercial wastewater. This is determined by the number of Pollution Equivalents (PEs).

Rationale for using the Pollution Equivalent (PE) as activity data (response to review question)
PEs, as measured and reported by all UWWTPs, reflect the total amount of organic degradable matter that is treated in the plants. 1 PE equals the wastewater (and degradable substances in it) from one person. Its basis and method of calculation are anchored in Dutch water laws.
As the PE is calculated from influent data on COD and Kjeldahl nitrogen, it includes the loads from industrial and commercial activities as well as loads from urban run-off into the sewerage system.
In formula 6.9, box 6.1 of the 2006 IPCC Guidelines, the total PE thus can replace the terms $P*T_{PLANT}*F_{IND-COM}$. For example, the PE value for 2019 is 26.1 million. With an average population of 17.3 million, this means that 8.8 million PE comes from industrial and commercial sources and urban run-off. With T_{PLANT} is almost 1, $F_{IND-COM}$ in 2019 is approximately equal to 1.5.

A description of the calculation of PE, the method and the EF used can also be found in paragraph 2.3.2.4.2 of Honig et al., (2021). Table 7.10 provides a time series of the PE. In 2019, the total PE equalled 26.1 million.

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).

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 N_2O emissions from wastewater effluents, the Netherlands uses the default EF of 0.005 kg N_2O-N/kg N discharged (IPCC, 2006) and country-specific activity data. The country-specific activity data on kg N discharged per year via industrial, domestic and commercial effluents is derived from the Netherlands' PRTR.

Rationale for country-specific activity data and not using the 'Note' in box 6.1 in 2006 IPCC Guidelines
For calculating indirect (or better: 'delayed') N_2O emissions from wastewater treatment effluent, the Netherlands uses country-specific activity data on the total N discharged to surface water via effluents of UWWTP, combined sewer overflows, plus industrial effluents and other direct discharges to surface water.

The Netherlands does not make use of equation 6.8 of the 2006 IPCC Guidelines. Hence, information on population, protein consumption, fraction of nitrogen in protein, $F_{NON-CON}$, $F_{IND-COM}$ and T_{PLANT} values are reported as 'NA' in the additional information table of CRF Table 5.D.

The use of equation 6.8 might result in an overestimation of N effluent, because FAO statistics seem to be based on protein supply data and might also include amounts not being consumed (e.g. food waste) and consequently not being discharged to wastewater. Instead, the Netherlands

has chosen to use activity data derived from other sources, such as statistical surveys, environmental reporting and models, often based on actual measurements. These data are inventoried yearly via the national emission inventory system, in which several agencies and institutes work together. The data include loads of N in (1) effluents of all UWWTPs, (2) direct discharges from companies and households (via septic tanks), (3) other estimated wastewater discharges such as those from combined sewer overflows.
As a consequence of using these data, the Netherlands does not take into account the Note in box 6.1 of IPCC, (2006). The discharges of N already represent ‘end of pipe’ values, so an adjustment for amounts of N related to emissions resulting from nitrification/dentrification processes in advanced centralised wastewater treatment is not needed.

Detailed information on activity data and EFs can be found in paragraph 2.3.2.4.6 of Honig et al., (2021). 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 calculated (NE) or not occurring (NO):

N_2O emissions from industrial wastewater treatment (5D2: NE)
The 2006 IPCC Guidelines do not provide a method for calculating N_2O emissions from industrial sources, except for industrial wastewater that is co-discharged with domestic wastewater into the sewerage system. N_2O emissions from industrial sources are believed to be insignificant in comparison with emissions from domestic wastewater. In the Netherlands most industries discharge their wastewater into the sewerage system/WWTPs (emissions included in 5D1). Indirect emissions from surface water resulting from the discharge of wastewater effluents are already included under 5D3 (Other, wastewater effluents).

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 the CBS it can be concluded that anaerobic sludge digestion within industries is not significant. These data are not published on www.cbs.statline.nl for reasons of confidentiality. Forthcoming CH_4 emissions are therefore not estimated (NE). It is likely, however, that these emissions are a very minor source and can be neglected.

7.5.3 *Uncertainty and time series consistency*

Uncertainty
The Approach 1 uncertainty analysis shown in Annex 2 provides estimates of uncertainties by IPCC source category and gas. The uncertainty in annual CH_4 and N_2O emissions from wastewater handling is estimated to be 38% and 102%, respectively.

The uncertainty in activity data is based on expert judgement and is estimated to be >20%. 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.
The uncertainty in the EFs for CH_4 and N_2O is estimated to be 32% and 100%, respectively.
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. In fact, 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 be determined only 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 for all years, 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 the CBS.

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 determining more precisely the factors and circumstances that lead to the formation of CH_4 and N_2O in public WWTP.

In the last four reviews it was recommended that future NIRs should include an estimate of biogas recovery at anaerobic IWWTPs. This could be elaborated only for the year 2019 (see section 7.52 and table 7.10). In the next submission, data on previous years shall be added.

7.5.5 *Category-specific 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 2018 with 0.00023 Gg N_2O (-0.14%) compared with the previous submission.
Due to final activity data on wastewater and sludge treatment, the CH_4 emissions from domestic wastewater treatment (5D1) decreased in 2018 with 0.11 Gg CH_4 (-1.3%) compared with the previous submission.

7.5.6 *Category-specific planned improvements*
There are no category-specific improvements planned.

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. In this chapter indirect CO_2 emissions as a result of this atmospheric oxidation are described.

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;
4. Waste.

Indirect CO_2 emissions decreased from 0.92 Tg in 1990 to 0.43 Tg in 2019 as a result of the Dutch policy to reduce NMVOC emissions.

9.2 Methodological issues

Indirect CO_2 emissions are calculated as follows:

$$CO_2 \text{ (in Gg)} = \text{NMVOC emission (in Gg)} * C * 44/12$$

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 to be 25% and the uncertainty in carbon content is estimated 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 2020

For the NIR 2021, the data for the most recent year (2019) have been added to the inventory and corresponding Common Reporting Format (CRF).

As a result of the recommendations of the ERT review of 2019, improvements have been made to both the inventory and the NIR. These include corrections of errors in previous submissions. These have resulted in changes in emissions over the entire 1990–2018 period.

Other recalculations have been performed as a result of methodical changes 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

10.1.1 GHG emissions inventory

For the NIR 2021, the Netherlands has used the CRF Reporter software v6.0.8.
The earlier ERT reviews of the UNFCCC and EU suggested in their reports that there was room for improvement in the Dutch GHG inventory. As there was no UNFCCC review of the NIR2020, most of the recalculations reported in this NIR are initiated by the issues raised during the comprehensive EU review and as a result of the annual inventory improvement plan. To the extent possible, the review recommendations have (where deemed necessary) been incorporated in this NIR and CRF; and also in the (revised) methodology reports.
In Annex 10 the UNFCCC review issues, which were not (fully) addressed in the NIR2020, are listed including the actions which were undertaken to resolve them. Please note that all recommendations from the 2020 EU review could be addressed in this submission so these are not listed in Annex10.

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 past years (process of assessing and documenting methodological changes) are still in place. This process (using a brief checklist for timely discussion on likely changes with relevant experts and information

users) improves the peer review and timely documentation of the background to and justification for changes made.
The most significant recalculations in this submission (compared with the NIR2020) are:

- *Energy sector:*
  - As every year the inventory follows all changes/improvement in the national energy statistics affecting the emissions of CO_2 and CH_4 and N_2O (only minor changes)
  - Activity data and emissions from natural gas combustion have been split in the fossil part and the biogenic part of natural gas. The data for the biogenic part have been reallocated to the biomass fuels (changes in biomass emission +6 Gg CO_2 eq (1990) to +263 kton CO_2 eq in 2018).
  - Part of the emissions from chemical waste gas in CRF category 1A2c has been reallocated to 2B10 for the years 2012-2018 (change in order of magnitude of -200 Gg CO_2 eq). See under IPPU, below.
  - In transport now a bottom up inventory is used taken into account detailed characteristics of the fleet. This allows a better estimate of the N_2O emissions as these are dependent on the age of the vehicles. (changes from 0 Gg CO_2 eq (1990) to 0.06 Gg CO_2 eq in 2018).
  - Implementation of improved EF for methane from modern heating appliances (affecting emissions in 1.A.4.b.i for the last decade, approximately -50 Gg CO_2 eq).
- IPPU sector:
  - Re-examination of data available from the ETS emission reports (as of 2012), show there is no CO_2 storage in products during the production of industrial gases, as considered in earlier submissions. Therefore, the series 1990-2019 is recalculated, resulting in recalculated emissions from 1990 to 2012, and a shift from combustion (1A2c) to process emissions (2B10) from 2013 onwards (changes from 454 Gg CO_2 eq (1990) to 4 Gg CO_2 eq 2018).
  - The CO_2 emissions in 2B1 (Urea production) were recalculated via a methodology consistent over the whole series (changes from – 1,035 Gg CO_2 eq (1990) to –1,289 Gg CO_2 eq (2018).
  - As response to the ERT review, the Overlap splicing technique from the IPCC Guidelines is used to create a consistent time series for 2F1 Stationary cooling, therefore emission for the period 1990–2012 are recalculated (changes from -25 Gg CO_2 eq (1995) to -532 Gg CO_2 eq 2010).
  - Recalculations for HFC emissions from mobile air-conditioning (2.F.1) from scrapped cars as of 2003, based on improved data.
- Agriculture sector:
  - Organic and mineral soils emit different quantities of N_2O when fertilised. To calculate these emissions a weighted average based on the number of ha of both soil types was used as of now. This has been changed into two separate EF's.
  - Furthermore, the model for the calculation of the nitrogen flows in Agriculture was improved.

Both, the differentiated EF's and the improved model, affect the total time series. Changes amounted to -544.5 Gg CO_2 eq (1990) and -380.5 Gg CO_2 eq (2018).
  - The CO_2 emissions from agricultural Urea application, are now estimated and allocated to the agricultural sector for the whole time series.
- LULUCF sector:
  - Recalculation of the total time series based on the incorporation of the land use map of 1970 in the calculation, which now incorporates the pre 1990 land-use changes. The recalculation also resolved some errors in HWP and forest litter. Changes amount for -490 Gg CO_2 eq (1990) to -279 Gg CO_2 eq (2018).
- Waste sector:
  - Compared with the previous submission, the EF for CH_4 from composting waste has been modified for the years 1990 to 2009. This resulted in a decrease of methane emissions during these years. Minor errors in the data have also been corrected in this submission.
  - Additionally, CH_4 emissions from the digesting of manure (category 5B2) have been added from the starting year 2006 (4 Gg CO_2 eq) up to 44 Gg CO_2 eq. in 2018.

Other minor recalculations due to data improvements are described in the sectoral sections.

Changes in source allocation
As a result of recommendations of the 2019 review, the CO_2 emission calculation from urea production has been changed. Due to this change in methodology part of the emissions formerly reported under urea production are now allocated to urea use and reported under Agriculture.
Furthermore, the improved method for calculating the CO_2 emissions from industrial gas production led to a shift of emissions from 1.A.2.c to 2.B.10.

Error correction and regular data improvements
In general, the 2018 and in some cases 2017 figures have been updated whenever improved statistical data have become available since the last submission. This applies, for example, to the improvement of the energy statistics for the total time series.
Other error corrections are:
- Due to an error, for 2A2 Sugar production, the 2018 CO_2 emission figure is recalculated.
- Due to an error in the 2018 dolomite figures as delivered by the producer, for 2C1 Iron and steel production the 2018 CO_2 emission figure is recalculated.
- Due to an error, for 2C3 Aluminium production the 2018 PFC's emission figures are recalculated.
- Due to an error, for 2F1 Mobile air-conditioning the 2018 CO_2 emission figure is recalculated.
- 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 2018 with 0.00023 Gg N_2O (-0.14%) compared with the previous submission.

- Due to final activity data on wastewater and sludge treatment, the CH_4 emissions from domestic wastewater treatment (5D1) decreased in 2018 with 0.11 Gg CH_4 (-1.3%) compared with the previous submission.

10.1.2 KP-LULUCF inventory

The methodological changes in the LULUCF sector, as reported in Section 6.2, have also resulted in recalculations in the KP-LULUCF inventory. Emissions from organic soils have decreased in all activities that the Netherlands reports (AR, D and FM), due to the changes in the EF from 2004 onwards and extrapolation of the decreasing extent of organic soils from 2014 onwards. N_2O emissions from potentially drained forest land are now included for AR and FM activities in CRF Table 4(KP-II)2. Improved allocation of the wood harvests to Forest land remaining forest land has resulted in changes in emissions and removals in the HWP pool under FM. This, however, has no effect on the carbon stock changes reported under FM itself.
Finally, the new map mask that includes recently reclaimed land only has marginal effects in AR and D, as this is mainly a harbour and industrial zone and hardly any of the new land is related to forest land.

10.2 Implications for emissions levels

10.2.1 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 in Gg CO_2 eq., compared with the 2020 submission, as a result of the recalculations.

For 1990 the recalculations resulted in a decreased emission total compared with the previous submission of -0.68% (including LULUCF; excluding LULUCF -0.51%). For 2018 the recalculated emissions also decreased in comparison with the previous submission (-0.89%; without LULUCF -0.77%).

Only in the last 5 years of the inventory, the changes in emissions are above -1% and never do they surpass -1.45%, which means that the recalculations have had only a limited impact on the total emissions figures.

As it is difficult to interpret the described changes in terms of emissions of individual gases, Table 10.2 shows the changes per gas and per sector in 1990 and 2018.

Table 10.1 Summary of recalculations for the period 1990–2018 (Gg CO_2 eq.)

Gas(es)		1990	2000	2005	2010	2015	2018
CO_2	1.A.1 Energy industries	-1.1	-9.0	-6.5	-198.0	-231.0	-269.8
CO_2, CH_4, N_2O	1.A.2 Manufacturing industries and construction	-2.1	-6.8	-3.0	-840.7	-517.6	-98.2
CO_2, CH_4, N_2O	1.A.3 Transport	1.4	-2.0	7.1	-24.8	1.3	11.2
CO_2, CH_4, N_2O	1.A.4 Other sectors	-2.6	-32.9	-58.3	-120.0	-130.8	498.9
CO_2	2.B. Chemical industry	-580.7	-773.9	-600.6	-1,100.9	-1,044.1	-1,284.9
CO_2, CH_4, N_2O	2. IPPU (other)	0.8	0.6	0.5	-6.4	-19.2	-16.0
HFC	2.F.1 Refrigeration and air-conditioning	0.0	-156.7	-532.1	0.0	0.0	18.6
CH_4	3.A Enteric Fermentation	0.0	0.0	0.0	0.0	0.0	-0.6
N_2O	3.B Manure management	0.0	6.8	18.0	28.9	35.8	34.2
N_2O	3.D Agricultural soils	-544.5	-623.5	-463.6	-513.7	-451.4	-380.5
CO_2	3.G Liming	0.0	0.0	0.0	0.0	0.0	-3.6
CO2	3.H Urea application	1.5	2.3	32.3	65.9	48.1	50.9
CO_2, N_2O	4 LULUCUF	-419.5	-529.5	-256.2	-186.8	-312.6	-279.7
CH_4	5.A Solid waste disposal	0.0	0.0	0.0	0.0	0.0	5.7
CH_4, N_2O	5.B Biological treatment of solid waste	-9.4	-66.0	0.0	0.0	0.0	-1.0
CH_4, N_2O	5.D Waste water Handling	0.0	0.0	0.0	0.0	0.0	-2.7
CO_2	Indirect emissions	0.0	0.0	0.0	0.0	0.0	0.0
Total Difference		**-1,556.2**	**-2,190.8**	**-1,862.4**	**-2,896.4**	**-2,621.6**	**-1,717.6**
	Total emissions NIR 2020(*)	228,150	225,830	219,014	200,975	198,377	193,112
	Total emissions NIR 2021(*)	**226,594**	**223,640**	**217,152**	**198,078**	**195,756**	**191,394**

(*) : including LULUCF and indirect CO_2 emissions

In relation to the above-mentioned changes (and others), figures for emissions from precursor gases changed over the entire time series. The explanation of the recalculations can be found in the IIR report (Wever et al., 2021).

Table 10.2 Summary of recalculations per gas and sector (Gg CO_2 eq.), 1990 and 2018.

CO_2	**1990**	**2018**
1 Energy	0.2	103.5
2 IPPU	-579.9	-1,300.9
3 Agriculture	1.5	47.2
4 LULUCF	-490.5	-279.1
5 Waste		
Indirect emissions	0.0	0.0
CH_4		
1 Energy	-4.7	37.2
2 IPPU	0.0	0.0
3 Agriculture	0.0	-4.7
4 LULUCF	0.0	0.0
5 Waste	-9.4	2.7
N_2O		
1 Energy	0.0	1.4
2 IPPU	0.0	0.0
3 Agriculture	-544.5	-342.3
4 LULUCF	71.0	-0.6
5 Waste	0,0	-0.7
HFC's		
2 IPPU	0.0	18.6
PFC's		
2 IPPU	0.0	0.0

10.2.2 *KP-LULUCF inventory*

The changes in the methodologies have resulted in recalculations in the whole time series. Table 10.3 shows the differences between the previous and recalculated emissions and removals.

Table 10.3 Summary of recalculations for KP-LULUCF 2013–2017 in Gg CO_2-eq.

Activity	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**
A. Article 3.3 activities						
A1 Afforestation and Reforestation	-0.8	-0.5	-0.3	-0.1	-0.2	-0.1
A2 Deforestation	-20.9	-21.0	-21.0	-19.7	-24.5	-25.8
B1 Forest management	-151.7	-126.5	-100.9	-75.1	-45.1	-20.9
Total	-173.4	-148	-122.2	-94.9	-69.8	-46.8

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 10.4 shows the changes made due to the recalculations for 1990, 2000, 2010 and 2018 (compared with the NIR 2020). From the table, it emerges that the recalculations changed national emissions to a small extent (<-1.5%) compared with the last NIR.

*Table 10.4 Differences between the NIR 2020 and NIR 2021 for the period 1990–2018 due to recalculations (Units: **Tg CO_2 eq**.; for F-gases: **Gg CO_2 eq.**).*

Gas	Source	1990	2000	2010	2015	2018
CO_2 [Tg]	NIR 2021	168.7	177.1	186.9	169.5	164.0
Incl. LULUCF	NIR 2020	169.8	178.4	187.7	171.8	165.4
	Difference	-0.6%	-0.8%	-0.4%	-1.4%	-0.9%
CO_2 [Tg]	NIR 2021	162.7	171.6	182.0	164.7	159.5
Excl. LULUCF	NIR 2020	163.3	172.4	182.6	166.8	160.6
	Difference	-0.4%	-0.5%	-0.3%	-1.3%	-0.7%
CH_4 [Tg]	NIR 2021	31.8	24.2	19.4	18.1	17.3
	NIR 2020	31.8	24.3	19.4	18.2	17.3
	Difference	0.0%	-0.4%	-0.2%	-0.3%	0.2%
N_2O [Tg]	NIR 2021	17.5	15.5	8.2	8.3	8.0
	NIR 2020	18.0	16.2	8.7	8.9	8.4
	Difference	-3.1%	-4.2%	-6.3%	-6.6%	-5.2%
PFCs [Gg]	NIR 2021	2,663	1,903	314	104	163
	NIR 2020	2,663	1,903	314	104	163
	Difference	0.0%	0.0%	0.0%	0.0%	0.0%
HFCs [Gg]	NIR 2021	5,606	4,608	2,129	1,801	1,660
	NIR 2020	5,606	4,765	2,661	1,801	1,642
	Difference	0.0%	-3.3%	-20.0%	0.0%	1.1%
SF_6 [Gg]	NIR 2021	207	259	154	139	124
	NIR 2020	207	259	154	139	124
	Difference	0.0%	0.0%	0.0%	0.0%	0.0%
Total	NIR 2021	226.6	223.6	217.2	198.1	191.4
[Tg CO_2-eq.]	NIR 2020	228.1	225.8	219.0	201.0	193.1
Incl. LULUCF	Difference	-0.7%	-1.0%	-0.9%	-1.4%	-0.9%
Total	NIR 2021	220.5	218.1	212.1	193.2	186.8
[Tg CO_2-eq.]	NIR 2020	221.7	219.8	213.7	195.9	188.2
Excl. LULUCF	Difference	-0.5%	-0.8%	-0.8%	-1.4%	-0.8%

10.4 Recalculations, response to the review process and planned improvements

10.4.1 GHG emissions inventory

10.4.1.1 Response to the review process

Public and peer review

Drafts of the NIR are subject to an annual process of general public review and a peer review. During the public review of the draft NIR of January 2021, no specific remarks were received.

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 draft NIR of January 2021 (South Pole, 2021) had a focus on the emissions and removals from the land use, land use change and forestry (LULUCF) sector. The peer review focussed on:

- the appropriateness of the methods applied relative to the applicable guidelines (e.g. the appropriate use of key notations, the use of the appropriate tier level for key categories, and the representativeness of methodologies in case of higher-level models and their quality assurance);
- the proper allocation of sources to IPCC categories (the correctness of reporting and comparability of the reported emissions including cross-cutting reporting categories in the waste and agricultural sectors);
- the calculations and assumptions made (the consistency between estimates reported in draft NIR and CRF Tables) files and in addition, conservativeness and transparency of the assumptions made).

Overall, none of the findings have revealed significant underestimations of emissions in the reporting years, or overestimations of removals in the baseline year. A number of suggestions were made to (further) improve transparency e.g. for the wetlands and settlements and the use of notation key, especially related to accuracy. It was also suggested to improve the transparency for the estimates of emissions and removals associated to conversion between grassland and croplands. For deforestation it was suggested to improve the reporting of temporary forest loss, to avoid overestimation of deforestation. As a result of this peer review no changes were needed for the final NIR in March 2021. Recommendations will be followed up during the preparation of the NIR 2022.

Peer reviews in past years have focused on the following sectors and categories:

- Waste (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 the way that the Netherlands calculates the emissions of greenhouse gases. The major recommendations refer to the readability and transparency of the NIR and suggestions for textual improvement.

UNFCCC review
The NIR 2020 was not reviewed by the UNFCCC. In the NIR 2020 we addressed almost all issues from the 2019 review (see Annex 10, NIR2020). In Annex 10 of this report the remaining issues are listed.

The former UNFCCC reviews recommended:
- the inclusion in the NIR of more detailed information on the annual sector-specific QA/QC cycles and their results
- the inclusion of confidential information in the NIR.

In general the Netherlands will only include detailed information on the QA/QC cycle in cases where an issue was found that requires attention in the NIR. Besides, efforts are made to include more sector-specific QA/QC information in the methodology reports (see for example a new paragraph 2.5 in methodology report for agriculture (Van der Zee, 2021).
The Netherlands will not follow up on a (recurring) request to include confidential information its NIR. We have a very good, long-standing track record for the timely and correct provision of such information to the review team during the UNFCCC reviews.

EU Comprehensive review
The NIR 2020 was scrutinized during a review by the EU. The review was carried out as a comprehensive review in line with Article 19(1) of Regulation (EU) No 525/2013 (the 'Monitoring Mechanism Regulation', MMR)[14]. 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). Step 2 was performed by a Technical Expert Review Team (TERT). The conclusions were:
1. The reviewers raised 45 issues with the Netherlands during the first and the second step of the 2020 comprehensive ESD review. The TERT provided recommendations for 3 of these issues. Other issues raised during the comprehensive review were clarified.
2. The TERT identified cases where inventory data were prepared in a manner which is inconsistent with UNFCCC guidance documentation or Union rules. In particular, the TERT identified a number of under- or over-estimates exceeding the threshold of

[14] 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, 340201/2019/814628/SER/CLIMA.C.2.

significance pursuant to Article 31 of Commission Implementing Regulation (EU) No 749/2014.

3. As a response to these cases The Netherlands provided 3 revised estimates that were accepted by the TERT.
   - 2B1 Ammonia Production, CO_2 , 1990-2018
   - 2B10 Other (Chemical Industry), CO_2, 2005-2018
   - 2F1 Refrigeration and Air Conditioning, HFCs, 1994-2018

   Please note that these revised estimates are included in this NIR and CRF.
4. The TERT did not deem necessary any technical corrections in the meaning of Article 19(3)(c) of Regulation (EU) No 525/2013.
5. The TERT identified non-binding recommendations in order to improve the national inventory data of the Netherlands.
6. The TERT considers that it received a response from the Netherlands that was sufficient in order to undertake the comprehensive review appropriately.

All recommendations from the 2020 EU review could be addressed in this NIR2021, so these are not listed in Annex10.

10.4.1.2 Completeness of 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 missing activity data;
- CO_2 from road paving (2A4d), due to missing activity data;
- CH_4 from enteric fermentation in poultry (3A4), due to missing EFs;
- N_2O from industrial wastewater treatment (5D2) and 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.

10.4.1.3 Completeness of CRF tables

Since 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.

10.4.1.4 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 of the inventory in September 2019 confirmed that the Netherlands' inventory and inventory process are still in line with the rules for National Systems.

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, 2020).

QA/QC programme
The QA/QC programme for this year (RVO, (2020)) 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 2021 and are governed by the annual Work Plan.

10.4.2 KP-LULUCF inventory
For the NIR 2022, following improvements and updates of data are planned.
A new forest inventory (NFI-7) is being prepared and will provide results by 2021. Results will be included in the NIR 2022, updating the data on carbon stock changes in forests between previous national forest inventory in 2021 and the new NFI in 2021.
In the NIR 2022 a new land-use map will be included, which will update the activity data for AR, D and FM for the period 2017-2021.

Part II: Supplementary information required under Article 7, paragraph 1

11 KP-LULUCF

11.1 General information

11.1.1 Definition of forest and any other criteria

In its Initial Report for the first commitment period, the Netherlands identified the single minimum values under Article 3.3 of the Kyoto Protocol. Following Annex 1 to Decision 2/CMP.8, these values are also to be used during the second commitment period of the Kyoto Protocol.

The complete forest definition the Netherlands uses for Kyoto reporting is: 'Forest is land with woody vegetation and with tree crown cover of more than 20% and area of more than 0.5 ha. The trees should be able to reach a minimum height of 5 m at maturity *in situ*. They may consist either of closed forest formations where trees of various storeys and undergrowth cover a high proportion of the ground, or open forest formations with a continuous vegetation cover in which tree crown cover exceeds 20%. Young natural stands and all plantations established for forestry purposes which have yet to reach a crown density of 20% or tree height of 5 m are included under forest as areas normally forming part of the forest area which are temporally un-stocked as a result of human intervention or natural causes but which are expected to revert to forest. Forest land also includes:

- forest nurseries and seed orchards that constitute an integral part of the forest;
- roads, cleared tracts, firebreaks and other small open areas, all narrower than 6 m, within the forest;
- forests in national parks, nature reserves and other protected areas, such as those of special environmental, scientific, historical, cultural or spiritual interest, with an area of more than 0.5 ha and a width of more than 30 m;
- windbreaks and shelter belts of trees with an area of more than 0.5 ha and a width of more than 30 m.

This definition excludes tree stands in agricultural production systems; for example, in fruit plantations and agro-forestry systems'.

This definition is in line with FAO reporting since 1984 and within the ranges set by the Kyoto Protocol. The definition also matches the category Forest land in the inventory under the Convention on Climate Change (Chapter 6 of this NIR, and Arets et al. 2021). During the second commitment period of the Kyoto Protocol this definition will also apply to the Forest Management activity under Article 3.4 of the Kyoto Protocol.

Under UNFCCC reporting (Chapter 6) a sub-category Trees outside forests (TOF) is included under Grassland. TOF consists of units of land with trees that do not meet the minimum area requirement for the forest definition. Conversions from TOF to Forest land are included under Afforestation and reforestation (AR), while conversions from Forest land to TOF are included under Deforestation (D).

11.1.2 *Elected activities under Article 3, paragraph 4 of the Kyoto Protocol*

The Netherlands has not elected any other activities to include under Article 3, paragraph 4 of the Kyoto Protocol.

11.1.3 *Description of how the definitions of each activity under Article 3.3 and each mandatory and elected activity under Article 3.4 have been implemented and applied consistently over time*

Units of land subject to Article 3.3 *Afforestation and Reforestation* (AR) are reported jointly and are defined as units of land that did not comply with the forest definition on 1 January 1990 but did so at any moment before 31 December 2018. Land is classified as re/afforested as long as it complies with the forest definition. Units of AR land that are deforested again later will be reported under Article 3.3 *Deforestation* from that point in time onwards.

Units of land subject to Article 3.3 *Deforestation* (D) are defined as units of land that did comply with the forest definition on or after 1 January 1990 but ceased to comply with this definition at any moment in time after 1 January 1990. Once land is classified as deforested (D) land, it remains in this category, even if it is subsequently reforested and thus complies with the forest definition again.

Units of land subject to Article 3.4 *Forest Management* (FM) are units of land meeting the definition of forest that are managed for stewardship and use of forest land and that have not been classified under AR or D. Here, the Netherlands applies the broad interpretation of FM. As a result, all Forest land under the UNFCCC that is not classified as AR or D land will be classified as FM land. Further, since all Forest land in the Netherlands is considered to be managed land, and conversions from other land uses to Forest land are always human-induced, such conversions to Forest land will always be reported under AR.

For each individual pixel, an overlay of land use maps shows all mapped land use changes since 1990. All these are taken into account to ensure that AR land remains AR land unless it is deforested and that D land remains D land, even when it is later reconverted to forest land. CRF Table 4(KP-I)A.2 provides the information for D land disaggregated for the land use categories in the reporting year, including forest land, i.e. units of land that were reforested after earlier deforestation.

11.1.4 *Description of precedence conditions and/or hierarchy among Article 3.4 activities and how they have been consistently applied in determining how land was classified*

This is not applicable, as besides the mandatory activity Forest Management, no Article 3.4 activities have been elected.

11.2 Land-related information

11.2.1 *Spatial assessment unit used for determining the area of the units of land under Article 3.3 and Article 3.4*

The Netherlands applies complete and spatially explicit land use mapping that allows for geographical stratification at 25 m x 25 m (0.0625 ha) pixel resolution (Kramer et al., 2009). This corresponds with the wall-to-wall approach used for reporting under the Convention, i.e. Approach 3 in chapter 3 in Volume 4 of the 2006 IPCC Guidelines, and is described as reporting method 2 in the 2013 IPCC KP Guidance (IPCC, 2014: para. 2.2.2). AR, D and FM activities are recorded on a pixel basis. The status of each pixel is monitored over the full time series.

Any group of pixels changing from non-compliance to compliance with the forest definition is treated as reforestation/afforestation. In order to comply with the forest definition a group of clustered pixels should together cover at least 0.5 ha. As a result, one pixel changing from non-forest to forest without connection to other forest pixels does not result in afforestation, but changes to TOF. On the other hand, one pixel changing to forest that is connected to other forested pixels that together cover an area smaller than 0.5 ha (i.e. classified as TOF) may result in the whole cluster changing to comply with the forest definition and hence result in the whole cluster being treated as afforestation. Similarly, any group of pixels changing from compliance with the Kyoto forest definition to non-compliance is treated as D. If for instance one pixel changes from tree cover to another land use, that pixel is treated as D. However if this one pixel results in a neighbouring cluster of forest pixels becoming smaller than 0.5 ha, the whole group changes to TOF and therefore the whole group of pixels is treated as Deforestation. Groups of clustered pixels that together cover at least 0.5 ha of Forest land in 1990 and continue to do so over the full time period since 1990 are treated as FM.

11.2.2 *Methodology used to develop the land transition matrix*

The basis for the spatially explicit land use mapping is wall-to-wall maps for 1 January 1970, 1 January 1990, 1 January 2004 (Kramer et al., 2007, 2009), 1 January 2009 (Van den Wyngaert et al., 2012), 1 January 2013 (Kramer and Clement, 2015), and 1 January 2017 (Arets et al., 2019); see Section 11.2.3 below. An overlay was made of these six land use maps plus two maps of soil types (Arets et al., 2021, also see section 6.3 in this NIR).
This resulted in five land use change matrices;

1) 1 January 1970 to 1 January 1990
2) 1 January 1990 to 1 January 2004,
3) 1 January 2004 to 1 January 2009,
4) 1 January 2009 to 1 January 2013,
5) 1 January 2013 to 1 January 2017

Together the four matrices thus cover the period 1 January 1970–1 January 2017, which ensures that we are able to capture all land use changes. Mean annual rates of change for all land use transitions between the map years were calculated by linear interpolation. From 2017 onwards, the annual changes as obtained from the matrix 2013–2017 are used to extrapolate land use changes. These values will be used until a new land use map is available (provisionally planned to be included in the NIR 2022 with a map date of 1 January 2021).

Table 11.1 gives the annual area change from 1990 onwards for the cells in Table NIR-2 that are related to the Article 3.3 activities and FM.
The summed values in Table 11.1 for AR (AR land remaining AR land + land converted to AR land) do not match the sum of values reported under Convention sub-category 4A2 (Land converted to forest land) because under the convention transitions form land converted to forest land from before 1990 are included with a 20 years transition period.

Additionally from 2004 onwards part of the afforestation that is included in Convention category 4A2 is on land that was deforested between 1990 and 2003. Additionally, due to the 20-year transition period for forests, from 2010 onwards, land reported under 4A2 that was converted to Forest land 20 years earlier will be reported under Convention category 4A1 (Forest land remaining forest land).

Table 11.1. Results of the calculations of the area change (in kha) of afforestation/ reforestation (AR), deforestation (D) and forest management (FM) in the period 1990–2018.

Year	Land to AR	AR remaining AR	AR to D	FM to D	D remaining D	FM remaining FM	Other (not in KP Article 3.3 or FM)
1990	2.5		0	2.0	0.0	360.1	3,788
1991	2.5	2.5	0	2.0	2.0	358.1	3,786
1992	2.5	5.1	0	2.0	3.9	356.1	3,783
1993	2.5	7.6	0	2.0	5.9	354.1	3,781
1994	2.5	10.2	0	2.0	7.9	352.2	3,778
1995	2.5	12.7	0	2.0	9.9	350.2	3,776
1996	2.5	15.2	0	2.0	11.8	348.2	3,773
1997	2.5	17.8	0	2.0	13.8	346.3	3,771
1998	2.5	20.3	0	2.0	15.8	344.3	3,768
1999	2.5	22.8	0	2.0	17.7	342.3	3,766
2000	2.5	25.4	0	2.0	19.7	340.4	3,763
2001	2.5	27.9	0	2.0	21.7	338.4	3,761
2002	2.5	30.5	0	2.0	23.7	336.4	3,758
2003	2.5	33.0	0	2.0	25.6	334.4	3,755
2004	2.5	34.7	0.8	1.6	27.6	332.8	3,753
2005	2.5	36.4	0.8	1.6	30.1	331.2	3,750
2006	2.5	38.0	0.8	1.6	32.5	329.5	3,748
2007	2.5	39.7	0.8	1.6	35.0	327.9	3,745
2008	2.5	41.4	0.8	1.6	37.4	326.2	3,743
2009	2.9	42.6	1.3	1.9	39.9	324.4	3,740
2010	2.9	44.1	1.3	1.9	43.1	322.5	3,737
2011	2.9	45.7	1.3	1.9	46.3	320.6	3,734
2012	2.9	47.3	1.3	1.9	49.4	318.7	3,731
2013	1.6	47.9	2.3	2.0	52.6	316.7	3,730
2014	1.6	47.2	2.3	2.0	56.9	314.7	3,728
2015	1.6	46.5	2.3	2.0	61.2	312.6	3,727
2016	1.6	45.8	2.3	2.0	65.5	310.6	3,725
2017	1.9	45.4	1.9	2.0	69.8	308.6	3,723
2018	1.9	45.5	1.9	2.0	73.7	306.7	3,721
2019	1.9	45.5	1.9	2.0	77.5	304.7	3,719

Up to 2009 the annual deforestation rates that can be calculated from the sum of conversions from Forest land to other land uses in CRF Table 4.1 (land transition matrix) as reported under the Convention are equal to the sum of deforestation (AR to D and FM to D) in Table 11.1. Because the land use changes used to identify the areas of deforested land are based on four consecutive land use *change matrices (excluding 1970-1990), there are small areas of land that were first deforested in the period 1990–2004, then reforested during 2004–2009 and deforested again after 2009. In the Convention table such units of land are reported under conversions from Forest land, while in Table 11.1 they are included under 'D remaining D' from the first deforestation event on the particular unit of land.*

11.2.3 Maps and/or database to identify geographical locations and the system of identification codes for geographical locations

The land use information reported under both the Convention (see also Section 6.3) and the Kyoto Protocol is based on five land use maps specifically monitoring nature development in the Netherlands: Basiskaart Natuur (Base Map Nature, BN) for 1 January 1990, 1 January 2004 (Kramer et al., (2007), 2009), 1 January 2009 (Van den Wyngaert et al., 2012), 1 January 2013 (Kramer and Clement, 2015) and 1 January 2017 (Arets et al., 2021).

To distinguish between mineral soils and organic soils and to include the temporal developments in organic soil, an overlay is also made with two versions of the soil maps. These are the initial version of the Dutch Soil Map (De Vries et al., 2003), dated 1977, and a 2014 update based on the latest information on organic soils from the soil information system Netherlands (BIS; see https://www.wur.nl/nl/show/Bodemkundig-Informatie-Systeem-BIS.htm). As a result of the oxidation that is caused by the drainage of cultivated soils, the total area of organic soils decreases over time (see Section 6.1). The total area of organic soils for the intermediate years is interpolated between 1990 and 2014. After 2014 the loss of organic soil area is extrapolated on the basis of the trend between 1990 and 2014. Due to the conversion of organic soils to mineral soils, the area of mineral soils consequently increases at the same rate (see Arets et al., 2021 for more details).

As a result, detailed land use information with national coverage is available. For each pixel, it identifies whether it was subject to AR or D or remained as FM between 1990 and 2004, 2004 and 2009, 2009 and 2013, and 2013 and 2017 and whether it is located on mineral or organic soil.

Because of the multiple-year intervals between the different land use maps, it is unknown for each individual location in which year exactly AR or D occurred. A mean annual rate for the Netherlands as a whole is derived from the aforementioned analysis by linear interpolation.

11.3 Activity-specific information

11.3.1 Methods for carbon stock change and GHG emissions and removal estimates

11.3.1.1 Description of the methodologies and the underlying assumptions used

Data on forests are based on three national forest inventories carried out during 1988–1992 (HOSP data, Schoonderwoerd and Daamen, 1999), 2000–2005 (NFI-5 data, Daamen and Dirkse, 2005) and 2012–2013 (NFI-6, Schelhaas et al., 2014). 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, representing the state of the forest at three moments in time; 1990 (HOSP), 2003 (NFI-5) and 2012

(NFI-6). Until a new NFI becomes available in 2021, the development of carbon stocks in forests is based on projections using the EFISCEN model (see Arets et al., 2021).

Using plot-level data from the HOSP, NFI-5 and NFI-6, changes in carbon stocks in living biomass in forests were calculated. In addition, changes in activity data were assessed using several databases of tree biomass information, with allometric equations to calculate above-ground biomass (AGB), below-ground biomass (BGB) and forest litter.

More detailed descriptions of the methods used and EFs can be found in Arets et al.. (2021).

Afforestation / reforestation
Reporting of AR is linked to the following land use categories used for reporting under the Convention:
- 4.A.2.1: Cropland converted to forest land;
- 4.A.2.2: Grassland converted to forest land;
- 4.A.2.3: Wetland converted to forest land;
- 4.A.2.4: Settlement converted to forest land;
- 4.A.2.5: Other Land converted to forest land.

The methodologies used to calculate carbon stock changes in biomass due to AR activities are in accordance with those under the Convention, as presented in section 6.4.2.2. The carbon stock changes due to changes in forest biomass were attributed to changes in above-ground or below-ground biomass based on the fact that carbon stocks in newly planted plots would reach the carbon stocks of the average forest in 30 years (see section 6.4.2.2 and Arets et al., 2021).

Carbon stock losses due to changes in AGB and BGB in land use conversions from Cropland and Grassland (non-TOF) were calculated on the basis of Tier 1 default carbon stocks. Carbon stock changes in litter and dead wood follow the approach for Land converted to forest land (section 4.2.2 Arets et al., 2021) during the first 20 years after establishment, which are not estimated due to lack of data. Twenty years after establishment, the carbon stock changes in litter and dead wood are calculated using the methods for Forest land remaining forest land (Section 4.2.1 and Arets et al., 2021). The analysis for litter in this category consistently showed a carbon sink in litter, but the magnitude was very uncertain. Therefore, applying the ‘not a source’ principle, assuming zero accumulation of carbon in litter was considered to be conservative (Section 4.2.1 and Arets et al., 2021). Carbon stock changes in litter therefore were reported as NE for AR. Carbon stock changes in dead wood are included.

Methods for calculating carbon stock changes in mineral and organic soils are presented below. Results for carbon stock changes for all pools during the second KP commitment period are given in Table 11.2. Carbon stock losses in organic soils are lower than reported in the previous submission as a result of method changes in organic soil estimates (activity data after 2014 and EF over the whole time series); see Sections 11.3.2 and 6.1. As a result of the changes in activity data for organic soils small differences also occur in the carbon stock changes of mineral soils because part of the peat or peaty soils have changed to mineral soil types.

Table 11.2. Net carbon stock changes (CSC) (in Gg C) from afforestation/ reforestation activities during the second commitment period and resulting total CO_2 emissions (Gg CO_2).

Year	Net Carbon stock changes in						Total CO_2 emissions
	AGB	BGB	litter	DW	mineral soil	organic soil	
2013	144.0	21.3	NE	4.4	2.1	-6.1	-607.1
2014	144.2	21.3	NE	4.5	1.7	-6.0	-607.6
2015	144.3	21.3	NE	4.6	1.3	-5.8	-607.5
2016	144.3	21.3	NE	4.6	0.9	-5.7	-607.0
2017	145.9	20.6	NE	4.7	0.8	-5.7	-609.6
2018	147.8	20.9	NE	4.7	0.60	-5.6	-617.4
2019	149.7	21.2	NE	4.6	0.5	-5.6	-625.0

AGB: above-ground biomass, BGB: below-ground biomass, DW: dead wood

Deforestation

Reporting of D is linked to the following land use categories used for reporting under the Convention:

- 4.B.2.1: Forest land converted to cropland;
- 4.C.2.1: Forest land converted to grassland;
- 4.D.2.1: Forest land converted to wetland;
- 4.E.2.1: Forest land converted to settlements;
- 4.F.2.1: Forest land converted to other land.

After deforestation, other land use changes are possible on D land. The methodologies used to calculate carbon stock changes in biomass due to deforestation and subsequent carbon stock changes on previously deforested land are in accordance with those under the Convention, as presented in Sections 6.4.2.3 and Sections 6.5–6.9 and Arets et al., (2021).

Carbon stock changes due to changes in forest biomass were differentiated into AGB and BGB using data generated by the bookkeeping model used (Arets et al., 2021). Data from the 6^{th} NFI 2012–2013, in combination with data from the previous NFI (NFI-5) in 2003, allowed the calculation of actual carbon stock changes from deforestation (see EF in Table 6.9 in Section 6.4.2.3). Carbon stock changes due to changes in AGB and BGB in land use conversions to Cropland and Grassland were calculated on the basis of Tier 1 default carbon stocks for Cropland and average carbon stocks as assessed for Grassland (non-TOF) (see Section 6.6.2 and Arets et al., 2021).

Deforestation to TOF may occur when surrounding units of Forest land are deforested and the remaining area no longer meets the minimum area of the forest definition. In such cases tree biomass is assumed to remain the same. As a result, deforestation to TOF will not result in loss of biomass, while in the years after the deforestation event, carbon stock gains will continue as a result of the growing biomass of TOF (see

Section 6.6.2 and Arets et al., 2021). Net carbon stock changes in the different carbon pools are given in Table 11.3.

Table 11.3. Net carbon stock changes (in Gg C) in carbon pools of deforestation activities during the second commitment period and resulting total CO_2 emissions (Gg CO_2).

Year	Carbon stock changes in						Total CO_2 emissions
	AGB	BGB	litter	DW	mineral soil	organic soil	
2013	-185.5	-22.7	-76.0	-4.5	4.4	-11.0	1,082.5
2014	-192.7	-24.0	-77.3	-4.7	4.9	-12.2	1,122.1
2015	-200.3	-25.4	-78.5	-5.0	5.4	-13.4	1,162.9
2016	-208.2	-26.7	-79.8	-5.25	5.8	-14.5	1,204.8
2017	-214.2	-28.4	-81.9	-5.6	5.9	-15.5	1,245.4
2018	-221.2	-29.6	-83.8	-5.9	6.2	-16.5	1,286.2
2019	-228.3	-30.9	-85.5	-6.2	6.4	-17.4	1,327.3

AGB: above-ground biomass, BGB: below-ground biomass, DW: dead wood

Carbon stock changes in mineral soils are reported using a 20-year transition period. Carbon stock changes in organic soils are reported for all organic soils under Article 3.3 activities. The methods are presented below.

Deforestation of AR land involves an emission of all accumulated carbon stocks up to the time of deforestation that have been calculated following the methodologies for AR.

Carbon stock changes per area for the litter pool under deforestation are found to be higher in the Netherlands than in other countries. As a result of a characteristic combination of geomorphological and climate conditions, a large share of Forest land in the Netherlands is on poor Pleistocene soils, characterised by relatively thick litter layers, which may explain the differences with other countries. The assessment of the carbon stocks and changes thereto in litter in Dutch forests is based on extensive datasets on litter thickness and carbon content in litter (see sections 4.2.1 and 4.2.3 in Arets et al., 2021). Additional information on geomorphological aspects is provided in Schulp et al., (2008) and de Waal et al., (2012).

Forest management
Reporting of FM is linked to the category 4A1 Forest land remaining forest land used for reporting under the Convention. Yet the area and total figures of carbon stock changes differ due to the fact that, under Convention reporting, from 2009 onwards land that was afforested after 1990 exceeds the 20-year transition period and is included in the category Forest land remaining forest land, while under KP reporting such land is still reported under AR.
The calculation of carbon stock changes and resulting EFs is the same as used under the Convention (see Section 6.4.2.1 and Arets et al., 2021). Net carbon stock changes are given in Table 11.4.

Table 11.4. Net carbon stock changes (in Gg C) in carbon pools of Forest management and total CO_2 emissions (Gg CO_2) during the second commitment period.

Year	Carbon stock changes in							Total CO_2 emissions
	AGB	BGB	litter	DW	mineral soil	organic soil	HWP	
2013	301.0	54.2	NE	17.7	NO	-14.1	-21.2	-1237.6
2014	294.2	53.0	NE	17.6	NO	-13.8	-21.9	-1206.4
2015	287.4	51.7	NE	17.4	NO	-13.4	-30.9	-1144.7
2016	280.4	50.5	NE	17.3	NO	-13.1	-23.0	-1144.6
2017	273.5	49.2	NE	17.2	NO	-12.8	-27.8	-1097.9
2018	266.5	48.0	NE	17.1	NO	-12.5	-32.1	-1052.4
2019	259.3	46.7	NE	17.0	NO	-12.1	-30.4	-1028.5

AGB: above-ground biomass, BGB: below-ground biomass, DW: dead wood, HWP: harvested wood products

Carbon stock changes in litter in Forest land remaining forest land were estimated, but a Monte Carlo uncertainty assessment showed that while litter consistently remained a carbon sink, the magnitude of this sink was very uncertain. Therefore, carbon stock change in litter was considered to be ‘not a source’ and the accumulation of carbon in FM was conservatively set to zero and subsequently reported as NE (see Arets et al., 2021).

Method of estimating carbon stock changes in AR or D land in mineral soils

Carbon stock changes in mineral and organic soils are reported for all soils changing land use under Article 3.3. This includes changes in the use of units of land reported under Deforestation. Carbon stock changes in mineral soils were calculated from base data taken from the LSK survey (de Groot et al., 2005; Lesschen et al., 2012). The LSK database contains quantified soil properties, including soil organic matter, for approximately 1,400 locations at five depths. The soil types for each of the sample points were reclassified to 11 main soil types, which represent the main variation in carbon stocks in the Netherlands. Combined with land use at the time of sampling, this led to a new soil/land use-based classification of all points (see Arets et al., (2021) for more details).

The LSK dataset contains only data on soil carbon stocks for the land uses Grassland, Cropland and Forest land. About 44% of deforested land is Grassland. For the remaining land use categories, separate estimates were made. For Settlements, which constitute about 32% of deforested land, the estimates make use of information in the 2006 IPCC Guidelines. An average soil carbon stock under Settlements of 0.9 times the carbon stock of the previous land use is calculated on the basis of the following assumptions:

(i) 50% of the area classified as Settlements is paved and has a soil carbon stock 0.8 times the corresponding carbon stock of the previous land use. Considering the high resolution of the land use change maps in the Netherlands (25 m x 25 m grid cells), it can be assumed that, in reality, a large portion of that grid cell is indeed paved.

(ii) The remaining 50% consists mainly of Grassland and wooded land, for which the reference soil carbon stock from the previous land use, i.e. Forest, is assumed.

For the land use category Wetland, which makes up 5% of deforested land, no change in carbon stocks in mineral soils is assumed upon conversion to or from Forest. For the category Other land, a carbon stock of zero is assumed. This is a conservative estimate, yet in many cases very realistic. (Other land in the Netherlands comprises mainly sandy beaches and inland (drifting) sandy areas.)

The estimated annual C flux associated with AR or D is then estimated from the difference between land use classes divided by 20 years (the IPCC default transition period):

$$E_{\min\_xy} = \sum_{1}^{i} \left(\frac{C_{yi} - C_{xi}}{T} \cdot A_{\min\_xyi} \right)$$

Where:

$E_{\min\_xy}$	annual emissions from land converted from land use *x* to land use *y* on soil-type i (Gg C yr^{-1});
$A_{\min\_xy}$	area of land converted from land use *x* to land use *y* on soil-type *i* in years more recent than the length of the transition period (i.e. <20 years ago) (ha);
C_{yi}, C_{xi}	carbon stocks of land use *x* or *y* on soil-type *i* (Gg $C.ha^{-1}$);
T	length of transition period (= 20 years).

For units of land subject to land use change during the transition period (e.g. changing from Forest to Grassland and then to Cropland), the estimated carbon stock at time of land use change was calculated with:

$$C_{\Delta yi_t} = C_{xi} + t \cdot \frac{C_{yi} - C_{xi}}{T}$$

Where (as above plus):

$C_{\Delta yi_t}$	carbon stock of land converted from land use *x* to land use *y* on soil-type *i* at time *t* years after conversion (Gg C ha^{-1});
t	years since land use change to land use *y*.

And this carbon stock was filled in the first formula to calculate the mineral soil emissions involved in another land use change.

Method of estimating carbon stock change in organic soils

The area of organic soils under forests on the 2017 map is small: 20.24 kha, which is 4.5% of the total area of organic soil. In 2018 the area of AR land on organic soils was 5.50 kha (11.6% of total AR area), the area of FM land on organic soils was 13.41 kha (4.5% of total FM area) and the area of D land on organic soils was 7.20 kha (9.2% of total D area). In 2018 the majority of this area of D (67%) on organic soils was on agricultural land (Cropland or Grassland).

Organic soils are divided into peat soils, which have a peat layer of at least 40 cm within the first 120 cm, and peaty soils (in Dutch: *moerige gronden*), which have a peat layer of 5–40 cm within the first 80 cm. Based on the available datasets, two different approaches to calculating the EFs for peat and peaty soils have been developed (see Arets et al., (2021) for details).

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 peat soils are then converted to an annual EF per ha peat soil to report emissions from peat soils for land use (change) categories involving Grassland (non-TOF), Cropland and Settlements (see section 11.3 in Arets et al., 2021). Using an intermediary peat map from 2004 an average EF of 19 tons CO_2 ha^{-1} was calculated. In addition, using the updated 2014 soil map, an EF of 17.7 tons CO_2 ha^{-1} was calculated (see Arets et al., 2021). Between 2004 and 2014 the EF is interpolated as between 19 and 17.7 tons CO_2 ha^{-1} and after 2014 the trend is extrapolated. (See also the paragraphs on organic soils in Section 6.1.) The EF in 2018 was 17.2 tons CO_2 ha^{-1}.

For peaty soils, a different approach was used, based on a large dataset of soil profile descriptions over time (de Vries et al., 2016). This dataset holds information on the change in thickness of the peat layer over time, and from these data the average loss rate of peat was calculated. This resulted in an average overall EF of 13.02 tonnes CO_2 per ha per year for peaty soils under agriculture. For Settlements no data were available, but the same average EF was used. Again two EFs were assessed on the basis of the areas of peaty soils present on the 2004 map and the 2014 map. For 2004 the average EF for peaty soils was 13 tons CO_2 ha^{-1}, which was applied to the period 1990–2004 and an average EF of 12 tons CO_2 ha^{-1} in 2014 (see Arets et al., 2021). Through interpolation the EF gradually decreases from 13 tons CO_2 ha^{-1} in 2004 to 12 tons CO_2 ha^{-1} in 2014. This decreasing trend of the EF then is extrapolated after 2014. The EF in 2018 was 11.6 tons CO_2 ha^{-1}.

For organic soils under deforestation for which the current land use is Cropland, Grassland or Settlements, these emissions from organic soils are applied.

Drainage of organic soils is usually not applied in forestry in the Netherlands. However, since afforestation often occurs on land with previous agricultural use, it cannot be entirely ruled out 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 that were in agricultural use before 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. Subsequently to 24.2% of the FM land and AR land on peat soils, the same country specific emission factors are applied as used for drained peat soils under Grassland, Cropland and Settlements. Similarly, to 22.0% of the FM land and AR land on peaty soils, the same country specific emission factors are applied as used for drained peaty soils under Grassland, Cropland and Settlements

N_2O emissions from drained organic soils
Nitrous oxide (N_2O) emissions from D land are reported in Table 3.D, under cultivation of organic soils. For FM and AR land emissions of N_2O associated with the C losses resulting from drainage are calculated using a Tier 1 approach. On average over the period 1990–2017, 79% of forest is on nutrient-rich organic soils and 21% on nutrient-poor organic soils (see Arets et al., 2021). Applying this ratio to 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 provides an average EF of 0.5 kg N_2O-N ha^{-1} for N_2O emissions from drained organic soils under AR or FM land.

N_2O emissions from N mineralisation/immobilisation due to carbon loss/gain associated with land use conversions and management change in mineral soils
Nitrous oxide (N_2O) emissions from soils due to disturbance associated with land use conversions are calculated with a Tier 2 methodology, using equation 11.8 of the 2006 IPCC Guidelines for each aggregated soil type (see Arets et al., (2021) section 11.2). The default EF of 0.01 kg N_2O-N/kg N was used. For three aggregated soil types, average C:N ratios, based on measurements, were available and used. For all other aggregated soil types, we used the default C:N ratio of 15 (2006 IPCC Guidelines: chapter 11.16). For aggregated soil types where conversion led to a net gain of carbon, N_2O emissions were set to zero.

GHG emissions due to biomass burning in units of land subject to Article 3.3 (AR and D) and Article 3.4 (FM)
Emissions of CO_2, CH_4 and N_2O related to controlled biomass burning in areas that are Afforested or reforested (AR) or under Forest management (FM) do not occur, as no slash burning, etc., is allowed in the Netherlands; they are therefore reported as not occurring (NO).

Because wildfires in the Netherlands are infrequent and relatively small-scale, there is no active monitoring of wildfires, and consequently no recent statistics on wildfires are available. Therefore, emissions of CO_2, CH_4 and N_2O from forest fires on AR and FM land and wildfires on D land are estimated using the Tier 1 method (see Arets et al., 2021) and are reported in Table 4(KP-II)4.

The average annual area of burned AR land and FM land was estimated from the historical series of total forest area burned between 1980 and 1992 (on average 37.8 ha, ~0.1% of the total area of Forest land; Wijdeven et al., (2006), scaled to the proportion of AR or FM to total forest area in a year.
Besides forest fires, the historical series in Wijdeven et al., (2006) also provides the total area of wildfires. The area of wildfires outside forests is then calculated from the difference between the total area of wildfires and

the area of forest fires, which on average is 210 ha per year. Other wildfires in the Netherlands are assumed to be burned nature grasslands.

The average annual area of D land burned is then estimated from the fraction of natural grassland that is D land. In the Netherlands, wildfires seldom lead to total loss of forest cover and therefore do not cause deforestation.

11.3.1.2 Justification for omitting any carbon pool or GHG emissions/removals from activities under Article 3.3 and mandatory and elected activities under Article 3.4

Carbon stock change due to changes in dead wood and litter in units of land subject to Article 3.3 (AR)
The NFI provides an estimate for the average amount of litter (in plots on sandy soils only) and the amount of dead wood (all plots) for plots in permanent forests. The data provide the age of the trees and assume that the plots are no older than the trees. However, it is possible that several cycles of forest have been grown and harvested on the same spot. The age of the plot does not take into account this history or any effect it may have on litter accumulation from previous forests in the same location. Therefore, the age of the trees does not necessarily represent the time since AR. This is reflected in a very weak relation between tree age and carbon in litter (Figure 11.1) and a large variation in dead wood, even for plots with young trees (Figure 11.2).

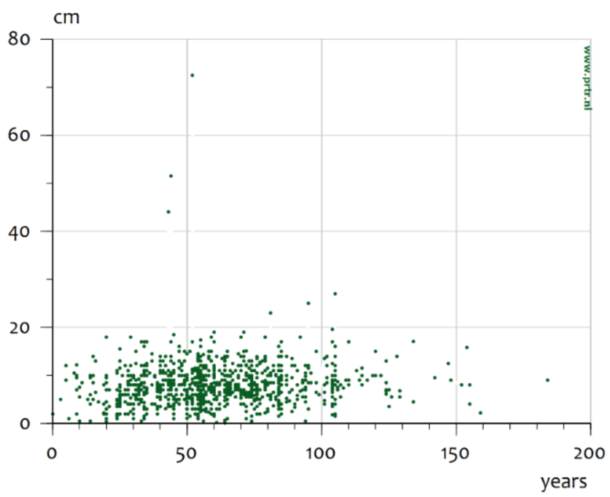


Figure 11.1. Thickness of litter layer in Dutch NFI plots in relation to tree age (measurements conducted only in plots on sandy soils).

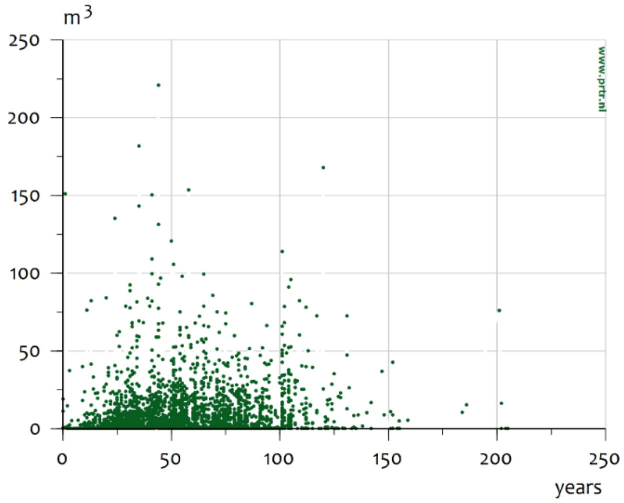


Figure 11.2. Volume of dead wood (standing and lying) in Dutch NFI plots in relation to tree age.

No other land use category has as much carbon stock in litter as Forest land (in Dutch Grassland, management prevents the built-up of a significant litter layer). The conversion of non-forest to forest, therefore, always involves a build-up of carbon in litter. But because good data are lacking to quantify this sink, we report the accumulation of carbon in litter for AR conservatively as 'not a source' and consequently use the notation key NE in CRF Table 4(KP-I)A.1.

Similarly, no other land use category has carbon in dead wood. The conversion of non-forest to forest, therefore, involves a build-up of carbon in dead wood. But as it is unlikely that much dead wood will accumulate in very young forests (regenerated in 1990 or later), the accumulation of carbon in dead wood in AR plots is most likely a very small sink that is too uncertain to quantify reliably. We therefore report this carbon sink during the first 20 years conservatively as zero. Once a unit of AR-forest becomes older (>20 years), changes in carbon stocks in dead wood are estimated in the same way as for Forest land remaining forest land under the Convention (see Arets et al., 2021).

N_2O emissions due to nitrogen fertilisation in units of land subject to Article 3.3 (AR and D) and Article 3.4 (FM)
Fertilisation does not occur in forests in the Netherlands. Therefore, fertilisation in AR and FM areas is reported as NO. In the Netherlands there is no law prohibiting use of fertilisers on AR or FM land. Nevertheless, the application of fertilisers in forests is not common practice because maximising wood production is not a high priority in forest management. Moreover, given the high background levels of N deposition in the Netherlands, the application of additional N in forests is not considered economically valuable.

N_2O emissions from the use of nitrogen fertilisers on units of D land used as grassland, cropland or settlements are included under categories 3Da1 (Inorganic N fertilisers) and 3Da2 (Organic N fertilisers) in the Agriculture sector.

11.3.1.3 Information on whether or not indirect and natural GHG emissions and removals have been factored out

For all Article 3.3 AR activities, forests were created only after 1990 and the factoring-out of effects on age structure of practices and activities before 1990 are not relevant. For Article 3.3 D activities, the increase in mean carbon stocks since 1990 may be partly an effect of changes in management as well as a change in age structure resulting from activities and practices before 1990. However, it is not known to what extent each factor contributes. There has been no factoring-out of indirect GHG emissions and removals due to the effects of elevated CO_2 concentrations or N deposition.

This increase in mean carbon stocks results in higher carbon emissions due to deforestation. Thus, not factoring out the effect of age structure dynamics since 1990 results in a more conservative estimate of emissions due to Article 3.3 D activities.

11.3.2 Changes in data and methods since the previous submission (recalculations)

This year, one methodological change, and a number of error corrections and updated data have been implemented, resulting in changes in various carbon stock changes and associated emissions and removals along the whole time series (see Chapter 6.1). These have also resulted in recalculations for AR, D and FM. Because the separate changes may interact with each other, the effects of the separate changes cannot be quantified. The changes are briefly explained below. More extensive descriptions are included in Chapter 6.1.

1. 1970 map: In order to improve the representation of the “land converted to” categories from 1990 onwards under the convention reporting, in the NIR 2021 a land-use map for 1970 has been included. As a result part of the lands that previously in the period 1990-2010 were reported and calculated as forest land remaining forest are now reported and calculated as “land converted to forest land”. Under the KP methodology bot types of land in 1990 were forest land and therefore reported under Forest Management. Since the emission and removals differ between land converted to forest land and forest land remaining forest land, this also affects the emissions and removals calculated for Managed Forest land. Similarly emissions and removals under deforestation will differ. Under afforested land only emissions and removals for soils differ as the carbon stock gains and losses in biomass in this category will not change as those forests are planted after on land that was not forest land in 1990 or after that date.
2. Error correction HWP: During an internal code review of the HWP module in the bookkeeping model used for the LULUCF calculations, two mistakes were detected and corrected. In the NIR2020, the methodology of allocating round wood harvest to forest land remaining forest land was changed, but this was not updated in the HWP module itself, only in the preceding calculations. Furthermore, the fraction of wood that is exported for each of the product categories (sawnwood, panels, other industrial wood and paper) were inadvertently all calculated based on data for sawnwood. Both mistakes have been corrected and will result in recalculations of emissions and removals from HWP

under the KP reporting during the whole time series from 2013 to 2018.

3. Error correction forest litter: As a result of an additional quality check applied to explain the differences in emissions resulting from loss of litter as part of the dead organic matter (DOM) pool under the categories forest land converted to other lands, an error in the information for litter for the years 2017 and 2018 as used in the NIR2020 was found. This now has been corrected and will result in changes in carbon stock changes for DOM in the years 2017 and 2018 under deforestation. It should be noted that this information will be updated again in the NIR 2022 with new information from the 7th National Forest Inventory which was finalized in 2020 and which information will be processed in 2021.
4. Updated forest harvest data: Because the FAO sometimes changes its forest statistics without notice or explanation, from this NIR onwards data on production, import and export of wood is directly taken from PROBOS, the Dutch national correspondent to the Joint Forest Sector Questionnaire (JFSQ), These JFSQ data are also used to report national forestry statistics to the FAO and other international organisations and therefore largely are the same as the data published by FAO. This should improve the transparency and consistency of the data used. The data for national round wood harvest and input values for calculation of the Harvested Wood Products have been updated for the years 2017-2019, based on data provided by Probos (Teeuwen et al., 2020). This will have an effect on carbon stock changes in living biomass under managed forest land and on the carbon stock changes in the HWP category.
5. Using new and updated information the area of fruit orchards after 2016 is updated. This has an effect on the emission factor for Grassland (non-TOF) which is partly determined by the fraction of orchards (see section 6,6) this changes the emission factor in the period 2016-2018. Additionally using new information on the age of fruit orchards in 2017 the carbon stocks in fruit orchards were recalculated and updated for the whole time series from 1990-2018 (see Arets et al 2021, and section 6.6). This affects the emission factor used for land use conversion to and from Grassland (non-TOF) in which the fruit orchards are included (see section 6.6, table 6.10). Under KP this will have an effect on the carbon stock losses associated with afforestation/reforestation on grassland and on the carbon stock gains associated with deforestation to grassland.

11.3.3 Uncertainty estimates

The uncertainty analysis uses Monte Carlo simulations for combining different types of uncertainties and correctly representing the uncertainties in the land use matrix (see chapter 14 in Arets et al., (2021) 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 acceleration in carbon sequestration and removals.

The uncertainty analysis is performed for Forest land and is based on the same data and calculations that were used for the KP Article 3.3

categories and FM. Thus, the uncertainty for total net emissions from units of land under Article 3.3 AR is estimated at +10% to -12%, which is equal to the uncertainty in Land converted to forest land. Similarly the uncertainty for total net removals from units of land under Article 3.4 FM is estimated at +26% to -21%, which is equal to the uncertainty of Forest land remaining forest land (see Section 6.4.3).

11.3.4 Information on other methodological issues
There is no additional information on other methodological issues.

11.3.5 The year of the onset of an activity, if after 2013
The forestry activities under Article 3, paragraphs 3 and 4, are reported from the beginning of the commitment period.

11.4 Article 3.3
11.4.1 Information that demonstrates that activities under Article 3.3 began on or after 1 January 1990 and before 31 December 2020 and are directly human-induced
Land use and land use change is mapped using regularly updated land use maps covering the whole land area of the Netherlands. Land use maps dated 1 January 1990, 2004, 2009, 2013 and 2017 have been used to track changes in land use on units of land. All observed AR and D activities between 1 January 1990 and 31 December 2016 have been taken into account. Subsequent land use changes are extrapolated from changes in the last period for which maps are available (2013–2017). A new land use map and corresponding land use matrix are foreseen for 1 January 2021. By the end of the second commitment period this will allow all land use changes between 1 January 1990 and 31 December 2020 to be taken into account.
In the Netherlands, forests are protected by the Forest Law (1961), which stipulates that 'The owner of ground on which a forest stands, other than through pruning, [or] forest has been harvested or otherwise destroyed, is obliged to replant the forest stand within a period of three years after the harvest or destruction of the stand'.

With the historic and current scarcity of land in the Netherlands, any land use is the result of deliberate human decisions.

11.4.2 Information on how harvesting or forest disturbance that is followed by the re-establishment of forest is distinguished from deforestation
Following the forest definition and the mapping practice applied in the Netherlands, areas subject to harvesting or forest disturbance are still classified as Forest land and therefore there will be no change in land use in the overlay of the land use maps (Kramer et al., 2009; Arets et al., 2021).

11.4.3 Information on the size and geographical location of forest areas that have lost forest cover but are not yet classified as deforested
The land use maps do not provide information on forest areas that have lost forest cover if they are not classified as deforested. From the NFIs, however, it can be estimated that approximately 0.3% of Forest land annually can be classified as 'clear-cut area', i.e. without tree cover.

11.4.4 *Information related to the natural disturbances provision under Article 3.3*

The Netherlands intends to apply the provisions to exclude emissions from natural disturbances for the accounting for AR under Article 3, paragraph 3, of the Kyoto Protocol and/or FM under Article 3, paragraph 4, of the Kyoto Protocol during the second commitment period. The Netherlands has established a background level and margin for natural disturbances as described below.

Types of natural disturbances
In the Netherlands natural disturbances in forests are relatively rare and therefore limited data are available. For AR the Netherlands includes wildfires as a disturbance type and for FM the Netherlands includes wildfires and wind storms (as an extreme weather event).

Time series for the calibration period
The time series of annual CO_2 emissions from natural disturbances for the calibration period is provided in Table 11.5. Based on the total extent of forest fires, GHG emissions from forest fires are calculated for FM and AR land under KP-LULUCF (see Section 11.3.1.1 on forest fires). Information on wind storms is based on a proprietary database that is maintained at Wageningen Environmental Research in which damage from major storm events is collected. Part of this data set is available through Schelhaas et al. (2003). Salvage logging is estimated to remove 60% of the fallen tree volume. The remaining 40% is included under natural disturbances for calibration.

Total areas of FM and AR land are provided in Table 11.6.

Background level and margin
The background level and margin are calculated on the basis of the area-specific emissions using the step-wise and iterative approach as provided in chapter 2.3.9.6 of the IPCC 2013 revised supplementary methods for KP (IPCC, 2014). In five iterative steps all outliers (e.g. wind storms in 1990 and 2007) have been removed. An error in the calculations that was introduced in a previous submission has been corrected. The resulting annual background level and margin (twice the standard error) are the following:

- FM: background level 2.77 Gg CO_2 eq., margin 0.27 Gg CO_2 eq.
- AR: background level 0.0077 Gg CO_2 eq., margin 0.0014 Gg CO_2 eq.

Table 11.5. Time series of total annual emissions for disturbance types included under FM and AR.

Activity	Disturbance type	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
		Inventory year during the calibration period									
		Total annual emission [Gg CO_2 eq.]									
FM	*Wildfires*	2.51	2.54	2.57	2.60	2.63	2.66	2.69	2.72	2.75	2.77
	Wind storms	283.80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Total	**286.31**	**2.54**	**2.57**	**2.60**	**2.63**	**2.66**	**2.69**	**2.72**	**2.75**	**2.77**
AR	*Wildfires*	0.02	0.04	0.06	0.08	0.10	0.13	0.15	0.18	0.20	0.23
	Total	0.02	0.04	0.06	0.08	0.10	0.13	0.15	0.18	0.20	0.23

Activity	Disturbance type	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
		Inventory year during the calibration period									
		Total annual emission [Gg CO_2 eq.]									
FM	*Wildfires*	2.80	2.83	2.85	2.88	2.89	2.91	2.92	2.94	2.95	2.97
	Wind storms	0.00	0.00	0.00	0.00	0.00	0.00	0.00	118.25	0.00	0.00
	Total	**2.80**	**2.83**	**2.85**	**2.88**	**2.89**	**2.91**	**2.92**	**121.19**	**2.95**	**2.97**
AR	*Wildfires*	0.25	0.28	0.31	0.34	0.36	0.38	0.40	0.42	0.44	0.46
	Total	0.25	0.28	0.31	0.34	0.36	0.38	0.40	0.42	0.44	0.46

Table 11.6. Areas of FM and AR.

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Area under FM (kha)	360	358	356	354	352	350	348	346	344	342
Area under AR (kha)	3	5	8	10	13	15	18	21	23	26
	2000	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
Area under FM (kha)	340	338	336	334	333	331	329	328	326	324
Area under AR (kha)	28	31	33	36	38	39	41	42	44	46

11.4.5 Information on harvested wood products under Article 3.3

The approach used to calculate the HWP pools and fluxes follows the guidance in chapter 2.8 of IPCC (2014). As required by the guidelines, carbon from harvests allocated to deforestation is reported using instantaneous oxidation (Tier 1) as the calculation method. The remainder of the harvests is allocated to FM and is subsequently added to the respective HWP pools. No harvest from AR forests is foreseen as these forests are considered too young for harvesting. As no country-specific methodologies or half-life constants exist, the calculations for the HWP pools follow the Tier 2 approach outlined in the 2013 IPCC KP guidance by applying equations 2.8.1–2.8.6 (Arets et al., 2021). During the first commitment period the Netherlands did not account for FM and HWP. Since no harvests from AR are included in the HWP, no emissions from harvested wood products originating from forests prior to the start of the second commitment period have been included in the accounting.

Four categories of HWP are taken into account: Sawn wood, Wood-based panels, Other industrial round wood, and Paper and paperboard. Emissions from wood harvested for energy purposes is included in the carbon stock losses in living biomass under FM, but is not used as an inflow into the HWP pool. As a result, these emissions are accounted for on the basis of instantaneous oxidation. Emissions from harvested wood products in solid waste disposal sites (SWDS) are not separately accounted for.

Total wood harvests are calculated on the basis of information on harvesting from permanent plots recorded in successive National Forest Inventories (see Arets et al., 2021). As the total harvest is from Forest land remaining forest land, it is allocated to FM activities. No harvests from deforestation are considered for HWP.

The distribution of material inflow into the different HWP pools is based on the forestry production and trade data reported to FAO (Teeuwen et al., 2020) as import, production and export for the different wood product categories (see Table 6.11 in Chapter 6), including those for industrial round wood and wood pulp as a whole (equations 2.8.1–2.8.4.). Equation 2.8.4 from the 2013 IPCC KP guidance (IPCC, 2014) is used to obtain the annual fractions of HWP from domestic harvests and to exclude imported HWP.
Material inflow is included from 1990 onwards. Consequently, inherited emissions since 1990 are taken into consideration in the accounting. The dynamics of the HWP pools are then calculated by applying equations 2.8.5 and 2.8.6 and the half-life constants reported in Table 2.8.2 of the 2013 IPCC KP guidance (see Arets et al., 2021).

To assess carbon amounts in the different HWP categories, the default carbon conversion factors for the aggregated HWP categories Sawn wood, Wood-based panels, and Paper and paperboard were used from the 2013 IPCC KP guidance (see Table 11.7). For the category Other industrial round wood, the values for Sawn wood were used. This category includes a variety of round wood use, such as the use of whole stems as piles in building foundations, roads 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.

Table 11.7. 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

Because the statistics on the production, import and export of industrial round wood in 1990 appeared not to be correct in the FAO forestry statistics database, the data for the base year 1990 were adjusted on the basis of the statistics reported by PROBOS, the Dutch national correspondent to the Joint Forest Sector Questionnaire, reporting national forestry statistics to the FAO and other international organisations (see Arets et al., 2021).

11.5 Article 3.4

11.5.1 Information that demonstrates that activities under Article 3.4 have occurred since 1 January 1990 and are human-induced

The land use mapping approach used allows changes in Forest land to be monitored over time. All Forest land in the Netherlands is considered to be managed land. With the historic and current scarcity of land in the Netherlands (which has the highest population density of any country in Europe), any land use is the result of deliberate human decisions (as indicated in Section 11.4.1, too).

11.5.2 Information relating to Forest management

11.5.2.1 Conversion of natural forest to planted forest

The vast majority of forest in the Netherlands is planted and all of the forest area is considered managed forest. Conversion from (natural) forest to highly productive plantations is not common. Moreover, the effects of such conversions will already be factored into the information on carbon stocks in Forest land available from the NFIs. Therefore, emissions arising from the possible conversion of (natural) forest to plantations are already included in the carbon stock changes calculated from the NFIs and are already reported under FM.

11.5.2.2 Forest Management Reference Levels (FMRLs)

The ‘Submission of information on forest management reference levels by the Netherlands’ of 20 April 2011 contains the information on the FMRLs as original submitted. It is published at https://unfccc.int/bodies/awg-kp/items/5896.php.

After a correction in the calculation matrix of the HWP model, changes in the submission of information on FMRLs by the Netherlands were communicated on 20 May 2011. These are published at https://unfccc.int/files/meetings/ad_hoc_working_groups/kp/application/pdf/awgkp_netherlands_corr.pdf. These corrections contain updated values of the proposed reference levels.

During the subsequent technical assessment of the submission mentioned above, the ERT noticed discrepancies in the area data used by the models. As result, the Netherlands reran the models with updated area data. This resulted in a revised FMRL of -1.464 Mt CO_2 eq. per year (average 2013–2020) assuming instantaneous oxidation of HWP and a revised FMRL of -1.425 Mt CO_2 eq. per year applying a first-order decay function to HWP. These numbers are included in the 'Report of the technical assessment of the forest management reference level submission of the Netherlands submitted in 2011', FCCC/TAR/2011/NLD, 19 September 2011, published at http://unfccc.int/resource/docs/2011/tar/nld01.pdf.

The calculation of the cap on Forest management as required by paragraph 13 of the annex to decision 2/CMP.7 follows the guidance provided in paragraph 12 of decision 6/CMP.7. It is calculated as 3.5% of the base year GHG emissions excluding LULUCF, taking into account the corrected amount after the review of the NIR 2015 and the Initial Report. These total base year GHG emissions excluding LULUCF were 223,198.40 Gg CO_2 eq., resulting in a 3.5% cap of 7,811.94 Gg CO_2 eq. annually, or in total 62,495,511 Gg CO_2 eq.

11.5.2.3 Technical corrections to FMRLs

A number of changes in the Netherlands' inventory caused methodological inconsistencies between the inventory and the FMRLs. This was partly because the accounting of HWP as agreed in decision 2/CMP.7 was not yet available at the time the FMRLs were submitted: natural disturbances were not yet included at the time of submission of the FMRLs. Additionally, new NFI statistics became available covering the period 2003–2012, and in the NIR 2021 a land-use map for 1970 was introduced, all resulting in recalculated historical data.
Moreover, also new methodologies on calculating the carbon stock changes in forest land have been introduced since the adoption of the FMRL and new information on land-use change from using additional maps for the years 2013 and 2017 is used resulting in inconsistencies between the reported emissions and removals in FM and those included in the FMRL.
To cover the various changes leading to these inconsistencies between FM and FMRL a technical correction was calculated. This technical correction is based on the difference between the adopted FMRL and a newly calculated FMRL ($FMRL_{corr}$). In summary the $FMRL_{corr}$ was calculated in a way that maintained the projected business-as-usual development in forest structure, harvests and HWP profile of the adopted FMRL (see 11.5.2.2). The projections of forest structure were carried out using the EFISCEN model, which was one of the forest models used for assessing the adopted FMRL, with the same parameters as used for the assessment of the adopted FMRL (see: https://unfccc.int/files/meetings/ad_hoc_working_groups/kp/application/pdf/awgkp_netherlands_corr.pdf). Outputs of the EFISCEN model then were used in the LULUCF bookkeeping model a similar way as the projections carried out to assess carbon stock changes in forest land for the period after the latest National Forest Inventory (see sections 4.2 and 13.4.2 in Arets et al., 2021). By doing both calculations of FM and $FMRL_{corr}$ in the same way consistency in the methodologies is secured. Both included the same carbon pools and emissions sources.

The calculated $FMRL_{corr}$ was -1.155 Mt CO_2 eq. per year (average 2013–2020) assuming instantaneous oxidation of HWP and a $FMRL_{corr}$ of -1.065 Mt CO_2 eq. per year applying a first-order decay function to HWP (HWP is an average net source of 90 Gg CO_2). Detailed assessment of the Technical Correction is provided in Schelhaas and Arets (2021). As a result the technical correction to be applied to the adopted FMRL is: +360 Gg CO_2

11.5.2.4 Information related to the natural disturbances provision under Article 3.4.
See section 11.4.4.

11.5.2.5 Information on harvested wood products under Article 3.4.
See section 11.4.5.

11.6 Other information

11.6.1 Key category analysis for Article 3.3 activities and any mandatory and elected activities under Article 3.4

The smallest key category based on the Approach 1 level analysis including LULUCF, is category 1A4 Liquids (excl 1A4c) (CO2), 573 Gg CO2 eq.; see Annex 1). With net emissions of -620.9 Gg CO_2 eq., the absolute annual contribution of afforestation/reforestation under the KP-LULUCF in 2019 is more than the
smallest key category (Approach 1 level analysis including LULUCF).
Deforestation under the KP-LULUCF in 2019 causes a net emission of 1,333.3 Gg CO_2 eq., which is more than the smallest key category (Approach 1 level analysis including LULUCF).
With a net emission of -1024.3 Gg CO_2 eq. the absolute annual contribution of Forest management is also larger than the smallest key category. Table 11.8 shows the net emissions from AR, D and FM for the years 2013–2019.

Table 11.8. Net emissions from AR, D and FM (including HWP) (Gg CO_2 eq.).

Activities	**Net emissions (Gg CO_2 eq.)**						
	2013	2014	2015	2016	2017	2018	2019
A. Article 3.3 activities							
A1 Afforestation and Reforestation	-602.7	-602.9	-603.0	-602.7	-605.3	-613.2	-620.9
A2 Deforestation	1086.7	1256.5	1167.6	1209.7	1250.7	1291.9	1333.3
B. Article 3.4 activities							
B1 Forest management	-1233.5	-1202.2	-1140.5	-1140.3	-1093.7	-1048.2	-1024.3

11.7 Information relating to Article 6

The Netherlands is not buying or selling any emissions reductions from Joint Implementation projects related to land that is subject to a project under Article 6 of the Kyoto Protocol.

12 Information on accounting of Kyoto units

12.1 Background information

The Netherlands' Standard Electronic Format (SEF) report for 2020 containing the information required by paragraph 11 of the annex to decision 15/CMP.1, as updated by decision 3 CMP.11, paragraph 12, and adhering to the guidelines of the SEF, has been submitted to the UNFCCC Secretariat electronically (RREG1_NL_2020_2_1.xlsx) and (RREG1_NL_2020_2_1.xml).

12.2 Summary of information reported in the SEF tables

There were 5.716.496 CERs in the registry at the end of 2020: 563.670 CERs were held in the Party holding accounts, 4.196.444 CERs were held in entity holding accounts and 956.382 CERs were held in the voluntary cancellation account.

There were 15.000 Emission Reduction Units (ERUs) in the registry at the end of 2020: All 15.000 were held in the voluntary cancellation account.
The total amount of the units (CERs and ERUs) in the registry corresponded to 5.731.496 tonnes CO_2 eq.

Annual submission item	Submission
15/CMP.1 annex I.E paragraph 11: Standard electronic format (SEF)	The Standard Electronic Format report for 2020 has been submitted to the UNFCCC Secretariat electronically (RREG1_NL_2020_2_1.xlsx) and (RREG1_NL_2020_2_1.xml).

12.3 Discrepancies and notifications

Annual submission item	Submission
15/CMP.1 annex I.E paragraph 12: List of discrepant transactions	There were no discrepant transactions in 2020.
15/CMP.1 annex I.E paragraph 13 & 14: List of CDM notifications	No CDM notifications occurred in 2020.
15/CMP.1 annex I.E paragraph 15: List of non-replacements	No non-replacements occurred in 2020.
15/CMP.1 annex I.E paragraph 16: List of invalid units	No invalid units existed as at 31 December 2020.
15/CMP.1 annex I.E paragraph 17: Actions and changes to address discrepancies	No actions were taken or changes made to address discrepancies for the period under review.

12.4 Publicly accessible information

<table>
<tr><th>Annual submission item</th><th>Submission</th></tr>
<tr><td>15/CMP.1 annex I.E Publicly accessible information</td><td>The information as described in 13/CMP.1 annex II.E paragraphs 44–48 is publicly available at the following internet addresses:
www.emissionsauthority.nl/topics/public-information-kyoto and/or here:
EUCR / NL / Kyoto Protocol Public Reports (europa.eu)

All required information for a Party with an active Kyoto registry is provided, with the following exceptions:

<u>paragraph 46</u>
Article 6 Project Information. The Netherlands does not host JI projects, as laid down in national legislation. This fact is stated in the information available at the above-mentioned internet address.
That the Netherlands does not host JI projects is implied by Article 16.46c of the Environment Act (Wet milieubeheer) and explicitly stated in the explanatory memorandum to the act implementing the EC linking Directive (Directive 2004/101/EC, the Directive that links the ETS to the project-based activities under the Kyoto Protocol). As is explained in the memorandum, the government decided not to allow JI projects in the Netherlands since these would only increase the existing shortage of emissions allowances/assigned amount units.

<u>paragraph 47a/d/f/l in/out/current</u>
Holding and transaction information is provided on a holding type level, due to more detailed information being declared confidential by EU regulation. This follows from Article 110 of Commission Regulation (EU) no 389/2013.

<u>paragraph 47c</u>
The Netherlands does not host JI projects, as laid down in national legislation (ref. submission paragraph 46 above).

<u>paragraph 47e</u>
The Netherlands does not perform LULUCF activities and therefore does not issue RMUs.

<u>paragraph 47g</u>
No ERUs, CERs, AAUs or RMUs have been cancelled on the basis of activities under Article 3, paragraphs 3 and 4, to date.

<u>paragraph 47h</u>
No ERUs, CERs, AAUs or RMUs have been cancelled following determination by the Compliance Committee that the Party is not in compliance with its commitment under Article 3, paragraph 1, to date.

<u>paragraph 47i</u>
The number of other ERUs, CERs, AAUs and RMUs that have been cancelled is published by means of the SEF report.</td></tr>
</table>

Annual submission item	Submission
	paragraph 47j The number of other ERUs, CERs, AAUs and RMUs that have been retired is published by means of the SEF report. paragraph 47k There is no previous commitment period to carry ERUs, CERs and AAUs over from.

12.5 Calculation of the commitment period reserve (CPR)

The commitment period reserve equals the lower of either 90% of a Party's assigned amount pursuant to Article 3(7bis), (8) and (8bis) or 100% of its most recently reviewed inventory, multiplied by 8.

For the purposes of the joint fulfilment, the commitment period reserve (CPR) applies to the EU, its Member States and Iceland individually.

The calculations of the CPR for the Netherlands are follows.
Method 1 (90% of assigned amount) results in:
0.90 * 924,777,902 = 832,300,112 tonnes of CO_2 equivalent.

Method 2 (100% of most recently reviewed inventory): taking the 2019 submission as this is the most recently reviewed inventory since the 2020 submission has not been reviewed - and multiplying by 8 results in: 221,710,817*8 = 1,773,368,536 tonnes of CO2 equivalent.

The CPR consequently amounts to 832,300,112 tonnes of CO_2 equivalent.

12.6 KP-LULUCF accounting

Not applicable, because the Netherlands has opted for end-of-period accounting for KP-LULUCF.

12.7 Carry-over and PPSR

Carry-over

The Netherlands will not make use of the carry-over possibility. It will not carry over any Kyoto Protocol Units from commitment period 1 to commitment period 2.

PPSR

Since 16 November 2016 the Union Registry has provided the technical facility to open a PPSR account. However, the legal base was missing (Doha amendment ratification). The entry into force of the Doha amendment in 2020 was a legal prerequisite to open a PPSR account. As such, the Netherlands will open the PPSR account in our National Registry to fulfil the requirements in time.

13 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' 7th National Communication, the 4th 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 only changes in the National System since the Initial Report are the following:

- 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 the PBL. As of 1 January 2010, coordination has been assigned to the RIVM. Processes, protocols and methods remain unchanged. Many of the experts from the 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) by five methodology reports (one for each PRTR Task Force). The 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 at 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 do not have any impact on the functions of the National System.

14 Information on changes in national registry in 2020

The following changes to the national registry of Netherlands have occurred in 2020. Note that the 2020 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	During the reported period, the alternative contact and release manager changed. No further changes occurred in the information below. **Administrator** Dutch Emissions Authority P.O. Box 91503 NL-2509 EC The Hague Tel.: +31 70 456 8050 Fax: +31 70 456 8247 Web: https://www.emissionsauthority.nl/ **Main contact** Mrs. Maaike Breukels Manager Emissions Trading Dutch Emissions Authority P.O. Box 91503 NL-2509 EC The Hague Tel.: +31 70 456 8311 Fax: +31 70 456 8247 Email: maaike.breukels@emissieautoriteit.nl **Alternative contact** Mrs. Renée Dubbeldeman Administrator registry Dutch Emissions Authority P.O. Box 91503 NL-2509 EC The Hague Tel.: +31 70 456 8050 Fax: +31 70 456 8247 Email: renee.dubbeldeman@emissieautoriteit.nl **Release Manager** Mrs. Renée Dubbeldeman Dutch Emissions Authority P.O. Box 91503 NL-2509 EC The Hague Tel.: +31 70 456 8050 Fax: +31 70 456 8247 Email: renee.dubbeldeman@emissieautoriteit.nl
15/CMP.1 annex II.E paragraph 32.(b) Change regarding cooperation arrangement	No change of cooperation arrangement occurred during the reporting period.

Reporting item	Description
15/CMP.1 annex II.E paragraph 32.(c) Change to database structure or the capacity of national registry	There has been a new EUCR release (version 11.5) after version 8.2.2 (the production version at the time of the last Chapter 14 submission). Due to the new release, some changes were applied to the database. The updated database 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 version 11.5 compared with version 8.2.2 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.
15/CMP.1 annex II.E paragraph 32.(f) Change regarding security	The use of soft tokens for authentication and signature was introduced for the registry end users
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.

15 Information on minimisation of adverse impacts in accordance with Article 3, paragraph 14

The Netherlands provided information on minimisation of adverse impacts in accordance with Article 3, paragraph 14 in previous NIRs and national communications in accordance with the guidelines for the preparation of the information required under Article 7 of the Kyoto Protocol (Decision 15/CMP.1, Section I. H. and paragraph 36 in Section II. G.).
The Netherlands strives to implement its commitments under the Kyoto Protocol in such a way that social, environmental and economic impacts on other countries, and on developing countries in particular, are minimised.

Since the submission of the NIR 2020, there have been no changes in the activities on minimising adverse impacts. Policies are still in place and are being executed.
Among the actions – a to f – listed in the Annex to Decision 15/CMP.1, Part I. H, 'Minimisation of adverse impacts in accordance with Article 3, paragraph 14', the Netherlands implemented national actions as well as actions to support and to assist developing countries.

With regard to the progressive reduction or phasing-out of market imperfections, fiscal incentives, tax and duty exemptions, and subsidies in all greenhouse-gas-emitting sectors, taking into account the need for energy price reforms to reflect market prices and externalities (action a), energy prices have reflected market prices for many years. With (increasing) environmental taxation the externalities of energy use related to GHG emissions are increasingly reflected in energy prices. Examples are: environmental taxes on the use of natural gas up to 170,000 m^3 increased from €0.1639 per m^3 in 2011 to € 0,1911 in 2015 and to € 0,3331 in 2020; excise duty on gasoline increased in the same period from €0.71827 per litre, to € 0.76607 and €0.80033 per litre in 2015 and 2020, respectively. An overview of all environmental taxes since 2013 is available at:
https://www.belastingdienst.nl/wps/wcm/connect/bldcontentnl/belastingdienst/zakelijk/overige_belastingen/belastingen_op_milieugrondslag/tarieven_milieubelastingen/tabellen_tarieven_milieubelastingen?projectid=6750bae7-383b-4c97-bc7a-802790bd1110

and on excise duties at:
https://download.belastingdienst.nl/douane/docs/tarievenlijst-accijns-acc0552z83fd.pdf

For many years, there have been no subsidies in the Netherlands associated with the use of environmentally unsound and unsafe technologies, referred to as action b. There are only subsidies for environmentally friendly technologies or technologies that ensure increased sustainability.

To promote Policy Coherence for Development, the Netherlands has adopted an Action Plan. One of its focus areas is climate change. In addition to integrating climate action into development cooperation, and increasing support for climate change adaptation and mitigation in developing countries, we have taken a number of other actions:

- We no longer provide public support, including export credits, to coal-fired power plants.
- In the international financial institutions we advocate more investment in renewable energy and support investment in fossil fuels only in exceptional circumstances, where no realistic alternatives are available.
- In climate funds such as the Green Climate Fund and the Climate Investment Funds we seek to ensure that funding benefits the poor.
- To halt deforestation in highly relevant supply chains such as timber, soy and palm oil, the Netherlands has initiated and promoted the Amsterdam Declarations. The two Declarations – one on stopping deforestation and one on sustainable palm oil – were launched on 7 December 2015 with the intention of achieving fully sustainable and deforestation-free agro-commodity supply chains in Europe by 2020. To date, in addition to the Netherlands; Denmark, Germany, Norway, the United Kingdom and France have signed. The Declarations are intended to stimulate private sector commitment and progress on agricultural commodities associated with deforestation (such as palm oil, soy and cocoa) for which Europe has a significant market share. By expanding market demand for sustainable commodities in the signatory European countries, the Declarations aim to incentivise sustainable production in producer countries.

The Netherlands also strives to accelerate the transition to renewable energy worldwide. The Netherlands is a founding member of the International Renewable Energy Agency (IRENA), an intergovernmental organization that supports countries in their transition to a sustainable energy future. Through the Energy Sector Management Assistance Program (ESMAP) of the World Bank and the Friends of Fossil Fuel subsidy reform, the Netherlands supports countries (mostly) in the MENA region to reform fossil fuel subsidies while maintaining social safety nets.

The Netherlands has decided to integrate development and climate action budgets, policies and activities for maximum impact and best results, especially for the poorest and most vulnerable. Committed to supporting developing countries in their climate action, we have been scaling up our climate finance. While public climate finance amounted in 2013 to €286 million, it increased to € 416 million in 2015 and € 419 million in 2017 and €575 million in 2018. In addition, in 2015 the Netherlands mobilized € 73 million private finance in 2015, €335 million in 2017 and € 411 million in 2018. We have provided support to multilateral climate funds such as the Least Developed Countries Fund, the Green Climate Fund, the GEF and the Scaling up Renewable Energy Program of the Strategic Climate Fund, one of the Climate Investment Funds. Furthermore, we focus our support on access to renewable energy, halting deforestation, climate-smart agriculture, integrated water resource management and the provision of climate-resilient water and sanitation (WASH) services. Disaster risk reduction is an integral part of our integrated water resource management programmes and receives support through Partners for Resilience. Gender is an important cross-cutting issue, as climate action is most effective when it builds on the capacities of both genders and addresses both their needs and their vulnerabilities.

There is no Dutch policy related to cooperating in the technological development of non-energy uses of fossil fuels (action c).

The Netherlands will continue to support and cooperate with developing country parties in relation to actions d–f. Examples from recent programmes include the following:

- The project Solar for Farms in Uganda/Milking the Sun makes high-quality and affordable solar lamps and solar home systems available to dairy cooperative members through the provision of financing, thereby increasing farm production, lowering household emissions (substituting kerosene for solar) and providing improved lighting for dairy and household activities.
- The African Biogas Partnership Program (ABPP) builds capacity in the biogas sector of five African countries: Ethiopia, Uganda, Burkina Faso, Kenya and Tanzania. The programme assists these countries in applying domestic biogas as a climate-friendly solution for energy, organic fertiliser and livestock keeping.
- The Netherlands funds capacity building in geothermal energy as delivered by both bilateral and multilateral programmes, in particular by the World Bank and the International Finance Corporation (IFC). These programmes share the common characteristic of being ‘upstream’ interventions, aimed at eliminating structural constraints such as feed-in tariff hurdles for electricity generated by geothermal sources.
- The National Geothermal Capacity-Building Programme in Indonesia works to develop Indonesia’s geothermic potential at various locations, calculated to be 27,000 MW, of which only 1,052 MW (4%) was being used in 2008. The objective of this public–private partnership is to develop and strengthen the structure of human resources development, which is needed to provide the workforce for the development and implementation of the planned infrastructure for geothermal energy in Indonesia.
- Energy Sector Management Assistance Program (ESMAP) supports, among other things, reform of fossil fuels subsidies through south-south cooperation (support for targeted research, design and preparation, capacity development, political economy strategies and communication). South-South exchange demonstrates that many countries struggle with the challenge of reducing the fiscal burden of fossil fuel subsidies and are keen to learn from experiences of front runner countries in their region, like Egypt in the MENA region.
- Ghana Climate Innovation Centre (GCIC), supported by the World Bank Group’s infoDev, helps local small and medium-sized enterprises (SMEs) in clean technology as well as climate innovators to commercialise and scale the most innovative

private-sector solutions to climate change. It provides entrepreneurs in clean technology with the knowledge, capital and market access required to launch and grow their businesses. The success of these enterprises leads to emission reductions and improved climate resilience, while also enabling developing countries to realise greater value in the innovation value chain, build competitive sectors and create jobs.

Public–private partnerships are an essential feature of Dutch climate policies. In recent years the Netherlands has also joined or initiated several alliances such as the Global Delta Coalition, the Climate Smart Agriculture Alliance and the Tropical Forest Alliance.

Collaboration between authorities, business and knowledge institutions
the Netherlands will be working more and more closely with companies and knowledge institutions to contribute to combating climate change and its consequences. The innovations and financial strength of these parties are essential to meet the challenges of climate change together. the Netherlands has, for example, a great deal of expertise in the fields of water, food security and energy and we are already collaborating with various countries in these fields: on water security, for instance, with Vietnam, Colombia and Indonesia. In the future, the private sector and knowledge institutions will be more closely involved and this is a key factor in the Dutch strategy. It is also in line with our ambitions for the new climate instrument: to offer customization and to let everyone make an appropriate contribution.

Market Mechanisms
The flexible mechanisms under the Protocol – (1) Emissions Trading (i.e. the European Union Emissions Trading Scheme EU-ETS), (2) Joint Implementation and (3) Clean Development – are all tools incorporated into the Protocol in order to share efforts aimed at reducing greenhouse gases, ensuring that investments are made where the money has optimal GHG-reducing effects, and thus ensuring a minimum impact on the world economy. The Netherlands has made use of each of the flexible mechanisms. It has also signed MoUs regarding Clean Development Mechanism (CDM) projects with several countries worldwide. The Netherlands is supporting the World Bank's 'Partnership for Market Readiness' (PMR), which will help countries use the carbon market. The PMR will promote new market instruments as well as adjustments or expansion of the CDM.
To buy carbon credits under the CDM, the Dutch Ministry of Infrastructure spent €151 million between 2005 and 2008 and €132.6 million in the period 2009–2012. The Ministry of Economic Affairs purchased carbon credits under Joint Implementation for €53.4 million between 2005 and 2008 and for €109.1 million for the period 2009–2012.

In total, the Netherlands has contracted 33.2 million tonnes of carbon credits from CDM projects, 17.1 million tonnes from JI projects, 3 million tonnes from Latvia (Green Investment Scheme) and 2.2 million tonnes from Participation in Carbon Funds (PCF).

Minimizing adverse effects regarding biofuels production
All biofuels on the market in Europe and the Netherlands must be in compliance with the sustainability criteria laid down by the Renewable Energy Directive (2009/28/EG). Only if biofuels are sustainable are they allowed to be used to fulfil the blending target. Compliance with these criteria must be demonstrated through one of the adopted certification systems. These certification systems are controlled by an independent audit. All biofuels produced in the Netherlands fulfil these requirements.

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, we allocated national emissions 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 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 (excluding LULUCF): 33 categories for annual level assessment (emissions in 2019) and 40 categories for the trend assessment out of a total of 118 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 (for details of the Approach 1 uncertainty analysis see Olivier et al., 2009). 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 Table A1.1. A combination of Approach 1 and 2 and level and trend assessments, shows a total of 55 key categories (excluding LULUCF) and 59 including LULUCF.

As expected, the Approach 2 level and trend assessments increase the importance of highly uncertain sources.
It can be concluded, that in using the results of an Approach 2 key category assessment, 12 categories are added to the list of 43 Approach 1 level and trend key categories (excluding LULUCF):

Table A1.0: Approach 2 additional key categories

1A1	Energy Industries:all fuels	N2O	Key(L2,T2)
1A3b	Road transportation	N2O	Key(T2)
1A4b	Residential:all fuels	CH4	Key(L2)
2B10	Other	N2O	Key(L2,T2)
2B8	Chemical industry: Petrochemical and carbon black production	CH4	Key(L2)
2D2	Paraffin wax use	CO2	Key(L2,T2)
2F6	Other	HFC	Key(T2)
3A3	Swine	CH4	Key(L2)
3B1	Mature dairy cattle	N2O	Key(L2)
3B1	Growing cattle	N2O	Key(L2)
3B5	Indirect emissions	N2O	Key(L2,T2)
5D	Wastewater treatment and discharge	CH4	Key(L2)

The share of these sources in the national annual total becomes larger when taking their uncertainty (50%–100%) into account (Table A1.4). When we include the most important Land use, land use change and forestry (LULUCF) emission sinks and sources in the Approach 1 and Approach 2 key category calculations, this results in 4 additional key categories, giving an overall total of 59 key categories; see also Table A1.2.

This Annex 1 also includes information on key categories in 1990; Table A1.3 shows the results.

The 2019 inventory contains, in comparison with 1990, 4 additional source categories on the basis of a level assessment. Please note that a trend assessment for 1990 Key categories is not relevant.

*Table A1.1: Key category list identified by the Approach 1 and 2 level and trend assessments for **2019** emissions (**excluding** LULUCF sources)*

IPCC	Source category	Gas	Key source?	Approach 1 level recent year without LULUCF	Approach 1 trend without LULUCF	Approach 2 level recent year without LULUCF	Approach 2 trend without LULUCF
1A1	Energy Industries:all fuels	CH4	Non key	0	0	0	0
1A1	Energy Industries:all fuels	N2O	Key(L2,T2)	0	0	1	1
1A1a	Public Electricity and Heat Production: liquids	CO2	Key(L1,T)	1	1	0	1
1A1a	Public Electricity and Heat Production: solids	CO2	Key(L,T)	1	1	1	1
1A1a	Public Electricity and Heat Production: gaseous	CO2	Key(L1,T1)	1	1	0	0
1A1a	Public Electricity and Heat Production: other fuels: waste incineration	CO2	Key(L,T)	1	1	1	1
1A1b	Petroleum Refining: liquids	CO2	Key(L,T)	1	1	1	1
1A1b	Petroleum Refining: gaseous	CO2	Key(L1,T1)	1	1	0	0
1A1c	Manufacture of Solid Fuels: solids	CO2	Key(L,T)	1	1	1	1
1A1c	Manufacture of Solid Fuels:.gaseous	CO2	Key(L,T)	1	1	1	1
1A2	Manufacturing Industries and Construction, liquids	CO2	Key(L,T)	1	1	1	1
1A2	Manufacturing Industries and Construction, solids	CO2	Key(L,T)	1	1	1	1
1A2	Manufacturing Industries and Construction, gaseous	CO2	Key(L,T1)	1	1	1	0
1A2	Manufacturing Industries and Construction:all fuels	CH4	Non key	0	0	0	0
1A2	Manufacturing Industries and Construction:all fuels	N2O	Non key	0	0	0	0
1A3 exl 1A3b	Other	CH4	Non key	0	0	0	0
1A3 exl 1A3b	Other	N2O	Non key	0	0	0	0

IPCC	Source category	Gas	Key source?	Approach 1 level recent year without LULUCF	Approach 1 trend without LULUCF	Approach 2 level recent year without LULUCF	Approach 2 trend without LULUCF
1A3a	Domestic aviation	CO2	Non key	0	0	0	0
1A3b	Road transportation: gasoline	CO2	Key(L,T)	1	1	1	1
1A3b	Road transportation: diesel oil	CO2	Key(L,T)	1	1	1	1
1A3b	Road transportation: LPG	CO2	Key(,T)	0	1	0	1
1A3b	Road transportation:gaseous	CO2	Non key	0	0	0	0
1A3b	Road transportation	CH4	Non key	0	0	0	0
1A3b	Road transportation	N2O	Key(,T2)	0	0	0	1
1A3c	Railways	CO2	Non key	0	0	0	0
1A3d	Domestic navigation	CO2	Key(L1,T1)	1	1	0	0
1A3e	Other	CO2	Non key	0	0	0	0
1A4	Liquids excl. 1A4c	CO2	Key(L,T)	1	1	1	1
1A4	Solids	CO2	Non key	0	0	0	0
1A4	Other Sectors:all fuels	N2O	Non key	0	0	0	0
1A4a	Commercial/Institutional:gaseous	CO2	Key(L,T1)	1	1	1	0
1A4a	Commercial/Institutional:all fuels	CH4	Non key	0	0	0	0
1A4b	Residential gaseous	CO2	Key(L,T1)	1	1	1	0
1A4b	Residential:all fuels	CH4	Key(L2,)	0	0	1	0
1A4c	Agriculture/Forestry/Fisheries: liquids	CO2	Key(L1,T1)	1	1	0	0
1A4c	Agriculture/Forestry/Fisheries:gaseous	CO2	Key(L,T)	1	1	1	1
1A4c	Agriculture/Forestry/Fisheries:all fuels	CH4	Key(L,T)	1	1	1	1
1A5	Military use:liquids	CO2	Non key	0	0	0	0
1A5	Military use:liquids	CH4	Non key	0	0	0	0

IPCC	Source category	Gas	Key source?	Approach 1 level recent year without LULUCF	Approach 1 trend without LULUCF	Approach 2 level recent year without LULUCF	Approach 2 trend without LULUCF
1A5	Military use:liquids	N2O	Non key	0	0	0	0
1B1b	Solid fuel transformation	CO2	Non key	0	0	0	0
1B1b	Solid fuel transformation	CH4	Non key	0	0	0	0
1B2	Fugitive emissions from oil and gas operations	CO2	Key(L1,T1)	1	1	0	0
1B2a	Oil	CH4	Non key	0	0	0	0
1B2b	Natural gas	CH4	Non key	0	0	0	0
1B2c	Venting and flaring	CH4	Key(,T)	0	1	0	1
2A1	Cement production	CO2	Key(,T1)	0	1	0	0
2A2	Lime production	CO2	Non key	0	0	0	0
2A3	Glass production	CO2	Non key	0	0	0	0
2A4a	Ceramics	CO2	Non key	0	0	0	0
2A4b	Other uses of soda ash	CO2	Non key	0	0	0	0
2A4d	Other	CO2	Key(L,T2)	1	0	1	1
2B	Fluorochemical production	HFC	Key(,T)	0	1	0	1
2B1	Ammonia production	CO2	Key(L,)	1	0	1	0
2B10	Other	CO2	Key(L1,T1)	1	1	0	0
2B10	Other	N2O	Key(L2,T2)	0	0	1	1
2B2	Nitric acid production	N2O	Key(,T)	0	1	0	1
2B4	Caprolactam production	N2O	Key(L,)	1	0	1	0
2B7	Soda ash production	CO2	Non key	0	0	0	0
2B8	Petrochemical and carbon black production	CO2	Key(L2,T)	0	1	1	1
2B8	Chemical industry: Petrochemical and carbon black production	CH4	Key(L2,)	0	0	1	0
2B9	Fluorochemical production	PFC	Non key	0	0	0	0
2C1	Iron and steel production	CO2	Non key	0	0	0	0

IPCC	Source category	Gas	Key source?	Approach 1 level recent year without LULUCF	Approach 1 trend without LULUCF	Approach 2 level recent year without LULUCF	Approach 2 trend without LULUCF
2C3	Aluminium production	CO2	Key(,T1)	0	1	0	0
2C3	Aluminium production	PFC	Key(,T)	0	1	0	1
2D1	Lubricant use	CO2	Non key	0	0	0	0
2D2	Paraffin wax use	CO2	Key(L2,T2)	0	0	1	1
2D2	Non-energy products from fuels and solvent use: Paraffin wax use	CH4	Non key	0	0	0	0
2D3	Other	CO2	Non key	0	0	0	0
2E	Electronic Industry	PFC	Non key	0	0	0	0
2F1	Refrigeration and airconditioning	HFC	Key(L,T)	1	1	1	1
2F6	Other	HFC	Key(,T2)	0	0	0	1
2G	Other product manufacture and use	CO2	Non key	0	0	0	0
2G	Other product manufacture and use	CH4	Non key	0	0	0	0
2G	Other product manufacture and use	N2O	Non key	0	0	0	0
2G2	SF6 use	SF6	Non key	0	0	0	0
2H	Other industrial	CO2	Non key	0	0	0	0
3A1	Mature dairy cattle	CH4	Key(L,T)	1	1	1	1
3A1	Other mature cattle	CH4	Non key	0	0	0	0
3A1	Young cattle	CH4	Key(L,T1)	1	1	1	0
3A3	Swine	CH4	Key(L2,)	0	0	1	0
3A4	Other	CH4	Non key	0	0	0	0
3B1	Mature dairy cattle	CH4	Key(L,T)	1	1	1	1
3B1	Other mature cattle	CH4	Non key	0	0	0	0
3B1	Growing cattle	CH4	Non key	0	0	0	0
3B1	Mature dairy cattle	N2O	Key(L2,)	0	0	1	0

IPCC	Source category	Gas	Key source?	Approach 1 level recent year without LULUCF	Approach 1 trend without LULUCF	Approach 2 level recent year without LULUCF	Approach 2 trend without LULUCF
3B1	Other mature cattle	N2O	Non key	0	0	0	0
3B1	Growing cattle	N2O	Key(L2,)	0	0	1	0
3B2	Sheep	N2O	Non key	0	0	0	0
3B2, 3B4	Other	CH4	Non key	0	0	0	0
3B3	Swine	CH4	Key(L,T)	1	1	1	1
3B3	Swine	N2O	Non key	0	0	0	0
3B4	Poultry	CH4	Key(,T)	0	1	0	1
3B4	Other livestock	N2O	Non key	0	0	0	0
3B5	Indirect emissions	N2O	Key(L2,T2)	0	0	1	1
3Da	Direct emissions from agricultural soils	N2O	Key(L,T)	1	1	1	1
3Db	Indirect emissions from managed soils	N2O	Key(L,T)	1	1	1	1
3G	Liming	CO2	Non key	0	0	0	0
3H	Ureum use	CO2	Non key	0	0	0	0
5A	Solid waste disposal	CH4	Key(L,T)	1	1	1	1
5B	Biological treatment of solid waste: composting	CH4	Non key	0	0	0	0
5B	Biological treatment of solid waste: composting	N2O	Non key	0	0	0	0
5C	Open burning of waste	CH4	Non key	0	0	0	0
5C	Open burning of waste	N2O	Non key	0	0	0	0
5D	Wastewater treatment and discharge	CH4	Key(L2,)	0	0	1	0
5D	Wastewater treatment and discharge	N2O	Non key	0	0	0	0
6	Indirect CO2	CO2	Key(,T)	0	1	0	1
	SUM			33	40	37	35

*Table A1.2 Key source list identified by the Approach 1 and Approach 2 level and trend assessments for **2019** emissions (**including** LULUCF sources)*

IPCC	Source category	Gas	Key source?	Approach 1 level recent year incl. LULUCF	Approach 1 trend incl. LULUCF	Approach 2 level recent year incl. LULUCF	Approach 2 trend incl. LULUCF
1A1a	Public Electricity and Heat Production: liquids	CO2	Key(L1,T)	1	1	0	1
1A1a	Public Electricity and Heat Production: solids	CO2	Key(L,T)	1	1	1	1
1A1a	Public Electricity and Heat Production: gaseous	CO2	Key(L1,T1)	1	1	0	0
1A1a	Public Electricity and Heat Production: other fuels: waste incineration	CO2	Key(L,T)	1	1	1	1
1A1b	Petroleum Refining: liquids	CO2	Key(L,T)	1	1	1	1
1A1b	Petroleum Refining: gaseous	CO2	Key(L1,T1)	1	1	0	0
1A1c	Manufacture of Solid Fuels: solids	CO2	Key(L,T)	1	1	1	1
1A1c	Manufacture of Solid Fuels:.gaseous	CO2	Key(L,T)	1	1	1	1
1A2	Manufacturing Industries and Construction, liquids	CO2	Key(L,T)	1	1	1	1
1A2	Manufacturing Industries and Construction, solids	CO2	Key(L,T)	1	1	1	1
1A2	Manufacturing Industries and Construction, gaseous	CO2	Key(L,T1)	1	1	1	0
1A4c	Agriculture/Forestry/Fisheries: liquids	CO2	Key(L1,T1)	1	1	0	0
1A4	Liquids excl. 1A4c	CO2	Key(L,T)	1	1	1	1
1A4	Solids	CO2	Non key	0	0	0	0
1A4a	Commercial/Institutional:gaseous	CO2	Key(L,T1)	1	1	1	0
1A4b	Residential gaseous	CO2	Key(L,T1)	1	1	1	0
1A4c	Agriculture/Forestry/Fisheries:gaseous	CO2	Key(L,T)	1	1	1	1
1A5	Military use:liquids	CO2	Non key	0	0	0	0
1A1	Energy Industries:all fuels	CH4	Non key	0	0	0	0
1A2	Manufacturing Industries and Construction:all fuels	CH4	Non key	0	0	0	0

IPCC	Source category	Gas	Key source?	Approach 1 level recent year incl. LULUCF	Approach 1 trend incl. LULUCF	Approach 2 level recent year incl. LULUCF	Approach 2 trend incl. LULUCF
1A4a	Commercial/Institutional:all fuels	CH4	Non key	0	0	0	0
1A4b	Residential:all fuels	CH4	Key(L2,)	0	0	1	0
1A4c	Agriculture/Forestry/Fisheries:all fuels	CH4	Key(L,T)	1	1	1	1
1A5	Military use:liquids	CH4	Non key	0	0	0	0
1A1	Energy Industries:all fuels	N2O	Key(L2,T2)	0	0	0	1
1A2	Manufacturing Industries and Construction:all fuels	N2O	Non key	0	0	0	0
1A4	Other Sectors:all fuels	N2O	Non key	0	0	0	0
1A5	Military use:liquids	N2O	Non key	0	0	0	0
1A3b	Road transportation: gasoline	CO2	Key(L,T)	1	1	1	1
1A3b	Road transportation: diesel oil	CO2	Key(L,T)	1	1	1	1
1A3b	Road transportation: LPG	CO2	Key(,T)	0	1	0	1
1A3b	Road transportation:gaseous	CO2	Non key	0	0	0	0
1A3d	Domestic navigation	CO2	Key(L1,T1)	1	1	0	0
1A3a	Domestic aviation	CO2	Non key	0	0	0	0
1A3c	Railways	CO2	Non key	0	0	0	0
1A3 exl 1A3b	Other	CH4	Non key	0	0	0	0
1A3 exl 1A3b	Other	N2O	Non key	0	0	0	0
1A3b	Road transportation	CH4	Non key	0	0	0	0
1A3b	Road transportation	N2O	Key(,T2)	0	0	0	1
1B2c	Venting and flaring	CH4	Key(,T)	0	1	0	1
1B2b	Natural gas	CH4	Non key	0	0	0	0
1B2a	Oil	CH4	Non key	0	0	0	0
1B1b	Solid fuel transformation	CO2	Non key	0	0	0	0
1B2	Fugitive emissions from oil and gas operations	CO2	Key(L1,T1)	1	1	0	0
2A1	Cement production	CO2	Key(,T1)	0	1	0	0

IPCC	Source category	Gas	Key source?	Approach 1 level recent year incl. LULUCF	Approach 1 trend incl. LULUCF	Approach 2 level recent year incl. LULUCF	Approach 2 trend incl. LULUCF
2A3	Glass production	CO2	Non key	0	0	0	0
2A4a	Ceramics	CO2	Non key	0	0	0	0
2A4b	Other uses of soda ash	CO2	Non key	0	0	0	0
2A4d	Other	CO2	Key(L,T2)	1	1	1	1
2B1	Ammonia production	CO2	Key(L,)	1	0	1	0
2B2	Nitric acid production	N2O	Key(,T)	0	1	0	1
2B4	Caprolactam production	N2O	Key(L,)	1	0	1	0
2B8	Petrochemical and carbon black production	CO2	Key(L2,T)	0	1	1	1
2C1	Iron and steel production	CO2	Non key	0	0	0	0
2C3	Aluminium production	CO2	Key(,T1)	0	1	0	0
2C3	Aluminium production	PFC	Key(,T)	0	1	0	1
2G2	SF6 use	SF6	Non key	0	0	0	0
2F1	Refrigeration and airconditioning	HFC	Key(L,T)	1	1	1	1
2F6	Other	HFC	Key(,T2)	0	0	0	1
2B	Fluorochemical production	HFC	Key(,T)	0	1	0	1
2E	Electronic Industry	PFC	Non key	0	0	0	0
2B10	Other	CO2	Key(L1,T1)	1	1	0	0
2D1	Lubricant use	CO2	Non key	0	0	0	0
2D2	Paraffin wax use	CO2	Key(L2,T2)	0	0	1	1
2D3	Other	CO2	Non key	0	0	0	0
2G	Other product manufacture and use	CO2	Non key	0	0	0	0
2H	Other industrial	CO2	Non key	0	0	0	0
2B8	Chemical industry: Petrochemical and carbon black production	CH4	Key(L2,)	0	0	1	0
2D2	Non-energy products from fuels and solvent use: Paraffin wax use	CH4	Non key	0	0	0	0
2G	Other product manufacture and use	CH4	Non key	0	0	0	0

IPCC	Source category	Gas	Key source?	Approach 1 level recent year incl. LULUCF	Approach 1 trend incl. LULUCF	Approach 2 level recent year incl. LULUCF	Approach 2 trend incl. LULUCF
2G	Other product manufacture and use	N2O	Non key	0	0	0	0
2B7	Soda ash production	CO2	Non key	0	0	0	0
3A1	Mature dairy cattle	CH4	Key(L,T)	1	1	1	1
3A1	Other mature cattle	CH4	Non key	0	0	0	0
3A1	Young cattle	CH4	Key(L,T1)	1	1	1	0
3A3	Swine	CH4	Key(L2,)	0	0	1	0
3A4	Other	CH4	Non key	0	0	0	0
3B3	Swine	CH4	Key(L,T)	1	1	1	1
3B4	Poultry	CH4	Key(,T)	0	1	0	1
3B2, 3B4	Other	CH4	Non key	0	0	0	0
3Da	Direct emissions from agricultural soils	N2O	Key(L,T)	1	1	1	1
3Db	Indirect emissions from managed soils	N2O	Key(L,T)	1	1	1	1
3G	Liming	CO2	Non key	0	0	0	0
3H	Ureum use	CO2	Non key	0	0	0	0
5A	Solid waste disposal	CH4	Key(L,T)	1	1	1	1
5B	Biological treatment of solid waste: composting	CH4	Non key	0	0	0	0
5B	Biological treatment of solid waste: composting	N2O	Non key	0	0	0	0
5D	Wastewater treatment and discharge	CH4	Key(L2,)	0	0	1	0
5D	Wastewater treatment and discharge	N2O	Non key	0	0	0	0
4	LULUCF: CH4	CH4	Non key	0	0	0	0
4A	Forest Land	CO2	Key(L,)	1	0	1	0
4B	Cropland	N2O	Non key	0	0	0	0
4B	Cropland	CO2	Key(L,T)	1	1	1	1
4C	Grassland	CO2	Key(L,T)	1	1	1	1
4C	Grassland	N2O	Non key	0	0	0	0

IPCC	Source category	Gas	Key source?	Approach 1 level recent year incl. LULUCF	Approach 1 trend incl. LULUCF	Approach 2 level recent year incl. LULUCF	Approach 2 trend incl. LULUCF
4G	Harvested wood products	CO2	Non key	0	0	0	0
4D	Wetlands	CO2	Non key	0	0	0	0
4E	Settlements	CO2	Key(L,T)	1	1	1	1
4F	Other Land	CO2	Non key	0	0	0	0
4H	Other	N2O	Non key	0	0	0	0
1A3e	Other	CO2	Non key	0	0	0	0
1B1b	Solid fuel transformation	CH4	Non key	0	0	0	0
2A2	Lime production	CO2	Non key	0	0	0	0
2B9	Fluorochemical production	PFC	Non key	0	0	0	0
2B10	Other	N2O	Key(L2,T2)	0	0	1	1
3B1	Mature dairy cattle	CH4	Key(L,T)	1	1	1	1
3B1	Other mature cattle	CH4	Non key	0	0	0	0
3B1	Growing cattle	CH4	Non key	0	0	0	0
3B1	Mature dairy cattle	N2O	Key(L2,)	0	0	1	0
3B1	Other mature cattle	N2O	Non key	0	0	0	0
3B1	Growing cattle	N2O	Key(L2,)	0	0	1	0
3B2	Sheep	N2O	Non key	0	0	0	0
3B3	Swine	N2O	Non key	0	0	0	0
3B4	Other livestock	N2O	Non key	0	0	0	0
3B5	Indirect emissions	N2O	Key(L2,T2)	0	0	1	1
5C	Open burning of waste	CH4	Non key	0	0	0	0
5C	Open burning of waste	N2O	Non key	0	0	0	0
6	Indirect CO2	CO2	Key(,T)	0	1	0	1
	SUM			37	44	40	38

Table A1.3 Key source list identified by the Approach 1 and Approach 2 level assessments for ***1990*** *emissions (****excluding*** *and* ***including*** *LULUCF sources)*

IPCC	Source category	Gas	Key source ? NB excl. LULUCF	Approach 1 level 1990 excl. LULUCF	Approach 1 level 1990 incl. LULUCF	Approach 2 level 1990 excl. LULUCF	Approach 2 level 1990 incl. LULUCF
1A1	Energy Industries:all fuels	CH4	Non key	0	0	0	0
1A1	Energy Industries:all fuels	N2O	Non key	0	0	0	0
1A1a	Public Electricity and Heat Production: liquids	CO2	Non key	0	0	0	0
1A1a	Public Electricity and Heat Production: solids	CO2	Key(L,)	1	1	1	1
1A1a	Public Electricity and Heat Production: gaseous	CO2	Key(L1,)	1	1	0	0
1A1a	Public Electricity and Heat Production: other fuels: waste incineration	CO2	Non key	0	0	0	0
1A1b	Petroleum Refining: liquids	CO2	Key(L,)	1	1	1	1
1A1b	Petroleum Refining: gaseous	CO2	Key(L1,)	1	1	0	0
1A1c	Manufacture of Solid Fuels: solids	CO2	Key(L,)	1	1	1	1
1A1c	Manufacture of Solid Fuels:.gaseous	CO2	Key(L,)	1	1	1	0
1A2	Manufacturing Industries and Construction, liquids	CO2	Key(L,)	1	1	1	1
1A2	Manufacturing Industries and Construction, solids	CO2	Key(L,)	1	1	1	1
1A2	Manufacturing Industries and Construction, gaseous	CO2	Key(L,)	1	1	1	1
1A2	Manufacturing Industries and Construction:all fuels	CH4	Non key	0	0	0	0
1A2	Manufacturing Industries and Construction:all fuels	N2O	Non key	0	0	0	0
1A3 exl 1A3b	Other	CH4	Non key	0	0	0	0
1A3 exl 1A3b	Other	N2O	Non key	0	0	0	0
1A3a	Domestic aviation	CO2	Non key	0	0	0	0
1A3b	Road transportation: gasoline	CO2	Key(L,)	1	1	1	1
1A3b	Road transportation: diesel oil	CO2	Key(L,)	1	1	1	1

IPCC	Source category	Gas	Key source ? NB excl. LULUCF	Approach 1 level 1990 excl. LULUCF	Approach 1 level 1990 incl. LULUCF	Approach 2 level 1990 excl. LULUCF	Approach 2 level 1990 incl. LULUCF
1A3b	Road transportation: LPG	CO2	Key(L1,)	1	1	0	0
1A3b	Road transportation:gaseous	CO2	Non key	0	0	0	0
1A3b	Road transportation	CH4	Non key	0	0	0	0
1A3b	Road transportation	N2O	Non key	0	0	0	0
1A3c	Railways	CO2	Non key	0	0	0	0
1A3d	Domestic navigation	CO2	Key(L1,)	1	1	0	0
1A3e	Other	CO2	Non key	0	0	0	0
1A4	Liquids excl. 1A4c	CO2	Key(L,)	1	1	1	1
1A4	Solids	CO2	Non key	0	0	0	0
1A4	Other Sectors:all fuels	N2O	Non key	0	0	0	0
1A4a	Commercial/Institutional:gaseous	CO2	Key(L,)	1	1	1	1
1A4a	Commercial/Institutional:all fuels	CH4	Non key	0	0	0	0
1A4b	Residential gaseous	CO2	Key(L,)	1	1	1	1
1A4b	Residential:all fuels	CH4	Key(L2,)	0	0	1	1
1A4c	Agriculture/Forestry/Fisheries: liquids	CO2	Key(L1,)	1	1	0	0
1A4c	Agriculture/Forestry/Fisheries:gaseous	CO2	Key(L,)	1	1	1	1
1A4c	Agriculture/Forestry/Fisheries:all fuels	CH4	Non key	0	0	0	0
1A5	Military use:liquids	CO2	Non key	0	0	0	0
1A5	Military use:liquids	CH4	Non key	0	0	0	0
1A5	Military use:liquids	N2O	Non key	0	0	0	0
1B1b	Solid fuel transformation	CO2	Non key	0	0	0	0
1B1b	Solid fuel transformation	CH4	Non key	0	0	0	0
1B2	Fugitive emissions from oil and gas operations	CO2	Key(L1,)	1	1	0	0
1B2a	Oil	CH4	Non key	0	0	0	0
1B2b	Natural gas	CH4	Non key	0	0	0	0

IPCC	Source category	Gas	Key source ? NB excl. LULUCF	Approach 1 level 1990 excl. LULUCF	Approach 1 level 1990 incl. LULUCF	Approach 2 level 1990 excl. LULUCF	Approach 2 level 1990 incl. LULUCF
1B2c	Venting and flaring	CH4	Key(L,)	1	1	1	1
2A1	Cement production	CO2	Non key	0	0	0	0
2A2	Lime production	CO2	Non key	0	0	0	0
2A3	Glass production	CO2	Non key	0	0	0	0
2A4a	Ceramics	CO2	Non key	0	0	0	0
2A4b	Other uses of soda ash	CO2	Non key	0	0	0	0
2A4d	Other	CO2	Key(L2,)	0	0	1	1
2B	Fluorochemical production	HFC	Key(L,)	1	1	1	1
2B1	Ammonia production	CO2	Key(L,)	1	1	1	1
2B10	Other	CO2	Key(L1,)	1	1	0	0
2B10	Other	N2O	Non key	0	0	0	0
2B2	Nitric acid production	N2O	Key(L,)	1	1	1	1
2B4	Caprolactam production	N2O	Key(L,)	1	0	1	0
2B7	Soda ash production	CO2	Non key	0	0	0	0
2B8	Petrochemical and carbon black production	CO2	Key(L2,)	0	0	1	1
2B8	Chemical industry: Petrochemical and carbon black production	CH4	Non key	0	0	0	0
2B9	Fluorochemical production	PFC	Non key	0	0	0	0
2C1	Iron and steel production	CO2	Non key	0	0	0	0
2C3	Aluminium production	CO2	Non key	0	0	0	0
2C3	Aluminium production	PFC	Key(L,)	1	1	1	1
2D1	Lubricant use	CO2	Non key	0	0	0	0
2D2	Paraffin wax use	CO2	Non key	0	0	0	0
2D2	Non-energy products from fuels and solvent use: Paraffin wax use	CH4	Non key	0	0	0	0
2D3	Other	CO2	Non key	0	0	0	0
2E	Electronic Industry	PFC	Non key	0	0	0	0

IPCC	Source category	Gas	Key source ? NB excl. LULUCF	Approach 1 level 1990 excl. LULUCF	Approach 1 level 1990 incl. LULUCF	Approach 2 level 1990 excl. LULUCF	Approach 2 level 1990 incl. LULUCF
2F1	Refrigeration and airconditioning	HFC	Non key	0	0	0	0
2F6	Other	HFC	Non key	0	0	0	0
2G	Other product manufacture and use	CO2	Non key	0	0	0	0
2G	Other product manufacture and use	CH4	Non key	0	0	0	0
2G	Other product manufacture and use	N2O	Non key	0	0	0	0
2G2	SF6 use	SF6	Non key	0	0	0	0
2H	Other industrial	CO2	Non key	0	0	0	0
3A1	Mature dairy cattle	CH4	Key(L,)	1	1	1	1
3A1	Other mature cattle	CH4	Non key	0	0	0	0
3A1	Young cattle	CH4	Key(L,)	1	1	1	1
3A3	Swine	CH4	Non key	0	0	0	0
3A4	Other	CH4	Non key	0	0	0	0
3B1	Mature dairy cattle	CH4	Key(L,)	1	1	1	1
3B1	Other mature cattle	CH4	Non key	0	0	0	0
3B1	Growing cattle	CH4	Non key	0	0	0	0
3B1	Mature dairy cattle	N2O	Key(L2,)	0	0	1	1
3B1	Other mature cattle	N2O	Non key	0	0	0	0
3B1	Growing cattle	N2O	Non key	0	0	0	0
3B2	Sheep	N2O	Non key	0	0	0	0
3B2, 3B4	Other	CH4	Non key	0	0	0	0
3B3	Swine	CH4	Key(L,)	1	1	1	1
3B3	Swine	N2O	Non key	0	0	0	0
3B4	Poultry	CH4	Non key	0	0	0	0
3B4	Other livestock	N2O	Non key	0	0	0	0
3B5	Indirect emissions	N2O	Key(L2,)	0	0	1	1
3Da	Direct emissions from agricultural soils	N2O	Key(L,)	1	1	1	1

IPCC	Source category	Gas	Key source ? NB excl. LULUCF	Approach 1 level 1990 excl. LULUCF	Approach 1 level 1990 incl. LULUCF	Approach 2 level 1990 excl. LULUCF	Approach 2 level 1990 incl. LULUCF
3Db	Indirect emissions from managed soils	N2O	Key(L,)	1	1	1	1
3G	Liming	CO2	Non key	0	0	0	0
3H	Ureum use	CO2	Non key	0	0	0	0
4	LULUCF: CH4	CH4	Non key		0		0
4A	Forest Land	CO2	Key(L1,)		1		0
4B	Cropland	N2O	Non key		0		0
4B	Cropland	CO2	Key(L,)		1		1
4C	Grassland	CO2	Key(L,)		1		1
4C	Grassland	N2O	Non key		0		0
4D	Wetlands	CO2	Non key		0		0
4E	Settlements	CO2	Key (L,)		1		1
4F	Other Land	CO2	Non key		0		0
4G	Harvested wood products	CO2	Non key		0		0
4H	Other	N2O	Non key		0		0
5A	Solid waste disposal	CH4	Key(L,)	1	1	1	1
5B	Biological treatment of solid waste: composting	CH4	Non key	0	0	0	0
5B	Biological treatment of solid waste: composting	N2O	Non key	0	0	0	0
5C	Open burning of waste	CH4	Non key	0	0	0	0
5C	Open burning of waste	N2O	Non key	0	0	0	0
5D	Wastewater treatment and discharge	CH4	Key(L2,)	0	0	1	1
5D	Wastewater treatment and discharge	N2O	Non key	0	0	0	0
6	Indirect CO2	CO2	Key(L,)	1	1	1	1
		SUM		34	37	33	34

A1.2 Changes in key categories compared with previous submission

Due to the use of emissions data for 2019, there are a few changes in key categorie in comparison with the previous NIR. One categorie that was key categorie in the previous submission, is no longer a key categorie: 3G Liming (CO_2)

The Netherlands includes 4 extra source categories in the Key category Analysis in 2021 compared to 2020: 1A1 Energy industries “all fuels” (N_2O), 2A1 Cement production (CO_2), 2B10 Other (N_2O) and 5D Wastewater treatment (CH_4).

A1.3 Changes in key categories 2019 compared with 1990

Table A1.4 shows the result of a comparison of the key categories in 1990 (level) and 2019 (level and trend). A comparison on the basis of a level assessment, shows 2 additonal key categories in 2019 compared to 1990. Five 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 2019 (compared to 1990)

1A1	Energy Industries:all fuels	N_2O	Key(L2,T2)
1A1a	Public Electricity and Heat Production,liquids	CO_2	Key(L1,T)
1A1a	Public Electricity and Heat Production: other fuels: waste incineration	CO_2	Key(L,T)
1A3b	Road transportation	N_2O	Key(,T2)
1A4c	Agriculture/Forestry/Fisheries:all fuels	CH_4	Key(L,T)
2A1	Cement production	CO_2	Key(,T1)
2B10	Other	N_2O	Key(L1,T1)
2B8	Chemical industry: Petrochemical and carbon black production	CH_4	Key(L2,T)
2C3	Aluminium production	CO_2	Key(,T)
2D2	Paraffin wax use	CO_2	Key(L2,T2)
2F1	Refrigeration and airconditioning	HFC	Key(L,T)
2F6	Other	HFC	Key(,T2)
3A3	Swine	CH_4	Key(L2,)
3B1	Growing cattle	N_2O	Key(L2,)
3B4	Poultry	CH_4	Key(,T)

A1.4 Approach 1 key source and uncertainty assessment

In Table A1.5 the source ranking is done according to the contribution to the 2019 annual emissions total and in Table A1.6 according to the base-year-to-2019 trend. This results in 37 level key sources and 44 trend key sources. Inclusion of LULUCF sources in the analysis adds four Approach 1 level and trend key sources (see Table A1.2).

*Table A1.5: Source ranking using IPCC Approach 1 **level** assessment for 2019 emissions, including LULUCF (amounts in Gg CO_2 eq.)*

IPCC Category		Gas	2019 estimate (Gg CO_2 eq.)	Level assessment %	Cumulative total %
1A1a	Public Electricity and Heat Production: gaseous	CO2	21874	11,6%	12%
1A1a	Public Electricity and Heat Production: solids	CO2	19349	10,2%	22%
1A3b	Road transportation: diesel oil	CO2	16487	8,7%	30%
1A4b	Residential gaseous	CO2	15241	8,1%	39%
1A2	Manufacturing Industries and Construction, gaseous	CO2	13523	7,1%	46%
1A3b	Road transportation: gasoline	CO2	12610	6,7%	52%
1A2	Manufacturing Industries and Construction, liquids	CO2	8675	4,6%	57%
1A4c	Agriculture/Forestry/Fisheries:gaseous	CO2	7444	3,9%	61%
1A1b	Petroleum Refining: liquids	CO2	7163	3,8%	65%
1A4a	Commercial/Institutional:gaseous	CO2	6781	3,6%	68%
3A1	Mature dairy cattle	CH4	5338	2,8%	71%
1A2	Manufacturing Industries and Construction, solids	CO2	4595	2,4%	73%
3Da	Direct emissions from agricultural soils	N2O	4241	2,2%	76%
4C	Grassland	CO2	2900	1,5%	77%
1A1b	Petroleum Refining: gaseous	CO2	2860	1,5%	79%
1A1a	Public Electricity and Heat Production: other fuels: waste incineration	CO2	2723	1,4%	80%
5A	Solid waste disposal	CH4	2370	1,3%	81%
2B1	Ammonia production	CO2	2349	1,2%	83%
4A	Forest Land	CO2	1845	1,0%	84%
3A1	Young cattle	CH4	1760	0,9%	85%
3B3	Swine	CH4	1751	0,9%	86%
1A4c	Agriculture/Forestry/Fisheries: liquids	CO2	1728	0,9%	86%
4B	Cropland	CO2	1574	0,8%	87%
2B10	Other	CO2	1544	0,8%	88%
3B1	Mature dairy cattle	CH4	1538	0,8%	89%
4E	Settlements	CO2	1479	0,8%	90%

IPCC Category		Gas	2019 estimate (Gg CO_2 eq.)	Level assessment %	Cumulative total %
1A1c	**Manufacture of Solid Fuels:.gaseous**	**CO2**	**1423**	**0,8%**	**90%**
2F1	**Refrigeration and airconditioning**	**HFC**	**1261**	**0,7%**	**91%**
1A4c	**Agriculture/Forestry/Fisheries:all fuels**	**CH4**	**1099**	**0,6%**	**92%**
1A1c	**Manufacture of Solid Fuels: solids**	**CO2**	**1044**	**0,6%**	**92%**
1B2	**Fugitive emissions from oil and gas operations**	**CO2**	**989**	**0,5%**	**93%**
1A3d	**Domestic navigation**	**CO2**	**916**	**0,5%**	**93%**
2B4	**Caprolactam production**	**N2O**	**675**	**0,4%**	**94%**
2A4d	**Other**	**CO2**	**656**	**0,3%**	**94%**
1A1a	**Public Electricity and Heat Production: liquids**	**CO2**	**604**	**0,3%**	**94%**
3Db	**Indirect emissions from managed soils**	**N2O**	**580**	**0,3%**	**95%**
1A4	**Liquids excl. 1A4c**	**CO2**	**573**	**0,3%**	**95%**
2B8	Petrochemical and carbon black production	CO2	554	0,3%	95%
3A4	Other	CH4	459	0,2%	95%
3A3	Swine	CH4	458	0,2%	96%
6	Indirect CO2	CO2	431	0,2%	96%
3B1	Growing cattle	CH4	418	0,2%	96%
2B10	Other	N2O	382	0,2%	96%
2B	Fluorochemical production	HFC	381	0,2%	96%
1A4b	Residential:all fuels	CH4	336	0,2%	97%
1A1	Energy Industries:all fuels	N2O	326	0,2%	97%
2B8	Chemical industry: Petrochemical and carbon black production	CH4	304	0,2%	97%
2B2	Nitric acid production	N2O	297	0,2%	97%
1A3b	Road transportation: LPG	CO2	281	0,1%	97%
1A3b	Road transportation	N2O	248	0,1%	97%
1B2b	Natural gas	CH4	243	0,1%	98%
3B5	Indirect emissions	N2O	241	0,1%	98%
5D	Wastewater treatment and discharge	CH4	231	0,1%	98%
2D2	Paraffin wax use	CO2	211	0,1%	98%
1B2c	Venting and flaring	CH4	196	0,1%	98%
3B1	Mature dairy cattle	N2O	192	0,1%	98%
2A2	Lime production	CO2	181	0,1%	98%
2F6	Other	HFC	175	0,1%	98%

IPCC Category		Gas	2019 estimate (Gg CO_2 eq.)	Level assessment %	Cumulative total %
4F	Other Land	CO2	175	0,1%	98%
1A5	Military use:liquids	CO2	159	0,1%	98%
1A3b	Road transportation:gaseous	CO2	151	0,1%	99%
3B1	Growing cattle	N2O	147	0,1%	99%
2A4a	Ceramics	CO2	125	0,1%	99%
1A1	Energy Industries:all fuels	CH4	122	0,1%	99%
3A1	Other mature cattle	CH4	121	0,1%	99%
2A4b	Other uses of soda ash	CO2	116	0,1%	99%
5B	Biological treatment of solid waste: composting	CH4	114	0,1%	99%
4G	Harvested wood products	CO2	111	0,1%	99%
2G2	SF6 use	SF6	111	0,1%	99%
3B4	Other livestock	N2O	100	0,1%	99%
3B3	Swine	N2O	100	0,1%	99%
2D1	Lubricant use	CO2	93	0,0%	99%
5B	Biological treatment of solid waste: composting	N2O	91	0,0%	99%
2G	Other product manufacture and use	N2O	86	0,0%	99%
1A3e	Other	CO2	85	0,0%	99%
5D	Wastewater treatment and discharge	N2O	75	0,0%	99%
3B4	Poultry	CH4	73	0,0%	99%
1B1b	Solid fuel transformation	CO2	73	0,0%	99%
2A3	Glass production	CO2	69	0,0%	100%
1A3c	Railways	CO2	66	0,0%	100%
1A3b	Road transportation	CH4	64	0,0%	100%
1A2	Manufacturing Industries and Construction:all fuels	CH4	62	0,0%	100%
1A4	Other Sectors:all fuels	N2O	51	0,0%	100%
4B	Cropland	N2O	50	0,0%	100%
2B9	Fluorochemical production	PFC	46	0,0%	100%
2G	Other product manufacture and use	CH4	46	0,0%	100%
3H	Ureum use	CO2	45	0,0%	100%
4H	Other	N2O	44	0,0%	100%
2E	Electronic Industry	PFC	44	0,0%	100%
1A2	Manufacturing Industries and Construction:all fuels	N2O	43	0,0%	100%

IPCC Category		Gas	2019 estimate (Gg CO_2 eq.)	Level assessment %	Cumulative total %
1A4a	Commercial/Institutional:all fuels	CH4	39	0,0%	100%
3B2, 3B4	Other	CH4	37	0,0%	100%
3G	Liming	CO2	35	0,0%	100%
1A3a	Domestic aviation	CO2	32	0,0%	100%
2C3	Aluminium production	PFC	27	0,0%	100%
4D	Wetlands	CO2	25	0,0%	100%
2D3	Other	CO2	21	0,0%	100%
2C1	Iron and steel production	CO2	18	0,0%	100%
2H	Other industrial	CO2	16	0,0%	100%
1B2a	Oil	CH4	16	0,0%	100%
1A4	Solids	CO2	13	0,0%	100%
3B1	Other mature cattle	CH4	11	0,0%	100%
4C	Grassland	N2O	8	0,0%	100%
1A3 exl 1A3b	Other	N2O	8	0,0%	100%
2A1	Cement production	CO2	6	0,0%	100%
1B1b	Solid fuel transformation	CH4	5	0,0%	100%
3B1	Other mature cattle	N2O	4	0,0%	100%
1A3 exl 1A3b	Other	CH4	3	0,0%	100%
1A5	Military use:liquids	N2O	3	0,0%	100%
5C	Open burning of waste	CH4	2	0,0%	100%
3B2	Sheep	N2O	2	0,0%	100%
5C	Open burning of waste	N2O	2	0,0%	100%
2G	Other product manufacture and use	CO2	1	0,0%	100%
1A5	Military use:liquids	CH4	0	0,0%	100%
4	LULUCF: CH4	CH4	0	0,0%	100%
2D2	Non-energy products from fuels and solvent use: Paraffin wax use	CH4	0	0,0%	100%
2C3	Aluminium production	CO2	0	0,0%	100%
2B7	Soda ash production	CO2	0	0,0%	100%

Lines in bold represent the key sources.

Table A1.6: Source ranking using IPCC Approach 1 ***trend*** *assessment for 2018 emissions compared to the base year,* ***including*** *LULUCF (Gg CO_2 eq.)*

IPCC Category		Gas	1990 Estimate (Gg CO_2 eq.)	2019 Estimate (Gg CO_2 eq.)	Trend Assessment %	% Contribution to trend	Cumulative Total %
1A1a	Public Electricity and Heat Production: gaseous	CO2	13329	21874	7,1	14,2	14
5A	Solid waste disposal	CH4	13679	2370	5,7	11,5	26
1A3b	Road transportation: diesel oil	CO2	13012	16487	3,8	7,6	33
2B2	Nitric acid production	N2O	6085	297	3,0	6,1	39
2B	Fluorochemical production	HFC	5606	381	2,7	5,5	45
1A3b	Road transportation: gasoline	CO2	10799	12610	2,4	4,9	50
1A1a	Public Electricity and Heat Production: other fuels: waste incineration	CO2	601	2723	1,4	2,9	53
2C3	Aluminium production	PFC	2638	27	1,4	2,8	55
1A2	Manufacturing Industries and Construction, gaseous	CO2	19044	13523	1,3	2,7	58
1A1b	Petroleum Refining: gaseous	CO2	1042	2860	1,3	2,6	61
1A3b	Road transportation: LPG	CO2	2640	281	1,2	2,4	63
1A1a	Public Electricity and Heat Production: solids	CO2	25862	19349	1,2	2,4	66
3Da	Direct emissions from agricultural soils	N2O	7122	4241	1,0	2,1	68
1A2	Manufacturing Industries and Construction, liquids	CO2	8777	8675	1,0	1,9	70
1A4c	Agriculture/Forestry/Fisheries: gaseous	CO2	7329	7444	0,9	1,9	72
2F1	Refrigeration and airconditioning	HFC	0	1261	0,8	1,6	73
3A1	Mature dairy cattle	CH4	5183	5338	0,7	1,4	75
1A4b	Residential gaseous	CO2	19894	15241	0,7	1,4	76
1A4c	Agriculture/Forestry/Fisheries: all fuels	CH4	73	1099	0,7	1,4	77
1B2c	Venting and flaring	CH4	1491	196	0,7	1,3	79
3B3	Swine	CH4	3369	1751	0,7	1,3	80
1A1b	Petroleum Refining: liquids	CO2	9968	7163	0,6	1,3	81
4C	Grassland	CO2	4691	2900	0,6	1,2	82
1A2	Manufacturing Industries and Construction, solids	CO2	6623	4595	0,5	1,1	84
4E	Settlements	CO2	848	1479	0,5	1,0	85

IPCC Category		Gas	1990 Estimate (Gg CO_2 eq.)	2019 Estimate (Gg CO_2 eq.)	Trend Assessment %	% Contribution to trend	Cumulative Total %
3Db	**Indirect emissions from managed soils**	**N2O**	**1607**	**580**	**0,5**	**1,0**	**86**
2B10	**Other**	**CO2**	**1038**	**1544**	**0,4**	**0,9**	**86**
3B1	**Mature dairy cattle**	**CH4**	**1083**	**1538**	**0,4**	**0,8**	**87**
3A1	**Young cattle**	**CH4**	**2802**	**1760**	**0,3**	**0,7**	**88**
4B	**Cropland**	**CO2**	**2565**	**1574**	**0,3**	**0,7**	**89**
1A1c	**Manufacture of Solid Fuels: gaseous**	**CO2**	**1184**	**1423**	**0,3**	**0,6**	**89**
1A4a	**Commercial/Institutional: gaseous**	**CO2**	**7758**	**6781**	**0,3**	**0,6**	**90**
1A4	**Liquids excl. 1A4c**	**CO2**	**1215**	**573**	**0,3**	**0,5**	**90**
1A1a	**Public Electricity and Heat Production: liquids**	**CO2**	**233**	**604**	**0,3**	**0,5**	**91**
1B2	**Fugitive emissions from oil and gas operations**	**CO2**	**775**	**989**	**0,2**	**0,5**	**91**
2C3	**Aluminium production**	**CO2**	**408**	**0**	**0,2**	**0,4**	**92**
2A1	**Cement production**	**CO2**	**416**	**6**	**0,2**	**0,4**	**92**
1A4c	**Agriculture/Forestry/Fisheries: liquids**	**CO2**	**2507**	**1728**	**0,2**	**0,4**	**93**
6	**Indirect CO2**	**CO2**	**917**	**431**	**0,2**	**0,4**	**93**
1A3d	**Domestic navigation**	**CO2**	**743**	**916**	**0,2**	**0,4**	**93**
1A1c	**Manufacture of Solid Fuels: solids**	**CO2**	**916**	**1044**	**0,2**	**0,4**	**94**
3B4	**Poultry**	**CH4**	**432**	**73**	**0,2**	**0,4**	**94**
2B8	**Petrochemical and carbon black production**	**CO2**	**336**	**554**	**0,2**	**0,4**	**95**
2A4d	**Other**	**CO2**	**481**	**656**	**0,2**	**0,3**	**95**
1A1	Energy Industries: all fuels	N2O	148	326	0,1	0,3	95
1A3e	Other	CO2	342	85	0,1	0,3	95
2B10	Other	N2O	244	382	0,1	0,2	96
2F6	Other	HFC	0	175	0,1	0,2	96
1A3b	Road transportation	N2O	98	248	0,1	0,2	96
4A	Forest Land	CO2	2048	1845	0,1	0,2	96
4F	Other Land	CO2	22	175	0,1	0,2	97
1A3b	Road transportation: gaseous	CO2	0	151	0,1	0,2	97
2B1	Ammonia production	CO2	2695	2349	0,1	0,2	97
2D2	Paraffin wax use	CO2	103	211	0,1	0,2	97

IPCC Category		Gas	1990 Estimate (Gg CO_2 eq.)	2019 Estimate (Gg CO_2 eq.)	Trend Assessment %	% Contribution to trend	Cumulative Total %
1A4	Solids	CO2	163	13	0,1	0,2	97
3G	Liming	CO2	183	35	0,1	0,1	97
5B	Biological treatment of solid waste: composting	CH4	4	114	0,1	0,1	98
1B2b	Natural gas	CH4	421	243	0,1	0,1	98
1A5	Military use: liquids	CO2	314	159	0,1	0,1	98
2G	Other product manufacture and use	N2O	225	86	0,1	0,1	98
1A3b	Road transportation	CH4	193	64	0,1	0,1	98
5B	Biological treatment of solid waste: composting	N2O	7	91	0,1	0,1	98
2B8	Chemical industry: Petrochemical and carbon black production	CH4	269	304	0,1	0,1	98
3B5	Indirect emissions	N2O	390	241	0,1	0,1	98
2B4	Caprolactam production	N2O	740	675	0,0	0,1	98
1A1	Energy Industries: all fuels	CH4	69	122	0,0	0,1	99
5D	Wastewater treatment and discharge	N2O	172	75	0,0	0,1	99
2A4b	Other uses of soda ash	CO2	69	116	0,0	0,1	99
2G2	SF6 use	SF6	207	111	0,0	0,1	99
2B7	Soda ash production	CO2	64	0	0,0	0,1	99
3A1	Other mature cattle	CH4	210	121	0,0	0,1	99
3B4	Other livestock	N2O	62	100	0,0	0,1	99
2A3	Glass production	CO2	142	69	0,0	0,1	99
2A2	Lime production	CO2	163	181	0,0	0,1	99
2B9	Fluorochemical production	PFC	0	46	0,0	0,1	99
3H	Ureum use	CO2	2	45	0,0	0,1	99
2H	Other industrial	CO2	72	16	0,0	0,1	99
4D	Wetlands	CO2	79	25	0,0	0,1	99
1A3a	Domestic aviation	CO2	85	32	0,0	0,0	99
4H	Other	N2O	9	44	0,0	0,0	99
3A4	Other	CH4	514	459	0,0	0,0	99
3B1	Mature dairy cattle	N2O	190	192	0,0	0,0	100
1A4b	Residential: all fuels	CH4	450	336	0,0	0,0	100

IPCC Category		Gas	1990 Estimate (Gg CO_2 eq.)	2019 Estimate (Gg CO_2 eq.)	Trend Assessment %	% Contribution to trend	Cumulative Total %
3A3	Swine	CH4	522	458	0,0	0,0	100
3B1	Growing cattle	N2O	145	147	0,0	0,0	100
2E	Electronic Industry	PFC	25	44	0,0	0,0	100
2D1	Lubricant use	CO2	85	93	0,0	0,0	100
5D	Wastewater treatment and discharge	CH4	309	231	0,0	0,0	100
4G	Harvested wood products	CO2	163	111	0,0	0,0	100
2D3	Other	CO2	0	21	0,0	0,0	100
1B1b	Solid fuel transformation	CO2	110	73	0,0	0,0	100
2C1	Iron and steel production	CO2	44	18	0,0	0,0	100
3B3	Swine	N2O	140	100	0,0	0,0	100
1A2	Manufacturing Industries and Construction: all fuels	N2O	36	43	0,0	0,0	100
1A4	Other Sectors: all fuels	N2O	50	51	0,0	0,0	100
2A4a	Ceramics	CO2	140	125	0,0	0,0	100
3B2, 3B4	Other	CH4	34	37	0,0	0,0	100
1A3c	Railways	CO2	91	66	0,0	0,0	100
3B1	Other mature cattle	CH4	22	11	0,0	0,0	100
1A2	Manufacturing Industries and Construction: all fuels	CH4	67	62	0,0	0,0	100
3B1	Growing cattle	CH4	503	418	0,0	0,0	100
2G	Other product manufacture and use	CH4	50	46	0,0	0,0	100
1B1b	Solid fuel transformation	CH4	11	5	0,0	0,0	100
3B2	Sheep	N2O	7	2	0,0	0,0	100
4C	Grassland	N2O	6	8	0,0	0,0	100
4B	Cropland	N2O	64	50	0,0	0,0	100
1A4a	Commercial/Institutional: all fuels	CH4	45	39	0,0	0,0	100
1A3 exl 1A3b	Other	N2O	7	8	0,0	0,0	100
1A5	Military use: liquids	N2O	6	3	0,0	0,0	100
3B1	Other mature cattle	N2O	7	4	0,0	0,0	100
1A3 exl 1A3b	Other	CH4	3	3	0,0	0,0	100

IPCC Category		Gas	1990 Estimate (Gg CO_2 eq.)	2019 Estimate (Gg CO_2 eq.)	Trend Assessment %	% Contribution to trend	Cumulative Total %
5C	Open burning of waste	CH4	4	2	0,0	0,0	100
2G	Other product manufacture and use	CO2	0	1	0,0	0,0	100
1B2a	Oil	CH4	20	16	0,0	0,0	100
1A5	Military use: liquids	CH4	1	0	0,0	0,0	100
5C	Open burning of waste	N2O	2	2	0,0	0,0	100
2D2	Non-energy products from fuels and solvent use: Paraffin wax use	CH4	0	0	0,0	0,0	100
4	LULUCF: CH4	CH4	0	0	0,0	0,0	100

Lines in bold represent the key sources.

A1.5 Approach 2 key category assessment

Using the uncertainty estimate for each key source as a weighting factor (see Annex 2), the key source assessment was performed again; both including and excluding LULUCF. This is called the Approach 2 key source assessment.
The results of this assessment – only the results **including** LULUCF – are presented in Tables A1.7 (contribution to the 2019 annual emissions total) and A1.8 (contribution to the trend).

Four LULUCF sources are identified as key sources: 4A Forest land, 4B Cropland, 4C Grassland and 4E Settlements.

*Table A1.7: Source ranking using IPCC Approach 2 **level** assessment for 2019 emissions, including LULUCF (Gg CO_2 eq.)*

IPCC Category		Gas	Gg CO_2 eq. 2019	Share %	Uncertainty estimate %	Level * uncertainty %	Share L*U %	Cum. Share L*U %
1A2	Manufacturing Industries and Construction, liquids	CO2	8675	4,6	23,7	1,1	7,4	7
1A1b	Petroleum Refining: liquids	CO2	7163	3,8	26,2	1,0	6,8	14
4C	Grassland	CO2	2900	1,5	51,3	0,8	5,4	20
3Db	Indirect emissions from managed soils	N2O	580	0,3	212,3	0,7	4,4	24
3B5	Indirect emissions	N2O	241	0,1	504,3	0,6	4,4	28
3Da	Direct emissions from agricultural soils	N2O	4241	2,2	27,0	0,6	4,1	33
1A1a	Public Electricity and Heat Production: solids	CO2	19349	10,2	5,7	0,6	4,0	37
1A4b	Residential gaseous	CO2	15241	8,1	6,4	0,5	3,5	40
1A2	Manufacturing Industries and Construction, solids	CO2	4595	2,4	21,1	0,5	3,5	44
1A4c	Agriculture/Forestry/Fisheries: gaseous	CO2	7444	3,9	12,9	0,5	3,5	47
1A4a	Commercial/Institutional: gaseous	CO2	6781	3,6	14,0	0,5	3,4	51
3A1	Mature dairy cattle	CH4	5338	2,8	15,2	0,4	2,9	53
2B1	Ammonia production	CO2	2349	1,2	27,4	0,3	2,3	56
3B1	Mature dairy cattle	CH4	1538	0,8	38,3	0,3	2,1	58
5A	Solid waste disposal	CH4	2370	1,3	23,7	0,3	2,0	60
1A4c	Agriculture/Forestry/Fisheries: all fuels	CH4	1099	0,6	49,7	0,3	2,0	62
1A1c	Manufacture of Solid Fuels: solids	CO2	1044	0,6	52,3	0,3	2,0	64
2F1	Refrigeration and airconditioning	HFC	1261	0,7	41,2	0,3	1,9	66
4B	Cropland	CO2	1574	0,8	32,4	0,3	1,8	68
1A3b	Road transportation: diesel oil	CO2	16487	8,7	3,0	0,3	1,8	69
3B3	Swine	CH4	1751	0,9	25,2	0,2	1,6	71
4E	Settlements	CO2	1479	0,8	29,8	0,2	1,6	73
2A4d	Other	CO2	656	0,3	65,5	0,2	1,6	74
1A3b	Road transportation: gasoline	CO2	12610	6,7	3,2	0,2	1,5	76
2B8	Petrochemical and carbon black production	CO2	554	0,3	71,3	0,2	1,4	77
3B1	Mature dairy cattle	N2O	192	0,1	198,2	0,2	1,4	78
1A2	Manufacturing Industries and Construction, gaseous	CO2	13523	7,1	2,2	0,2	1,1	79

IPCC Category		Gas	Gg CO_2 eq. 2019	Share %	Uncertainty estimate %	Level * uncertainty %	Share L*U%	Cum. Share L*U%
2B10	**Other**	**N2O**	**382**	**0,2**	**72,6**	**0,1**	**1,0**	**80**
1A1c	**Manufacture of Solid Fuels: gaseous**	**CO2**	**1423**	**0,8**	**19,0**	**0,1**	**1,0**	**81**
1A4	**Liquids excl. 1A4c**	**CO2**	**573**	**0,3**	**44,0**	**0,1**	**0,9**	**82**
5D	**Wastewater treatment and discharge**	**CH4**	**231**	**0,1**	**100,9**	**0,1**	**0,8**	**83**
1A1a	**Public Electricity and Heat Production: other fuels: waste incineration**	**CO2**	**2723**	**1,4**	**8,0**	**0,1**	**0,8**	**84**
2D2	**Paraffin wax use**	**CO2**	**211**	**0,1**	**103,0**	**0,1**	**0,8**	**85**
2B8	**Chemical industry: Petrochemical and carbon black production**	**CH4**	**304**	**0,2**	**71,5**	**0,1**	**0,8**	**86**
2B4	**Caprolactam production**	**N2O**	**675**	**0,4**	**30,4**	**0,1**	**0,7**	**86**
3A1	**Young cattle**	**CH4**	**1760**	**0,9**	**11,1**	**0,1**	**0,7**	**87**
3B1	**Growing cattle**	**N2O**	**147**	**0,1**	**130,7**	**0,1**	**0,7**	**88**
3A3	**Swine**	**CH4**	**458**	**0,2**	**40,6**	**0,1**	**0,7**	**88**
1A4b	**Residential: all fuels**	**CH4**	**336**	**0,2**	**52,1**	**0,1**	**0,6**	**89**
4A	**Forest Land**	**CO2**	**1845**	**1,0**	**8,6**	**0,1**	**0,6**	**90**
1A1	Energy Industries: all fuels	N2O	326	0,2	48,1	0,1	0,6	90
1A1a	Public Electricity and Heat Production: liquids	CO2	604	0,3	24,8	0,1	0,5	91
1A4c	Agriculture/Forestry/Fisheries: liquids	CO2	1728	0,9	8,4	0,1	0,5	91
1A1a	Public Electricity and Heat Production: gaseous	CO2	21874	11,6	0,7	0,1	0,5	92
2A2	Lime production	CO2	181	0,1	75,1	0,1	0,5	92
3A4	Other	CH4	459	0,2	28,9	0,1	0,5	93
1A3b	Road transportation	N2O	248	0,1	49,5	0,1	0,4	93
1B2c	Venting and flaring	CH4	196	0,1	61,9	0,1	0,4	94
6	Indirect CO2	CO2	431	0,2	27,1	0,1	0,4	94
3B4	Other livestock	N2O	100	0,1	115,4	0,1	0,4	94
3B3	Swine	N2O	100	0,1	100,9	0,1	0,4	95
2F6	Other	HFC	175	0,1	54,1	0,1	0,3	95
2A4a	Ceramics	CO2	125	0,1	71,5	0,0	0,3	95
1B2b	Natural gas	CH4	243	0,1	33,0	0,0	0,3	96
3B1	Growing cattle	CH4	418	0,2	18,8	0,0	0,3	96
2D1	Lubricant use	CO2	93	0,0	72,0	0,0	0,2	96
5B	Biological treatment of solid waste: composting	CH4	114	0,1	58,1	0,0	0,2	97

IPCC Category		Gas	Gg CO_2 eq. 2019	Share %	Uncertainty estimate %	Level * uncertainty %	Share L*U %	Cum. Share L*U %
4F	Other Land	CO2	175	0,1	35,3	0,0	0,2	97
2A4b	Other uses of soda ash	CO2	116	0,1	49,5	0,0	0,2	97
5B	Biological treatment of solid waste: composting	N2O	91	0,0	62,3	0,0	0,2	97
1A3d	Domestic navigation	CO2	916	0,5	5,7	0,0	0,2	97
1B2	Fugitive emissions from oil and gas operations	CO2	989	0,5	5,2	0,0	0,2	98
1A4	Other Sectors: all fuels	N2O	51	0,0	92,2	0,0	0,2	98
2B	Fluorochemical production	HFC	381	0,2	12,2	0,0	0,2	98
1A1	Energy Industries: all fuels	CH4	122	0,1	35,2	0,0	0,2	98
2B10	Other	CO2	1544	0,8	2,5	0,0	0,1	98
2G2	SF6 use	SF6	111	0,1	33,3	0,0	0,1	98
2A3	Glass production	CO2	69	0,0	50,1	0,0	0,1	98
1A3b	Road transportation	CH4	64	0,0	50,2	0,0	0,1	99
3B4	Poultry	CH4	73	0,0	40,7	0,0	0,1	99
3A1	Other mature cattle	CH4	121	0,1	20,7	0,0	0,1	99
5D	Wastewater treatment and discharge	N2O	75	0,0	32,9	0,0	0,1	99
2B2	Nitric acid production	N2O	297	0,2	7,9	0,0	0,1	99
2G	Other product manufacture and use	CH4	46	0,0	50,0	0,0	0,1	99
1A1b	Petroleum Refining: gaseous	CO2	2860	1,5	0,7	0,0	0,1	99
1A2	Manufacturing Industries and Construction: all fuels	CH4	62	0,0	30,9	0,0	0,1	99
1A3b	Road transportation: LPG	CO2	281	0,1	6,5	0,0	0,1	99
1A4a	Commercial/Institutional: all fuels	CH4	39	0,0	39,1	0,0	0,1	99
4D	Wetlands	CO2	25	0,0	54,6	0,0	0,0	99
3B2, 3B4	Other	CH4	37	0,0	33,9	0,0	0,0	99
3H	Ureum use	CO2	45	0,0	26,6	0,0	0,0	99
1B2a	Oil	CH4	16	0,0	72,6	0,0	0,0	99
2C3	Aluminium production	PFC	27	0,0	42,7	0,0	0,0	99
2G	Other product manufacture and use	N2O	86	0,0	13,5	0,0	0,0	100
2E	Electronic Industry	PFC	44	0,0	25,3	0,0	0,0	100
1B1b	Solid fuel transformation	CO2	73	0,0	14,9	0,0	0,0	100
1A2	Manufacturing Industries and Construction: all fuels	N2O	43	0,0	24,3	0,0	0,0	100

IPCC Category		Gas	Gg CO_2 eq. 2019	Share %	Uncertainty estimate %	Level * uncertainty %	Share L*U %	Cum. Share L*U %
1A5	Military use: liquids	CO2	159	0,1	6,4	0,0	0,0	100
2B9	Fluorochemical production	PFC	46	0,0	19,8	0,0	0,0	100
3G	Liming	CO2	35	0,0	25,4	0,0	0,0	100
1A3b	Road transportation: gaseous	CO2	151	0,1	5,5	0,0	0,0	100
3B1	Other mature cattle	N2O	4	0,0	203,0	0,0	0,0	100
5C	Open burning of waste	CH4	2	0,0	333,4	0,0	0,0	100
1A4	Solids	CO2	13	0,0	49,1	0,0	0,0	100
5C	Open burning of waste	N2O	2	0,0	356,3	0,0	0,0	100
2D3	Other	CO2	21	0,0	26,8	0,0	0,0	100
3B2	Sheep	N2O	2	0,0	217,6	0,0	0,0	100
4G	Harvested wood products	CO2	111	0,1	3,7	0,0	0,0	100
1A3 excl 1A3b	Other	N2O	8	0,0	46,1	0,0	0,0	100
3B1	Other mature cattle	CH4	11	0,0	33,4	0,0	0,0	100
1A3a	Domestic aviation	CO2	32	0,0	10,2	0,0	0,0	100
1A3e	Other	CO2	85	0,0	2,5	0,0	0,0	100
1A3 excl 1A3b	Other	CH4	3	0,0	51,0	0,0	0,0	100
1A3c	Railways	CO2	66	0,0	2,4	0,0	0,0	100
1A5	Military use: liquids	N2O	3	0,0	50,1	0,0	0,0	100
2C1	Iron and steel production	CO2	18	0,0	5,9	0,0	0,0	100
2H	Other industrial	CO2	16	0,0	5,8	0,0	0,0	100
2A1	Cement production	CO2	6	0,0	9,9	0,0	0,0	100
1B1b	Solid fuel transformation	CH4	5	0,0	11,2	0,0	0,0	100
2G	Other product manufacture and use	CO2	1	0,0	54,5	0,0	0,0	100
2D2	Non-energy products from fuels and solvent use: Paraffin wax use	CH4	0	0,0	115,6	0,0	0,0	100
4B	Cropland	N2O	50	0,0	0,6	0,0	0,0	100
1A5	Military use: liquids	CH4	0	0,0	44,8	0,0	0,0	100
4H	Other	N2O	44	0,0	0,3	0,0	0,0	100
4C	Grassland	N2O	8	0,0	0,6	0,0	0,0	100

IPCC Category		Gas	Gg CO_2 eq. 2019	Share %	Uncertainty estimate %	Level * uncertainty %	Share L*U %	Cum. Share L*U %
4	LULUCF: CH4	CH4	0	0,0	0,2	0,0	0,0	100
2C3	Aluminium production	CO2	0	0,0	5,3	0,0	0,0	100
2B7	Soda ash production	CO2	0	0,0	0,1	0,0	0,0	100

Lines in bold represent the key sources.

With respect to Approach 2 level key sources, Public Electricity and Heat production, with the highest share in the national total, are 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:

- 1A2; Manufacturing Industries and Construction, liquids (CO_2)
- 1A1b Petroleum refining (liquids), CO_2;
- 4C Grassland CO_2.

The uncertainty in these emissions is estimated in the range of 25-55%, an order of magnitude higher than the 1% uncertainty for CO_2 from1A1a Public Electricity and Heat Production: gaseous

*Table A1.8: Source ranking using IPCC Approach 2 **trend** assessment for 2019 emissions compared to the base year, including LULUCF (Gg CO_2 eq.)*

IPCC Category		Gas	Gg CO_2 eq 1990	Gg CO_2 eq 2019	level assessment latest year %	trend assessment %	Uncertainty estimate %	Trend * uncertainty %	% Contr. to trend	Cumulative %
5A	Solid waste disposal	CH4	13679	2370	1,3	5,7	24	1,4	14,6	15
3Db	Indirect emissions from managed soils	N2O	1607	580	0,3	0,5	212	1,0	10,9	26
2C3	Aluminium production	PFC	2638	27	0,0	1,4	43	0,6	6,4	32
1B2c	Venting and flaring	CH4	1491	196	0,1	0,7	62	0,4	4,4	36
2F1	Refrigeration and airconditioning	HFC	0	1261	0,7	0,8	41	0,3	3,6	40
1A4c	Agriculture/Forestry/Fisheries:all fuels	CH4	73	1099	0,6	0,7	50	0,3	3,6	44
2B	Fluorochemical production	HFC	5606	381	0,2	2,7	12	0,3	3,6	47
4C	Grassland	CO2	4691	2900	1,5	0,6	51	0,3	3,4	51
3Da	Direct emissions from agricultural soils	N2O	7122	4241	2,2	1,0	27	0,3	3,0	54
3B5	Indirect emissions	N2O	390	241	0,1	0,1	504	0,3	2,7	56
2B2	Nitric acid production	N2O	6085	297	0,2	3,0	8	0,2	2,6	59
1A2	Manufacturing Industries and Construction, liquids	CO2	8777	8675	4,6	1,0	24	0,2	2,5	61
1A1b	Petroleum Refining: liquids	CO2	9968	7163	3,8	0,6	26	0,2	1,8	63
3B3	Swine	CH4	3369	1751	0,9	0,7	25	0,2	1,8	65
3B1	Mature dairy cattle	CH4	1083	1538	0,8	0,4	38	0,2	1,7	67
4E	Settlements	CO2	848	1479	0,8	0,5	30	0,2	1,6	68
2B8	Petrochemical and carbon black production	CO2	336	554	0,3	0,2	71	0,1	1,4	70
1A4c	Agriculture/Forestry/Fisheries:gaseous	CO2	7329	7444	3,9	0,9	13	0,1	1,3	71
1A4	Liquids excl. 1A4c	CO2	1215	573	0,3	0,3	44	0,1	1,3	72
1A1a	Public Electricity and Heat Production: other fuels: waste incineration	CO2	601	2723	1,4	1,4	8	0,1	1,2	74
1A2	Manufacturing Industries and Construction, solids	CO2	6623	4595	2,4	0,5	21	0,1	1,2	75
1A3b	Road transportation: diesel oil	CO2	13012	16487	8,7	3,8	3	0,1	1,2	76

IPCC Category		Gas	Gg CO_2 eq 1990	Gg CO_2 eq 2019	level assessment latest year %	trend assessment %	Uncertainty estimate %	Trend * uncertainty %	% Contr. to trend	Cumulative %
2A4d	**Other**	**CO2**	**481**	**656**	**0,3**	**0,2**	**65**	**0,1**	**1,2**	**77**
4B	**Cropland**	**CO2**	**2565**	**1574**	**0,8**	**0,3**	**32**	**0,1**	**1,2**	**78**
3A1	**Mature dairy cattle**	**CH4**	**5183**	**5338**	**2,8**	**0,7**	**15**	**0,1**	**1,2**	**80**
1A1c	**Manufacture of Solid Fuels: solids**	**CO2**	**916**	**1044**	**0,6**	**0,2**	**52**	**0,1**	**1,1**	**81**
2B10	**Other**	**N2O**	**244**	**382**	**0,2**	**0,1**	**73**	**0,1**	**0,9**	**82**
2D2	**Paraffin wax use**	**CO2**	**103**	**211**	**0,1**	**0,1**	**103**	**0,1**	**0,9**	**82**
1A3b	**Road transportation: gasoline**	**CO2**	**10799**	**12610**	**6,7**	**2,4**	**3**	**0,1**	**0,9**	**83**
1A3b	**Road transportation: LPG**	**CO2**	**2640**	**281**	**0,1**	**1,2**	**6**	**0,1**	**0,9**	**84**
3B4	**Poultry**	**CH4**	**432**	**73**	**0,0**	**0,2**	**41**	**0,1**	**0,8**	**85**
1A1a	**Public Electricity and Heat Production: solids**	**CO2**	**25862**	**19349**	**10,2**	**1,2**	**6**	**0,1**	**0,7**	**86**
1A1a	**Public Electricity and Heat Production: liquids**	**CO2**	**233**	**604**	**0,3**	**0,3**	**25**	**0,1**	**0,7**	**86**
1A1	**Energy Industries:all fuels**	**N2O**	**148**	**326**	**0,2**	**0,1**	**48**	**0,1**	**0,7**	**87**
2F6	**Other**	**HFC**	**0**	**175**	**0,1**	**0,1**	**54**	**0,1**	**0,7**	**88**
6	**Indirect CO2**	**CO2**	**917**	**431**	**0,2**	**0,2**	**27**	**0,1**	**0,6**	**88**
1A1c	**Manufacture of Solid Fuels:.gaseous**	**CO2**	**1184**	**1423**	**0,8**	**0,3**	**19**	**0,1**	**0,6**	**89**
1A3b	**Road transportation**	**N2O**	**98**	**248**	**0,1**	**0,1**	**49**	**0,1**	**0,6**	**90**
1A1a	Public Electricity and Heat Production: gaseous	CO2	13329	21874	11,6	7,1	1	0,0	0,5	90
3B1	Mature dairy cattle	N2O	190	192	0,1	0,0	198	0,0	0,5	91
1A4b	Residential gaseous	CO2	19894	15241	8,1	0,7	6	0,0	0,5	91
5B	Biological treatment of solid waste: composting	CH4	4	114	0,1	0,1	58	0,0	0,5	91
1A4a	Commercial/Institutional:gaseous	CO2	7758	6781	3,6	0,3	14	0,0	0,4	92
2B8	Chemical industry: Petrochemical and carbon black production	CH4	269	304	0,2	0,1	71	0,0	0,4	92
3A1	Young cattle	CH4	2802	1760	0,9	0,3	11	0,0	0,4	93
1A4	Solids	CO2	163	13	0,0	0,1	49	0,0	0,4	93

IPCC Category		Gas	Gg CO_2 eq 1990	Gg CO_2 eq 2019	level assessment latest year %	trend assessment %	Uncertainty estimate %	Trend * uncertainty %	% Contr. to trend	Cumulative %
3B4	Other livestock	N2O	62	100	0,1	0,0	115	0,0	0,4	94
4F	Other Land	CO2	22	175	0,1	0,1	35	0,0	0,4	94
5B	Biological treatment of solid waste: composting	N2O	7	91	0,0	0,1	62	0,0	0,4	94
1A3b	Road transportation	CH4	193	64	0,0	0,1	50	0,0	0,3	95
1A2	Manufacturing Industries and Construction, gaseous	CO2	19044	13523	7,1	1,3	2	0,0	0,3	95
2B1	Ammonia production	CO2	2695	2349	1,2	0,1	27	0,0	0,3	95
3B1	Growing cattle	N2O	145	147	0,1	0,0	131	0,0	0,3	95
2A2	Lime production	CO2	163	181	0,1	0,0	75	0,0	0,2	96
1B2b	Natural gas	CH4	421	243	0,1	0,1	33	0,0	0,2	96
2A1	Cement production	CO2	416	6	0,0	0,2	10	0,0	0,2	96
2A4b	Other uses of soda ash	CO2	69	116	0,1	0,0	49	0,0	0,2	96
3G	Liming	CO2	183	35	0,0	0,1	25	0,0	0,2	97
1A4c	Agriculture/Forestry/Fisheries: liquids	CO2	2507	1728	0,9	0,2	8	0,0	0,2	97
2A3	Glass production	CO2	142	69	0,0	0,0	50	0,0	0,2	97
1A1	Energy Industries:all fuels	CH4	69	122	0,1	0,0	35	0,0	0,2	97
5D	Wastewater treatment and discharge	CH4	309	231	0,1	0,0	101	0,0	0,2	97
4D	Wetlands	CO2	79	25	0,0	0,0	55	0,0	0,2	97
5D	Wastewater treatment and discharge	N2O	172	75	0,0	0,0	33	0,0	0,2	98
2B4	Caprolactam production	N2O	740	675	0,4	0,0	30	0,0	0,1	98
2G2	SF6 use	SF6	207	111	0,1	0,0	33	0,0	0,1	98
1B2	Fugitive emissions from oil and gas operations	CO2	775	989	0,5	0,2	5	0,0	0,1	98
2C3	Aluminium production	CO2	408	0	0,0	0,2	5	0,0	0,1	98
1A3d	Domestic navigation	CO2	743	916	0,5	0,2	6	0,0	0,1	98
1A4b	Residential:all fuels	CH4	450	336	0,2	0,0	52	0,0	0,1	98
2B10	Other	CO2	1038	1544	0,8	0,4	2	0,0	0,1	98
2D1	Lubricant use	CO2	85	93	0,0	0,0	72	0,0	0,1	99

IPCC Category		Gas	Gg CO_2 eq 1990	Gg CO_2 eq 2019	level assessment latest year %	trend assessment %	Uncertainty estimate %	Trend * uncertainty %	% Contr. to trend	Cumulative %
3B3	Swine	N2O	140	100	0,1	0,0	101	0,0	0,1	99
4A	Forest Land	CO2	2048	1845	1,0	0,1	9	0,0	0,1	99
1A1b	Petroleum Refining: gaseous	CO2	1042	2860	1,5	1,3	1	0,0	0,1	99
2G	Other product manufacture and use	N2O	225	86	0,0	0,1	13	0,0	0,1	99
3A3	Swine	CH4	522	458	0,2	0,0	41	0,0	0,1	99
3H	Ureum use	CO2	2	45	0,0	0,0	27	0,0	0,1	99
3A4	Other	CH4	514	459	0,2	0,0	29	0,0	0,1	99
3A1	Other mature cattle	CH4	210	121	0,1	0,0	21	0,0	0,1	99
1A4	Other Sectors:all fuels	N2O	50	51	0,0	0,0	92	0,0	0,1	99
2B9	Fluorochemical production	PFC	0	46	0,0	0,0	20	0,0	0,1	99
3B2	Sheep	N2O	7	2	0,0	0,0	218	0,0	0,1	99
1A3b	Road transportation:gaseous	CO2	0	151	0,1	0,1	6	0,0	0,1	100
2A4a	Ceramics	CO2	140	125	0,1	0,0	72	0,0	0,0	100
1A5	Military use:liquids	CO2	314	159	0,1	0,1	6	0,0	0,0	100
2E	Electronic Industry	PFC	25	44	0,0	0,0	25	0,0	0,0	100
2D3	Other	CO2	0	21	0,0	0,0	27	0,0	0,0	100
1A3e	Other	CO2	342	85	0,0	0,1	2	0,0	0,0	100
1A3a	Domestic aviation	CO2	85	32	0,0	0,0	10	0,0	0,0	100
3B1	Other mature cattle	N2O	7	4	0,0	0,0	203	0,0	0,0	100
1A2	Manufacturing Industries and Construction:all fuels	N2O	36	43	0,0	0,0	24	0,0	0,0	100
3B2, 3B4	Other	CH4	34	37	0,0	0,0	34	0,0	0,0	100
1B1b	Solid fuel transformation	CO2	110	73	0,0	0,0	15	0,0	0,0	100
3B1	Other mature cattle	CH4	22	11	0,0	0,0	33	0,0	0,0	100
2H	Other industrial	CO2	72	16	0,0	0,0	6	0,0	0,0	100
5C	Open burning of waste	CH4	4	2	0,0	0,0	333	0,0	0,0	100
2G	Other product manufacture and use	CH4	50	46	0,0	0,0	50	0,0	0,0	100
1A2	Manufacturing Industries and	CH4	67	62	0,0	0,0	31	0,0	0,0	100

IPCC Category		Gas	Gg CO_2 eq 1990	Gg CO_2 eq 2019	level assessment latest year %	trend assessment %	Uncertainty estimate %	Trend * uncertainty %	% Contr. to trend	Cumulative %
	Construction:all fuels									
3B1	Growing cattle	CH4	503	418	0,2	0,0	19	0,0	0,0	100
2C1	Iron and steel production	CO2	44	18	0,0	0,0	6	0,0	0,0	100
1A5	Military use:liquids	N2O	6	3	0,0	0,0	50	0,0	0,0	100
1A3 exl 1A3b	Other	N2O	7	8	0,0	0,0	46	0,0	0,0	100
5C	Open burning of waste	N2O	2	2	0,0	0,0	356	0,0	0,0	100
1A4a	Commercial/Institutional:all fuels	CH4	45	39	0,0	0,0	39	0,0	0,0	100
4G	Harvested wood products	CO2	163	111	0,1	0,0	4	0,0	0,0	100
1A3 exl 1A3b	Other	CH4	3	3	0,0	0,0	51	0,0	0,0	100
1B1b	Solid fuel transformation	CH4	11	5	0,0	0,0	11	0,0	0,0	100
1B2a	Oil	CH4	20	16	0,0	0,0	73	0,0	0,0	100
2G	Other product manufacture and use	CO2	0	1	0,0	0,0	55	0,0	0,0	100
2D2	Non-energy products from fuels and solvent use: Paraffin wax use	CH4	0	0	0,0	0,0	116	0,0	0,0	100
1A3c	Railways	CO2	91	66	0,0	0,0	2	0,0	0,0	100
1A5	Military use:liquids	CH4	1	0	0,0	0,0	45	0,0	0,0	100
4H	Other	N2O	9	44	0,0	0,0	0	0,0	0,0	100
2B7	Soda ash production	CO2	64	0	0,0	0,0	0	0,0	0,0	100
4C	Grassland	N2O	6	8	0,0	0,0	1	0,0	0,0	100
4B	Cropland	N2O	64	50	0,0	0,0	1	0,0	0,0	100
4	LULUCF: CH4	CH4	0	0	0,0	0,0	0	0,0	0,0	100

Lines in bold represent the key sources.

Annex 2 Assessment of uncertainty

2.1 Description of methodology used for estimating uncertainty

In this NIR an Approach 2 uncertainty assessment (based on Monte Carlo analysis has been performed to estimate the uncertainty in total national GHG emissions and emissions trends. Results of this analysis for both level and trend are presented in table A2.1.

A Monte Carlo analysis is programmed to randomly sample all variables (considering the distribution of the uncertainty of each variable) and to calculate the total national emissions In this case, emission calculation is based on activity data and emission factors with their uncertainties. The Monte Carlo analysis performs 10.000 random calculations of the emissions. The uncertainty range is calculated as 1.96 times the standard deviation of these 10.000 random calculations.
Correlations between activity data are programmed when the sum of the activity data is known more accurately than the activity data of the separate emission sources. For example, the total gasoline consumption is less uncertain than the gasoline consumption per vehicle type.
Correlations between emission factors are programmed when the uncertainty of the emission factor is only known for a group of emission sources. For example, the emission calculation for NOx emissions from natural gas combustion in industry is calculated for several industrial sectors separately, while the expert can only make an expert judgement of the emission factor for natural gas combustion in the entire sector (and not for each sector separately).

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 2 level and trend uncertainty estimates related to 2019 emissions (trend: 1990 – 2019)

	Uncertainty in emissions level	**Uncertainty in emissions trend**
CO_2	±2%	±1% of 5% decrease
CH_4	±8%	±5% of 46% decrease
N_2O	±27%	±6% of 55% decrease
F-gases	±26%	±9% of 76% decrease
Total	**±3%**	**±2% of 18% decrease**

Details of the Approach 2 calculation can be found in Table A2.3. It should be stressed that most uncertainty estimates in Table A2.3 are ultimately based on collective expert judgement and are therefore themselves rather uncertain (usually in the order of 50%). Nevertheless, these estimates help to identify the most important uncertain sources. For this purpose, a reasonable order-of-magnitude estimate of the uncertainty in activity data and in EFs is usually sufficient. Uncertainty estimates are a means of identifying and prioritizing inventory improvement activities, rather than an objective in themselves.

Part of the uncertainty is due to an inherent lack of knowledge concerning the sources. Another part, however, can be attributed to elements of the inventory whose uncertainty could be reduced over time by dedicated research initiated by either the NIE or other researchers. When this type of uncertainty is in sources that are expected to be significant for emission reduction policies, the effectiveness of these policies could be greatly reduced if the unreduced emissions turn out to be much lower than originally estimated.

Table A2.2 ranks the ten sources contributing most to the *trend* uncertainty in the national total emisssions excluding LULUCF in 2019 (based on the Approach 2).

Table A2.2: Ten sources contributing most to trend uncertainty in the national total in 2019 emissions (based on the Approach 2 Monte Carlo uncertainty assessment)

IPCC cat.	Category	Gas	Uncertainty introduced into the trend in total national emissions (%)
5A	Solid waste disposal	CH4	14,6
3Db	Indirect emissions from managed soils	N2O	10,9
2C3	Aluminium production	PFC	6,4
1B2c	Venting and flaring	CH4	4,4
2F1	Refrigeration and airconditioning	HFC	3,6
1A4c	Agriculture/Forestry/Fisheries:all fuels	CH4	3,6
2B	Fluorochemical production	HFC	3,6
4C	Grassland	CO2	3,4
3Da	Direct emissions from agricultural soils	N2O	3,0
3B5	Indirect emissions	CH4	2,7

Table A2.3 is ranked in the order of categories contributing most to the variance in 2019 (based on the Approach 2 Monte Carlo uncertainty assessment). Note that 5 of the categories included in table A2.2, are also among the 10 sources contributing most to the total annual uncertainty in 2019.

Table A2.3: Approach 2 level and trend uncertainty assessment 1990–2019 with the categories of the IPCC potential key source list (without adjustment for correlation sources), excluding LULUCF. Ranked in order of their contribution to the variance in 2019.

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	CO2	8777	8675	1,0%	1,0%	25,0%	25,0%	23,7%	23,7%	0,00013	-1	2,6
1A1b	Petroleum Refining: liquids	CO2	9968	7163	5,0%	5,0%	25,0%	25,0%	26,2%	26,2%	0,00011	-28	2,0
3Db	Indirect emissions from managed soils	N2O	1607	580	50,0%	50,0%	200,0%	200,0%	212,3%	212,3%	0,00005	-64	11,8
3B5	Indirect emissions	N2O	390	241	10,0%	10,0%	100,0%	100,0%	504,3%	504,3%	0,00005	-38	3,0
3Da	Direct emissions from agricultural soils	N2O	7122	4241	10,0%	10,0%	60,0%	60,0%	27,0%	27,0%	0,00004	-40	3,2
1A1a	Public Electricity and Heat Production: solids	CO2	25862	19349	1,0%	1,0%	3,0%	3,0%	5,7%	5,7%	0,00004	-25	0,8
1A4b	Residential gaseous	CO2	19894	15241	5,0%	5,0%	0,3%	0,3%	6,4%	6,4%	0,00003	-23	0,5
1A2	Manufacturing Industries and Construction, solids	CO2	6623	4595	2,0%	2,0%	10,0%	10,0%	21,1%	21,1%	0,00003	-31	1,3
1A4c	Agriculture/Forestry/Fisheries:gaseous	CO2	7329	7444	10,0%	10,0%	0,3%	0,3%	12,9%	12,9%	0,00003	2	1,4
1A4a	Commercial/Institutional:gaseous	CO2	7758	6781	10,0%	10,0%	0,3%	0,3%	14,0%	14,0%	0,00003	-13	0,4
3A1	Mature dairy cattle	CH4	5183	5338	5,0%	5,0%	15,0%	15,0%	15,2%	15,2%	0,00002	3	1,2
2B1	Ammonia production	CO2	2695	2349	2,0%	2,0%	10,0%	10,0%	27,4%	27,4%	0,00001	-13	0,3
3B1	Mature dairy cattle	CH4	1083	1538	2,0%	2,0%	38,0%	38,0%	38,3%	38,3%	0,00001	42	1,9
5A	Solid waste disposal	CH4	13679	2370	0,4%	0,4%	24,0%	24,0%	23,7%	23,7%	0,00001	-83	15,7
1A4c	Agriculture/Forestry/Fisheries:all fuels	CH4	73	1099	9,8%	9,8%	48,8%	48,8%	49,7%	49,7%	0,00001	1.400	3,9
1A1c	Manufacture of Solid Fuels: solids	CO2	916	1044	2,0%	2,0%	10,7%	10,7%	52,3%	52,3%	0,00001	14	1,1

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 %
2F1	Refrigeration and airconditioning	HFC	0	1261	20,0%	20,0%	50,0%	50,0%	41,2%	41,2%	0,00001	-	3,9
1A3b	Road transportation: diesel oil	CO2	13012	16487	2,0%	2,0%	2,0%	2,0%	3,0%	3,0%	0,00001	27	1,3
3B3	Swine	CH4	3369	1751	10,0%	10,0%	100,0%	100,0%	25,2%	25,2%	0,00001	-48	1,9
2A4d	Other	CO2	481	656	50,0%	50,0%	5,0%	5,0%	65,5%	65,5%	0,00001	36	1,3
1A3b	Road transportation: gasoline	CO2	10799	12610	2,0%	2,0%	2,0%	2,0%	3,2%	3,2%	0,00001	17	0,9
2B8	Petrochemical and carbon black production	CO2	336	554	50,0%	50,0%	50,0%	50,0%	71,3%	71,3%	0,00000	65	1,5
3B1	Mature dairy cattle	N2O	190	192	2,0%	2,0%	178,0%	178,0%	198,2%	198,2%	0,00000	1	0,5
1A2	Manufacturing Industries and Construction, gaseous	CO2	19044	13523	2,0%	2,0%	0,3%	0,3%	2,2%	2,2%	0,00000	-29	0,3
2B10	Other	N2O	244	382	20,0%	20,0%	23,0%	23,0%	72,6%	72,6%	0,00000	56	1,0
1A1c	Manufacture of Solid Fuels:.gaseous	CO2	1184	1423	20,0%	20,0%	5,0%	5,0%	19,0%	19,0%	0,00000	20	0,6
1A4	Liquids excl. 1A4c	CO2	1215	573	20,0%	20,0%	2,0%	2,0%	44,0%	44,0%	0,00000	-53	1,4
5D	Wastewater treatment and discharge	CH4	309	231	20,0%	20,0%	32,0%	32,0%	100,9%	100,9%	0,00000	-25	0,2
1A1a	Public Electricity and Heat Production: other fuels: waste incineration	CO2	601	2723	3,2%	3,2%	5,7%	5,7%	8,0%	8,0%	0,00000	353	1,3
2D2	Paraffin wax use	CO2	103	211	100,0%	100,0%	20,0%	20,0%	103,0%	103,0%	0,00000	106	1,0
2B8	Chemical industry: Petrochemical and carbon black production	CH4	269	304	50,0%	50,0%	50,0%	50,0%	71,5%	71,5%	0,00000	13	0,4
2B4	Caprolactam production	N2O	740	675	20,0%	20,0%	23,0%	23,0%	30,4%	30,4%	0,00000	-9	0,2
3A1	Young cattle	CH4	2802	1760	5,0%	5,0%	20,0%	20,0%	11,1%	11,1%	0,00000	-37	0,4
3B1	Growing cattle	N2O	145	147	1,0%	1,0%	130,0%	130,0%	130,7%	130,7%	0,00000	2	0,3
3A3	Swine	CH4	522	458	5,0%	5,0%	50,0%	50,0%	40,6%	40,6%	0,00000	-12	0,1

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 %
1A4b	Residential:all fuels	CH4	450	336	38,4%	38,4%	39,9%	39,9%	52,1%	52,1%	0,00000	-25	0,1
1A1	Energy Industries:all fuels	N2O	148	326	2,5%	2,5%	18,4%	18,4%	48,1%	48,1%	0,00000	120	0,7
1A1a	Public Electricity and Heat Production: liquids	CO2	233	604	0,5%	0,5%	20,0%	20,0%	24,8%	24,8%	0,00000	159	0,8
1A4c	Agriculture/Forestry/Fisheries: liquids	CO2	2507	1728	10,0%	10,0%	0,3%	0,3%	8,4%	8,4%	0,00000	-31	0,2
1A1a	Public Electricity and Heat Production: gaseous	CO2	13329	21874	0,5%	0,5%	0,3%	0,3%	0,7%	0,7%	0,00000	64	0,5
2A2	Lime production	CO2	163	181	5,0%	5,0%	10,0%	10,0%	75,1%	75,1%	0,00000	11	0,3
3A4	Other	CH4	514	459	5,0%	5,0%	30,0%	30,0%	28,9%	28,9%	0,00000	-11	0,1
1A3b	Road transportation	N2O	98	248	2,0%	2,0%	70,0%	70,0%	49,5%	49,5%	0,00000	153	0,6
1B2c	Venting and flaring	CH4	1491	196	2,0%	2,0%	25,0%	25,0%	61,9%	61,9%	0,00000	-87	4,8
6	Indirect CO2	CO2	917	431	19,0%	19,0%	19,0%	19,0%	27,1%	27,1%	0,00000	-53	0,7
3B4	Other livestock	N2O	62	100	10,0%	10,0%	100,0%	100,0%	115,4%	115,4%	0,00000	63	0,4
3B3	Swine	N2O	140	100	10,0%	10,0%	100,0%	100,0%	100,9%	100,9%	0,00000	-29	0,1
2F6	Other	HFC	0	175	20,0%	20,0%	50,0%	50,0%	54,1%	54,1%	0,00000	-	0,7
2A4a	Ceramics	CO2	140	125	50,0%	50,0%	5,0%	5,0%	71,5%	71,5%	0,00000	-11	0,1
1B2b	Natural gas	CH4	421	243	2,0%	2,0%	50,0%	50,0%	33,0%	33,0%	0,00000	-42	0,3
3B1	Growing cattle	CH4	503	418	1,0%	1,0%	20,0%	20,0%	18,8%	18,8%	0,00000	-17	0,0
2D1	Lubricant use	CO2	85	93	50,0%	50,0%	29,2%	29,2%	72,0%	72,0%	0,00000	9	0,1
5B	Biological treatment of solid waste: composting	CH4	4	114	0,0%	0,0%	62,7%	62,7%	58,1%	58,1%	0,00000	2.577	0,5
2A4b	Other uses of soda ash	CO2	69	116	50,0%	50,0%	5,0%	5,0%	49,5%	49,5%	0,00000	69	0,2
5B	Biological treatment of solid waste: composting	N2O	7	91	0,0%	0,0%	49,4%	49,4%	62,3%	62,3%	0,00000	1.296	0,4
1A3d	Domestic navigation	CO2	743	916	5,0%	5,0%	2,0%	2,0%	5,7%	5,7%	0,00000	23	0,1
1B2	Fugitive emissions from oil and gas operations	CO2	775	989	50,0%	50,0%	2,0%	2,0%	5,2%	5,2%	0,00000	28	0,1

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 %
1A4	Other Sectors:all fuels	N2O	50	51	17,8%	17,8%	43,1%	43,1%	92,2%	92,2%	0,00000	2	0,1
2B	Fluorochemical production	HFC	5606	381	10,0%	10,0%	20,0%	20,0%	12,2%	12,2%	0,00000	-93	3,8
1A1	Energy Industries:all fuels	CH4	69	122	2,5%	2,5%	18,4%	18,4%	35,2%	35,2%	0,00000	77	0,2
2B10	Other	CO2	1038	1544	1,0%	1,0%	30,0%	30,0%	2,5%	2,5%	0,00000	49	0,1
2G2	SF6 use	SF6	207	111	30,0%	30,0%	15,0%	15,0%	33,3%	33,3%	0,00000	-46	0,1
2A3	Glass production	CO2	142	69	25,0%	25,0%	5,0%	5,0%	50,1%	50,1%	0,00000	-51	0,2
1A3b	Road transportation	CH4	193	64	2,0%	2,0%	50,0%	50,0%	50,2%	50,2%	0,00000	-67	0,4
3B4	Poultry	CH4	432	73	10,0%	10,0%	100,0%	100,0%	40,7%	40,7%	0,00000	-83	0,9
3A1	Other mature cattle	CH4	210	121	5,0%	5,0%	20,0%	20,0%	20,7%	20,7%	0,00000	-42	0,1
5D	Wastewater treatment and discharge	N2O	172	75	20,0%	20,0%	100,0%	100,0%	32,9%	32,9%	0,00000	-56	0,2
2B2	Nitric acid production	N2O	6085	297	5,0%	5,0%	6,0%	6,0%	7,9%	7,9%	0,00000	-95	2,8
2G	Other product manufacture and use	CH4	50	46	9,9%	9,9%	49,5%	49,5%	50,0%	50,0%	0,00000	-9	0,0
1A1b	Petroleum Refining: gaseous	CO2	1042	2860	0,5%	0,5%	0,3%	0,3%	0,7%	0,7%	0,00000	174	0,1
1A2	Manufacturing Industries and Construction:all fuels	CH4	67	62	2,0%	2,0%	15,8%	15,8%	30,9%	30,9%	0,00000	-7	0,0
1A3b	Road transportation: LPG	CO2	2640	281	5,0%	5,0%	2,0%	2,0%	6,5%	6,5%	0,00000	-89	0,9
1A4a	Commercial/Institutional:all fuels	CH4	45	39	10,4%	10,4%	47,6%	47,6%	39,1%	39,1%	0,00000	-13	0,0
3B2, 3B4	Other	CH4	34	37	10,0%	10,0%	100,0%	100,0%	33,9%	33,9%	0,00000	10	0,0
3H	Ureum use	CO2	2	45	26,6%	26,6%	1,0%	1,0%	26,6%	26,6%	0,00000	2.882	0,1
1B2a	Oil	CH4	20	16	20,0%	20,0%	50,0%	50,0%	72,6%	72,6%	0,00000	-20	0,0
2C3	Aluminium production	PFC	2638	27	2,0%	2,0%	20,0%	20,0%	42,7%	42,7%	0,00000	-99	6,8
2G	Other product manufacture and use	N2O	225	86	50,0%	50,0%	50,0%	50,0%	13,5%	13,5%	0,00000	-62	0,1

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 %
2E	Electronic Industry	PFC	25	44	5,0%	5,0%	25,0%	25,0%	25,3%	25,3%	0,00000	73	0,0
1B1b	Solid fuel transformation	CO2	110	73	2,0%	2,0%	15,0%	15,0%	14,9%	14,9%	0,00000	-34	0,0
1A2	Manufacturing Industries and Construction:all fuels	N2O	36	43	3,3%	3,3%	58,6%	58,6%	24,3%	24,3%	0,00000	20	0,0
1A5	Military use:liquids	CO2	314	159	20,0%	20,0%	2,0%	2,0%	6,4%	6,4%	0,00000	-49	0,0
2B9	Fluorochemical production	PFC	0	46	10,0%	10,0%	20,0%	20,0%	19,8%	19,8%	0,00000		0,1
3G	Liming	CO2	183	35	10,0%	10,0%	100,0%	100,0%	25,4%	25,4%	0,00000	-81	0,2
1A3b	Road transportation:gaseous	CO2	0	151	5,0%	5,0%	2,0%	2,0%	5,5%	5,5%	0,00000		0,1
3B1	Other mature cattle	N2O	7	4	2,0%	2,0%	192,0%	192,0%	203,0%	203,0%	0,00000	-43	0,0
5C	Open burning of waste	CH4	4	2	100,0%	100,0%	300,0%	300,0%	333,4%	333,4%	0,00000	-37	0,0
1A4	Solids	CO2	163	13	50,0%	50,0%	10,0%	10,0%	49,1%	49,1%	0,00000	-92	0,4
5C	Open burning of waste	N2O	2	2	100,0%	100,0%	300,0%	300,0%	356,3%	356,3%	0,00000	-29	0,0
2D3	Other	CO2	0	21	25,0%	25,0%	9,4%	9,4%	26,8%	26,8%	0,00000		0,0
3B2	Sheep	N2O	7	2	10,0%	10,0%	100,0%	100,0%	217,6%	217,6%	0,00000	-73	0,1
1A3 exl 1A3b	Other	N2O	7	8	2,0%	2,0%	70,0%	70,0%	46,1%	46,1%	0,00000	12	0,0
3B1	Other mature cattle	CH4	22	11	2,0%	2,0%	33,0%	33,0%	33,4%	33,4%	0,00000	-52	0,0
1A3a	Domestic aviation	CO2	85	32	30,0%	30,0%	4,0%	4,0%	10,2%	10,2%	0,00000	-63	0,0
1A3e	Other	CO2	342	85	0,5%	0,5%	0,3%	0,3%	2,5%	2,5%	0,00000	-75	0,0
1A3 exl 1A3b	Other	CH4	3	3	2,0%	2,0%	50,0%	50,0%	51,0%	51,0%	0,00000	30	0,0
1A3c	Railways	CO2	91	66	5,0%	5,0%	2,0%	2,0%	2,4%	2,4%	0,00000	-27	0,0
1A5	Military use:liquids	N2O	6	3	7,2%	7,2%	82,0%	82,0%	50,1%	50,1%	0,00000	-55	0,0
2C1	Iron and steel production	CO2	44	18	3,0%	3,0%	5,0%	5,0%	5,9%	5,9%	0,00000	-59	0,0
2H	Other industrial	CO2	72	16	2,8%	2,8%	5,0%	5,0%	5,8%	5,8%	0,00000	-77	0,0
2A1	Cement production	CO2	416	6	5,0%	5,0%	10,0%	10,0%	9,9%	9,9%	0,00000	-98	0,2
1B1b	Solid fuel transformation	CH4	11	5	2,0%	2,0%	15,0%	15,0%	11,2%	11,2%	0,00000	-56	0,0

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 %
2G	Other product manufacture and use	CO2	0	1	50,0%	50,0%	20,0%	20,0%	54,5%	54,5%	0,00000	225	0,0
2D2	Non-energy products from fuels and solvent use: Paraffin wax use	CH4	0	0	100,0%	100,0%	50,0%	50,0%	115,6%	115,6%	0,00000	106	0,0
1A5	Military use:liquids	CH4	1	0	7,6%	7,6%	59,9%	59,9%	44,8%	44,8%	0,00000	-56	0,0
2C3	Aluminium production	CO2	408	0	2,0%	2,0%	5,0%	5,0%	5,3%	5,3%	0,00000	-100	0,1
2B7	Soda ash production	CO2	64	0	0,0%	0,0%	5,0%	5,0%	0,1%	0,1%	0,00000	-100	0,0

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, the emissions per source category in 1990 combined with uncertainty insights per source category are added in a separate column.

Table A2.5 Uncertainties Greenhouse Gas emissions in 1990 (Approach 1)

Gas	activity	Emission level base year (Gg)	Uncertainty 1990 (%) 2000	Uncertainty 1990 (%) 2020(1)
CO_2	Fuel combustion	149.7	2	
	IPPU	11.7	25	
	(Land Use)	(-1.5)	(60)	
subtotal		**161.4**	**3**	**3**
CH_4	Energy	4.5	25	
	Agriculture	10.6	25	
	Waste	11.9	30	
subtotal		**27.0**	**17**	**21**
N_2O	Energy use	2.3	75	
	IPPU	9.8	35	
	Agriculture	6.9	75	
subtotal		**19.0**	**34**	**70**
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**	**4.3**

(1) uncertainty 1990 assessed with 2020 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 at more or less the same level. However, according to the 2020 methodology, uncertainties for N_2O are substantially higher than what we thought in 2000.

The uncertainties in 2019 are substantially lower as a result of:

(1) The inventory improvement programme over the years (especially effective for and focused on non-CO_2 gases);

(2) The change in relative contribution to the total emissions in 2019 compared with 1990. The share of non-CO_2 gases was substantially higher in 1990.

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 CO2: the national energy balance for the most recent inventory year

The national energy balance for 2019 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, 4 pages each

Energy Balance the Netherlands 2019, part 1-1

Energy balance sheet the Netherlands 2019	Anthracite	Coking coal	Steam coal	Lignite	Coke-oven cokes	BKB (Braunkohlenbriketts)	Patent fuel	Coal tar	Gas works gas	Coke oven gas	Blast furnace gas	Crude oil	Natural gas liquids	Additives	Other hydrocarbons	Residual gas	Lpg
Energy supply																	
Total Primary Energy Supply (TPES)	1.5	121.8	146.6	0.2	-1.5	0.9		-0.6				2430.9	222.7	33.6		13.5	56.8
Indigenous production												31.9	5.8	10.3		13.5	
Imports	1.5	123.1	150.2	0.2	3.0	0.9						4329.9	212.2	37.5			149.3
Exports					3.5			0.6				1901.0	6.3	17.4			94.9
Bunkers																	
Stock change	0.0	-1.3	-3.5	0.0	-1.0			0.0				-29.9	10.9	3.2			2.4
Energy consumption																	
Net energy consumption	1.5	121.8	146.6	0.2	-1.5	0.9		-0.6				2430.9	222.7	33.6		13.6	56.8
Energy transformation																	
Total energy transformation input		121.8	146.6		53.8					2.2	22.9	2430.9	161.7	33.5		23.8	48.9
Electricity and CHP transformation input			146.6							2.2	22.9					17.3	
Other transformation input		121.8			53.8							2430.9	161.7	33.5		6.5	48.9
Total energy transformation output					56.7			2.8		15.7	34.1					201.9	76.1
Electricity / CHP transformation output																	
Other transformation					56.7			2.8		15.7	34.1					201.9	76.1

Energy balance sheet the Netherlands 2019	Anthracite	Coking coal	Steam coal	Lignite	Coke-oven cokes	BKB (Braunkohlenbriketts)	Patent fuel	Coal tar	Gas works gas	Coke oven gas	Blast furnace gas	Crude oil	Natural gas liquids	Additives	Other hydrocarbons	Residual gas	Lpg
output																	
Total net energy transformation		121.8	146.6		-2.8			-2.8		-13.5	-11.2	2430.9	161.7	33.5		-178.2	-27.2
Net electricity / CHP transformation			146.6							2.2	22.9					17.3	
Net other transformation		121.8			-2.8			-2.8		-15.7	-34.1	2430.9	161.7	33.5		-195.4	-27.2
Energy sector own use																	
Total energy sector own use										6.2	1.5					87.3	1.6
Extraction of crude petroleum and gas																	0.0
Coke-oven plants										6.2	1.5						
Oil refineries																87.3	1.6
Electricity and gas supply																	
Distribution losses																	
Distribution losses																	
Final consumption																	
Total final consumption	1.5			0.2	1.3	0.9				7.3	9.6		61.0	0.1		104.4	82.4
Total final energy consumption	1.3			0.2	1.1	0.9				7.3	9.6					104.4	12.8
Total industry	1.3			0.2	1.1	0.7				7.3	9.6					104.4	0.3
Iron and steel					0.0					7.3	9.6						0.1

Energy balance sheet the Netherlands 2019	Anthracite	Coking coal	Steam coal	Lignite	Coke-oven cokes	BKB (Braunkohlenbriketts)	Patent fuel	Coal tar	Gas works gas	Coke oven gas	Blast furnace gas	Crude oil	Natural gas liquids	Additives	Other hydrocarbons	Residual gas	Lpg
Chemical and petrochemical																104.4	0.0
Non-ferrous metals																	0.0
Non-metallic minerals	0.0			0.1	1.0												0.0
Transport equipment																	0.0
Machinery																	0.0
Mining and quarrying				0.1													0.0
Food and tobacco	1.3																0.0
Paper, pulp and printing																	0.0
Wood and wood products																	
Construction					0.0												
Textile and leather																	0.0
Non-specified	##	#N/A	#N/A	##	#N/A	##	##	##	##	#N/A	#N/A	#N/A	#N/A	#N/A	##	#N/A	#N/A
Total transport																	5.8
Domestic aviation																	
Road transport																	5.8
Rail transport																	
Pipeline transport																	
Domestic navigation																	
Non-specified																	
Total other sectors	0.0					0.1											6.7
Services, waste, water						0.1											4.4

Energy balance sheet the Netherlands 2019	Anthracite	Coking coal	Steam coal	Lignite	Coke-oven cokes	BKB (Braunkohlenbriketts)	Patent fuel	Coal tar	Gas works gas	Coke oven gas	Blast furnace gas	Crude oil	Natural gas liquids	Additives	Other hydrocarbons	Residual gas	Lpg
and repair																	
Households	0.0					0.0											1.0
Agriculture																	1.3
Fishing																	
Non-specified																	
Total non-energy use	0.2				0.2								61.0	0.1			69.6
Industry (excluding the energy sector)	0.2				0.2								61.0	0.1			69.6
Of which chemistry and pharmaceuticals													61.0	0.1			69.6
Transport																	
Other sectors																	
Statistical difference																	
Statistical differences																	

Energy Balance the Netherlands 2019, part 1-2

Energy balance sheet the Netherlands 2019	Naphtha	Motor gasoline	Gasoline type jet fuel	Aviation gasoline	Kerosene type jet fuel	Other kerosene	Heating and other gasoil	Fuel oil	White spirit and industrial spirit (SBP)	Lubricants	Bitumen	Paraffin waxes	Petroleum coke	Other petroleum products	Natural gas	Municipal waste; renewable fraction	Solid and liquid biomass	Biogas	Non-rene.municipal waste + residual heat
Energy supply																			
Total Primary Energy Supply (TPES)	479.7	-778.2		-2.2	-377.7	0.1	-622.4	-305.6	22.2	-13.5	-6.6	0.9	14.3	-62.6	1341.6	38.5	101.8	14.9	42.0
Indigenous production															1002.4	32.2	134.8	14.9	36.4
Imports	1009.5	305.4			149.8	17.3	550.4	480.1	84.1	64.7	14.6	5.8	58.9	667.0	1778.8	8.0	24.8		7.1
Exports	523.2	1089.2		2.1	352.8	17.7	1031.5	396.9	62.7	76.7	20.8	4.5	44.5	711.7	1430.0	1.7	58.0		1.5
Bunkers					166.3		109.0	385.2		3.8					2.5				
Stock change	-6.6	5.6		-0.1	-8.4	0.5	-32.3	-3.5	0.8	2.3	-0.4	-0.5	-0.1	-18.0	-7.1		0.1		
Energy consumption																			
Net energy consumption	479.7	-778.2		-2.2	-377.7	0.1	-611.3	-305.6	22.2	-13.5	-6.6	0.9	14.3	-62.6	1332.7	38.5	101.8	15.2	42.0
Energy transformation																			
Total energy transformation input	807.6	1.4			3.3	11.5	111.1	342.6	56.7	6.0	0.1	0.9		209.4	574.5	38.5	75.3	13.6	42.0
Electricity and CHP transformation input							0.8								548.8	38.5	37.7	9.1	34.1
Other	807.6	1.4			3.3	11.5	110.3	342.6	56.7	6.0	0.1	0.9		209.4	25.6		37.6	4.5	7.9

Energy balance sheet the Netherlands 2019	Naphtha	Motor gasoline	Gasoline type jet fuel	Aviation gasoline	Kerosene type jet fuel	Other kerosene	Heating and other gasoil	Fuel oil	White spirit and industrial spirit (SBP)	Lubricants	Bitumen	Paraffin waxes	Petroleum coke	Other petroleum products	Natural gas	Municipal waste; renewable fraction	Solid and liquid biomass	Biogas	Non-rene.municipal waste + residual heat
transformation input																			
Total energy transformation output	535.6	962.8		2.2	382.5	13.9	1031.8	648.6	35.8	26.0	10.6	3.1	15.6	281.7	5.9				
Electricity / CHP transformation output																			
Other transformation output	535.6	962.8		2.2	382.5	13.9	1031.8	648.6	35.8	26.0	10.6	3.1	15.6	281.7	5.9				
Total net energy transformation	272.0	-961.4		-2.2	-379.2	-2.4	-920.7	-305.9	20.9	-20.1	-10.5	-2.2	-15.6	-72.2	568.6	38.5	75.3	13.6	42.0
Net electricity / CHP transformation							0.8								548.8	38.5	37.7	9.1	34.1
Net other transformation	272.0	-961.4		-2.2	-379.2	-2.4	-921.5	-305.9	20.9	-20.1	-10.5	-2.2	-15.6	-72.2	19.7		37.6	4.5	7.9
Energy sector own use																			
Total energy sector own use							0.1				0.0		10.3		45.6				
Extraction of							0.0								21.8				

Energy balance sheet the Netherlands 2019	Naphtha	Motor gasoline	Gasoline type jet fuel	Aviation gasoline	Kerosene type jet fuel	Other kerosene	Heating and other gasoil	Fuel oil	White spirit and industrial spirit (SBP)	Lubricants	Bitumen	Paraffin waxes	Petroleum coke	Other petroleum products	Natural gas	Municipal waste; renewable fraction	Solid and liquid biomass	Biogas	Non-rene.municipal waste + residual heat
crude petroleum and gas																			
Coke-oven plants																			
Oil refineries							0.0				0.0		10.3		22.2				
Electricity and gas supply															1.6				
Distribution losses																			
Distribution losses																			
Final consumption																			
Total final consumption	207.7	183.2		0.0	1.5	2.5	309.3	0.3	1.3	6.5	3.9	3.1	19.6	9.6	718.5		26.5	1.6	
Total final energy consumption		183.2		0.0	1.5	0.3	309.1	0.3						1.8	608.2		26.5	1.6	
Total industry						0.0	21.0							1.8	176.9		3.6	1.1	
Iron and steel							0.1								10.5				
Chemical and petrochemical						0.0	0.0							1.8	69.0				

Energy balance sheet the Netherlands 2019	Naphtha	Motor gasoline	Gasoline type jet fuel	Aviation gasoline	Kerosene type jet fuel	Other kerosene	Heating and other gasoil	Fuel oil	White spirit and industrial spirit (SBP)	Lubricants	Bitumen	Paraffin waxes	Petroleum coke	Other petroleum products	Natural gas	Municipal waste; renewable fraction	Solid and liquid biomass	Biogas	Non-rene.municipal waste + residual heat
Non-ferrous metals							0.1								2.9				
Non-metallic minerals							0.3								16.7				
Transport equipment							0.2								2.0				
Machinery						0.0	0.0								10.4				
Mining and quarrying							0.1								2.1				
Food and tobacco							0.1								43.1				
Paper, pulp and printing							0.0								7.2				
Wood and wood products															0.4				
Construction							19.9								5.3		0.2		
Textile and leather															2.5				
Non-specified	#N/A	#N/A	##	###	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	###	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
Total transport		183.2		0.0	0.4		257.2								2.7				
Domestic				0.0	0.4														

Energy balance sheet the Netherlands 2019	Naphtha	Motor gasoline	Gasoline type jet fuel	Aviation gasoline	Kerosene type jet fuel	Other kerosene	Heating and other gasoil	Fuel oil	White spirit and industrial spirit (SBP)	Lubricants	Bitumen	Paraffin waxes	Petroleum coke	Other petroleum products	Natural gas	Municipal waste; renewable fraction	Solid and liquid biomass	Biogas	Non-rene.municipal waste + residual heat
aviation																			
Road transport		183.2					244.4								2.7				
Rail transport							1.0												
Pipeline transport																			
Domestic navigation							11.7												
Non-specified																			
Total other sectors					1.1	0.2	31.0	0.3							428.6		22.9	0.5	
Services, waste, water and repair							5.5								120.0		1.5	0.5	
Households						0.2	0.3								270.2		16.3		
Agriculture							17.4								38.3		5.1		
Fishing							6.1	0.3											
Non-specified					1.1		1.6								0.1				
Total non-energy use	207.7					2.2	0.2		1.3	6.5	3.9	3.1	19.6	7.8	110.3				

Energy balance sheet the Netherlands 2019	Naphtha	Motor gasoline	Gasoline type jet fuel	Aviation gasoline	Kerosene type jet fuel	Other kerosene	Heating and other gasoil	Fuel oil	White spirit and industrial spirit (SBP)	Lubricants	Bitumen	Paraffin waxes	Petroleum coke	Other petroleum products	Natural gas	Municipal waste; renewable fraction	Solid and liquid biomass	Biogas	Non-rene.municipal waste + residual heat
Industry (excluding the energy sector)	207.7					2.1	0.2		1.3	2.2	3.9	3.1	19.6	7.8	110.3				
Of which chemistry and pharmaceuticals	207.7					2.1	0.2		0.7	0.1		2.3	10.1	7.8	110.3				
Transport										2.8									
Other sectors						0.1				1.5									
Statistical difference																			
Statistical differences							-11.1								8.8			-0.3	

Annex 5 The Netherlands’ fuel list and standard CO2 emission factors. Version January 2021

Colophon

Project name	Annual update of fuel list for the Netherlands
Project number	113569/BL2021
Version number	January 2021
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 2021) 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 2021

Name (Dutch)	Name (English)	Unit	Net Calorific Value (MJ/unit)				CO_2 EF (kg/GJ)			
			2019	2020	2021	Ref [1)]	2019	2020	2021	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/ Products									
Motorbenzine	Gasoline	kg	43.0	43.0	43.0	CS	73.0	73.0	73.0	CS
Vliegtuigbenzine	Aviation gasoline	kg	44.0	44.0	44.0	CS	72.0	72.0	72.0	CS
Kerosine luchtvaart	Jet Kerosene	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	Gas/Diesel oil	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

Name (Dutch)	Name (English)	Unit	Net Calorific Value (MJ/unit)				CO_2 EF (kg/GJ)			
			2019	2020	2021	Ref [1)]	2019	2020	2021	Ref [1)]
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	67.0	67.0	67.0	CS
Chemisch restgas	Chemical Waste Gas	kg	45.2	45.2	45.2	CS	62.4	62.4	62.4	CS
Overige oliën	Other oil	kg	40.2	40.2	40.2	IPCC	73.3	73.3	73.3	IPCC
Paraffine	Paraffin Waxes	kg	42.7	42.7	42.7	CS	73.3	73.3	73.3	IPCC
Terpentine	White Spirit and SBP	kg	43.6	43.6	43.6	CS	73.3	73.3	73.3	IPCC
Overige aardolie producten	Other Petroleum Products	kg	42.7	42.7	42.7	CS	73.3	73.3	73.3	IPCC
	B. Solid Fossil, Primary Fuels									
Antraciet	Anthracite	kg	29.3	29.3	29.3	CS	98.3	98.3	98.3	IPCC
Cokeskolen	Coking Coal	kg	28.6	28.6	28.6	CS	94.0	94.0	94.0	CS
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 [2)]	Other Bituminous Coal [2)]	kg	25.0	25.0 [2)]	25.0 [2)]	CS	94.7	94.7	94.7	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

Name (Dutch)	Name (English)	Unit	Net Calorific Value (MJ/unit)				CO_2 EF (kg/GJ)			
			2019	2020	2021	Ref [1)]	2019	2020	2021	Ref [1)]
Cokesoven/ gascokes	Coke Oven/Gas Coke	kg	28.5	28.5	28.5	CS	106.8	106.8	106.8	CS
Cokesovengas	Coke Oven gas	MJ	1.0	1.0	1.0	CS	42.8	42.8	42.8	CS
Hoogovengas	Blast Furnace Gas	MJ	1.0	1.0	1.0	CS	247.4	247.4	247.4	CS
Oxystaalovengas	Oxy Gas	MJ	1.0	1.0	1.0	CS	191.9	191.9	191.9	CS
Fosforovengas	Fosfor Gas	Nm3	11.0	11.0	11.0	CS	143.9	143.9	143.9	CS
Steenkool bitumen	Coal tar	kg	41.9	41.9	41.9	CS	80.7	80.7	80.7	IPCC
	C. Gaseous Fossil Fuels									
Aardgas [3)]	Natural Gas (dry) [3)]	Nm3 ae	31.65	31.65	31.65	CS	56.6[3)]	56.4[3)]	56.4[3)]	CS
Compressed natural gas (CNG) [3)]	Compressed natural gas (CNG) [3)]	Nm3 ae	31.65	31.65	31.65	CS	56.6[3)]	56.4[3)]	56.4[3)]	CS
Liquified natural gas (LNG) [3)]	Liquified natural gas (LNG) [3)]	Nm3 ae	31.65	31.65	31.65	CS	56.6[3)]	56.4[3)]	56.4[3)]	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	Biogasoline	kg	27.0	27.0	27.0	CS	70.7	70.7	70.7	CS
Biodiesel	Biodiesels	kg	37.0	37.0	37.0	CS	76.8	76.8	76.8	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

Name (Dutch)	Name (English)	Unit	Net Calorific Value (MJ/unit)				CO_2 EF (kg/GJ)			
			2019	2020	2021	Ref [1)]	2019	2020	2021	Ref [1)]
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 [2) 5)]	Waste [2) 5)]	kg	9.8	9.8[2)]	9.8[2)]	CS	105.0	105.0[2)]	105.0 [2)]	CS

1) IPCC: default value from the 2006 IPCC Guidelines; CS: country specific
2) The calorific value and/or emission factor for these fuels are updated annually. Since the values for 2020 and 2021 are not yet known, they are set equal to the value for 2019. The figures in the above list may be modified in subsequent versions of the fuel list
3) 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.
4) 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
b. Under the Kyoto Protocol the emission factor for biomass is always zero.
c. 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.
5) The percentage biogenic in the heating value is 53%. The percentage biogenic in the emission factor is 64%.

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. 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
  - The country-specific calorific value and/or emission factor for some fuels (natural gas, other bituminous coal and waste) are updated annually. In the present document (version January 2021) these values have been updated.

Readers are referred to the TNO report (Dröge, 2014) 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 2021), the years in question are 2019, 2020 and 2021. The values in these columns are used for the following purposes:

1. **2019**: these values are used in 2021 for calculations concerning the calendar year 2019, which are required for international reports concerning greenhouse gas emissions pursuant to the UN Framework Convention on Climate Change (UNFCCC), the Kyoto Protocol and the European Regulation on the monitoring and reporting of greenhouse gas emissions (MMR, 525/2013/EU). The National Inventory Report for 2021 (NIR 2021) gives full details of greenhouse gas emissions in the Netherlands up to and including 2019. The fuel list forms an integral part of the NIR 2021.
2. **2020**: these values are used in 2021 for reports on energy consumption and CO_2 emission for the calendar year 2020 in the Electronic Environmental Annual Report (e-MJV), in the monitoring of MJA3/LTA3 (Long Term Agreement on energy efficiency for the period 2005-2020) and the monitoring of the MEE/LEE covenant (Long Term Agreement on Energy-Efficiency for ETS Companies).

3. **2021**: these values will be used in 2022 in emission reports for the calendar year 2021 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 2021.

Table A5.2 CH4 and N_2O emission factors

Name (Dutch)	**Name (English)**	**Unit**	**CH_4 EF**		**N_2O EF**		**Notes**
			2017	**Ref**	**2017**	**Ref**	
	A. Liquid Fossil, Primary Fuels						
Ruwe aardolie	Crude oil	g/GJ	1,4	Scheffer 1997	0,6	IPCC 2006	
Orimulsion	Orimulsion						1)
Aardgascondensaat	Natural Gas Liquids	g/GJ	1,9	Scheffer 1997	0,6	IPCC 2006	
Fossiele additieven	Fossil fuel additives	g/GJ	3,4	Scheffer 1997	0,6	IPCC 2006	2)
	Liquid Fossil, Secondary Fuels / Products						
Motorbenzine	Gasoline	g/GJ	3,4	Scheffer 1997	0,6	IPCC 2006	2)
Vliegtuigbenzine	Aviation gasoline	g/GJ	3,4	Scheffer 1997	0,6	IPCC 2006	2)
Kerosine luchtvaart	Jet Kerosene	g/GJ	3,4	Scheffer 1997	0,6	IPCC 2006	2)
Petroleum	Other kerosene	g/GJ	3,4	Scheffer 1997	0,6	IPCC 2006	
Leisteenolie	Shale oil						1)
Gas-/dieselolie	Gas/Diesel oil	g/GJ	3,4	Scheffer 1997	0,6	IPCC 2006	2)
Zware stookolie	Residual Fuel oil	g/GJ	1,6	Scheffer 1997	0,6	IPCC 2006	
LPG	Liquefied Petroleum Gas (LPG)	g/GJ	0,7	Scheffer 1997	0,1	IPCC 2006	
Ethaan	Ethane	g/GJ	3,6	Scheffer 1997	0,1	IPCC 2006	8)
Nafta's	Naphta	g/GJ	3,4	Scheffer 1997	0,6	IPCC 2006	
Bitumen	Bitumen	g/GJ	1,6	Scheffer 1997	0,6	IPCC 2006	
Smeeroliën	Lubricants	g/GJ	1	Scheffer 1997	0,6	IPCC 2006	2)
Petroleumcokes	Petroleum Coke	g/GJ	3,8	Scheffer 1997	1,5	IPCC 2006	
Raffinaderij	Refinery Feedstocks	g/GJ	1,4	Scheffer 1997	0,6	IPCC	

Name (Dutch)	Name (English)	Unit	CH_4 EF		N_2O EF		Notes
			2017	Ref	2017	Ref	
grondstoffen						2006	
Raffinaderijgas	Refinery Gas	g/GJ	3,6	Scheffer 1997	0,1	IPCC 2006	
Chemisch restgas	Chemical Waste Gas	g/GJ	3,6	Scheffer 1997	0,1	IPCC 2006	
Overige oliën	Other oil	g/GJ	3,4	Scheffer 1997	0,6	IPCC 2006	
Paraffine	Paraffin Waxes	g/GJ	1,5	Scheffer 1997	0,6	IPCC 2006	
Terpentine	White Spirit and SBP	g/GJ	3,4	Scheffer 1997	0,6	IPCC 2006	
Overige aardolie producten	Other Petroleum Products	g/GJ	1,6 / 3,4 / 7,5	Scheffer 1997	0,6	IPCC 2006	4)
	B. Solid Fossil, Primary Fuels						
Antraciet	Anthracite	g/GJ	0,44	Scheffer 1997	1,5	IPCC 2006	
Cokeskolen	Coking Coal	g/GJ	0,44	Scheffer 1997	1,5	IPCC 2006	
Cokeskolen	Coking Coal (used in coke oven)	g/GJ	0,44	Scheffer 1997	1,5	IPCC 2006	
Cokeskolen	Coking Coal (used in blast furnaces)	g/GJ	0,44	Scheffer 1997	1,5	IPCC 2006	
Overige bitumineuze steenkool	Other Bituminous Coal	g/GJ	0,44	Scheffer 1997	1,5	IPCC 2006	
Sub-bitumineuze kool	Sub-Bituminous Coal	g/GJ	0,44	Scheffer 1997	1,5	IPCC 2006	
Bruinkool	Lignite	g/GJ	4,4	Scheffer 1997	1,5	IPCC 2006	
Bitumineuze Leisteen	Oil Shale						1)
Turf	Peat						1)
	Solid Fossil, Secondary Fuels						
Steenkool- and bruinkoolbriketten	BKB & Patent Fuel	g/GJ	4,4	Scheffer 1997	1,5	IPCC 2006	
Cokesoven/ gascokes	Coke Oven/Gas Coke	g/GJ	44,4	Scheffer 1997	1,5	IPCC 2006	
Cokesovengas	Coke Oven gas	g/GJ	2,8	Scheffer 1997	0,1	IPCC 2006	
Hoogovengas	Blast Furnace Gas	g/GJ	0,35	Scheffer 1997	0,1	IPCC 2006	
Oxystaalovengas	Oxy Gas	g/GJ	0,35	Scheffer 1997	0,1	IPCC 2006	
Fosforovengas	Fosfor Gas	g/GJ	3,6	Scheffer 1997	0,1	IPCC 2006	
Steenkool bitumen	Coal tar	g/GJ	1,6	Scheffer 1997	0,6	IPCC	

Name (Dutch)	Name (English)	Unit	CH_4 EF		N_2O EF		Notes
			2017	**Ref**	**2017**	**Ref**	
						2006	
	C. Gaseous Fossil Fuels						
Aardgas	Natural Gas (dry)	g/GJ	5,7	Scheffer 1997	0,1	IPCC 2006	5)
Compressed natural gas (CNG)	Compressed natural gas (CNG)						3)
Liquified natural gas (LNG)	Liquified natural gas (LNG)						3)
Koolmonoxide	Carbon Monoxide	g/GJ	3,6	Scheffer 1997	0,1	IPCC 2006	8)
Methaan	Methane	g/GJ	3,6	Scheffer 1997	0,1	IPCC 2006	8)
Waterstof	Hydrogen	g/GJ	3,6	Scheffer 1997	0,1	IPCC 2006	8)
	Biomass						
Biomassa vast	Solid Biomass	g/GJ	30 / 300	Scheffer 1997	4	IPCC 2006	6)
Houtskool	Charcoal	g/GJ	200	IPCC 2006	1	IPCC 2006	
Biobenzine	Biogasoline	g/GJ	3,4	Scheffer 1997	0,6	IPCC 2006	2)
Biodiesel	Biodiesels	g/GJ	3,4	Scheffer 1997	0,6	IPCC 2006	2)
Overige vloeibare biobrandstoffen	Other liquid biofuels	g/GJ	30	Scheffer 1997	4	IPCC 2006	
Biomassa gasvormig	Gas Biomass	g/GJ	5	Scheffer 1997	0,1	IPCC 2006	
RWZI biogas	Wastewater biogas	g/GJ	5	Scheffer 1997	0,1	IPCC 2006	
Stortgas	Landfill gas	g/GJ	5	Scheffer 1997	0,1	IPCC 2006	
Industrieel fermentatiegas	Industrial organic waste gas	g/GJ	5	Scheffer 1997	0,1	IPCC 2006	
	D Other fuels						
Afval	Waste	g/ton	0	Rijkswaterstaat, 2013	20 / 100	Spoelstra, 1993 & Oonk, 1995	7)

Notes:
1) This fuel is not used in the Netherlands, and therefore no CH_4 and N_2O emission factors have been derived.
2) The emission factors presented in this table are only valid for stationary combustion. See 3.2.6 for more information on CH_4 and N_2O emissions from mobile combustion.
3) This fuel is only used for mobile combustion. See 3.2.6 for more information on CH_4 and N_2O emissions from mobile combustion.
4) The CH_4 emission factor for other oil products differs per product. The emission factor of 1.6 g/GJ is used for raw materials for carbon black, the emission factor of 3.4 g/GJ is used for other crude oil products and the emission factor of 7.5 g/GJ is used for anti-knock preparations and additives for lubricants

5) CH_4 emission factors for natural gas are only valid for natural gas not combusted in gas engines. For gas engines, the emission factors are presented in Table A5.3. Residential gas leakage before ignition in cooking, hot water and space heating are not included in the CH_4 emission factor for natural gas; these are separately estimated to be 35 g/GJ.
6) CH_4 emission factors for wood are 30 kg/TJ for CRF categories 1A1 and 1A2 and 300 kg/TJ for CRF category 1A4.
7) The N_2O emission factor differs per DeNOx plant type. The emission factor of 20 g/GJ is used for SCR plants and the emission factor of 100 g/GJ s used for SNCR plants.
8) Ethane, carbon monoxide, methane and hydrogen are not reported separately, but as part of chemical waste gas.

Table A5.3 CH_4 emission factors for natural gas combusted in gas engines (g/GJ).

Year	EF CH_4 gas engines in agriculture	EF CH_4 gas engines in other sectors
1990	305.0	305.0
1991	305.0	305.0
1992	305.0	305.0
1993	305.0	305.0
1994	305.0	305.0
1995	305.0	305.0
1996	305.0	305.0
1997	305.0	305.0
1998	294.0	294.0
1999	283.0	283.0
2000	272.0	272.0
2001	261.0	261.0
2002	250.0	250.0
2003	250.0	250.0
2004	268.9	250.0
2005	301.5	250.0
2006	354.6	250.0
2007	382.3	250.0
2008	395.3	250.0
2009	403.9	250.0
2010	410.1	250.0
2011	416.0	250.0
2012	421.8	250.0
2013	427.0	250.0
2014	431.7	250.0
2015	436.5	250.0
2016	441.3	250.0
2017	446.1	250.0
2018	450.0	250.0

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 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 organization 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.
- N_2O emissions from industrial wastewater treatment (5D2): the IPCC 2006 Guidelines do not provide a method for estimating N_2O emissions from industrial sources, except for industrial wastewater that is co-discharged with domestic wastewater into the sewerage system. N_2O emissions from industrial sources are believed to be insignificant compared with emissions from domestic wastewater. In the Netherlands most industries

discharge their wastewater into the sewerage system/WWTPs (emissions included in 5D1). Indirect emissions from surface water resulting from discharges of wastewater effluent are already included (IE) under 5D3 (Other, wastewater effluents).

- 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'.
- No data are available to report CH_4 emissions from drainage and rewetting of organic soils (LULUCF CRF Table 4(II)). Such emissions may occur from drainage ditches used in agriculture areas on organic soils. However, the extent of these ditches is not known and in therefore in the current methodology these ditches are included under the respective Cropland and Grassland areas. As a result also CO2 emissions for these areas are included, which are higher than potential CH_4 emissions (in CO_2 eq.). Therefore this is considered to be a conservative approach.

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 2020. These reports are to be considered as an integrated part of this NIR2020.

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 2021-0003
E. Honig, J.A. Montfoort, R. Dröge, B. Guis, C. Baas, B. van Huet, O.R. van Hunnik, A.C.W.M. van den Berghe

Transport:
Methods for calculating the emissions of transport in the Netherlands - 2021
G. Geilenkirchen, J. Hulskotte, S. Dellaert, N. Ligterink, M. Sijstermans, K. Roth,

IPPU
Methods used for the Dutch Emission Inventory. Product usage by consumers, construction and services
RIVM Report 2021-0002
A.J.H. Visschedijk, J.A.J. Meesters, M.M. Nijkamp, B.I. Jansen, B.I., W.W.R Koch, R. Dröge.

Agriculture:
Methodology for estimating emissions from agriculture in the Netherlands
RIVM Report 2021-0008.
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) – Update 2021
Van der Zee, T. C., ; Bannink, A., van Bruggen, C., Groenestein, C.M.; Huijsmans, J.F.M.; van der Kolk, J.W.H., Lagerwerf, L.A., Luesink, H.H., Velthof, G.L., Vonk, J.

LULUCF
Greenhouse gas reporting for the LULUCF sector in the Netherlands
Methodological background, update 2021, WOt-technical report 201
Arets, E.J.M.M, J.W.H van der Kolk, G.M. Hengeveld, J.P. Lesschen, H. Kramer, P.J. Kuikman & 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)]	25
N_2O	298
HFCs [3)]:	
HFC-23	14,800
HFC-32	675
HFC-125	3,500
HFC-134a	1,413
HFC-143a	4,470
HFC-152a	124
HFC-227ea	*3,220*
HFC-236fa	*9,810*
HFC-245ca	*693*
PFCs [3)]:	
CF_4	7,390
C_2F_6	12,200
C_3F_8	*8,830*
C_4F_{10}	*8,860*
C_6F_{14}	*9,300*
SF_6	22,800
NF_3	17,200

1) GWPs calculated with a 100-year time horizon in compliance with the UNFCCC Guidelines for reporting (UNFCCC, 2006).
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: UNFCCC (2013).

A8.3 Units

MJ	Mega Joule (10^6 Joule)
GJ	Giga Joule (10^9 Joule)
TJ	Tera Joule (10^{12} Joule)
PJ	Peta Joule (10^{15} Joule)
Mg	Mega gramme (10^6 gramme)
Gg	Giga gramme (10^9 gramme)
Tg	Tera gramme (10^{12} gramme)
Pg	Peta gramme (10^{15} gramme)
ton	metric ton (= 1,000 kilogramme = 1 Mg)
kton	kiloton (= 1,000 metric ton = 1 Gg)
Mton	Megaton (= 1,000,000 metric ton = 1 Tg)
ha	hectare (= 10^4 m^2)
kha	kilo hectare (= 1,000 hectare = 10^7 m^2 = 10 km^2)
mln	million (= 10^6)

A8.4 Conversion factors for emissions

From element basis to full molecular mass:		From full molecular mass to element basis	
C → CO_2:	x 44/12 = 3.67	CO_2 →C:	x 12/44 = 0.27
C → CH_4:	x 16/12 = 1.33	CH_4 →C:	x 12/16 = 0.75
C → CO:	x 28/12 = 2.33	CO → C:	x 12/28 = 0.43
N → N_2O:	x 44/28 = 1.57	N_2O → N:	x 28/44 = 0.64
N → NO:	x 30/14 = 2.14	NO → N:	x 14/30 = 0.47
N → NO_2:	x 46/14 = 3.29	NO_2 → N:	x 14/46 = 0.30
N → NH_3:	x 17/14 = 1.21	NH_3 → N:	x 14/17 = 0.82
N → HNO_3:	x 63/14 = 4.50	HNO_3 → N:	x 14/63 = 0.22
S → SO_2:	x 64/32 = 2.00	SO_2 → S:	x 32/64 = 0.50

Annex 9 List of abbreviations

AD	activity data
AGB	above-ground biomass
AR	afforestation and reforestation
AER	Annual Environmental Report
BCEF	biomass expansion function
BF	blast furnace gas
BGB	below-ground biomass
BOD	biological oxygen demand
C	Carbon or Confidential information(notation code in CRF)
CO	coke oven gas
COD	chemical oxygen demand
CBS	Statistics Netherlands
CDM	Clean Development Mechanism
CHP	combined heat and power
CLRTAP	Convention on Long-Range Transboundary Transport of Air Pollutants
COD	chemical oxygen demand
CPR	commitment period reserve
CRF	Common Reporting Format (of emissions data files, annexed to an NIR)
CSC	carbon stock changes
D	deforestation
DM	dry matter
DOC	degradable organic carbon
DOCf	degradable organic carbon fraction
DOM	dead organic matter
DW	dead wood
e-AER	electronic Annual Environmental Report
EEA	European Environment Agency
EF	emission factor
ENINA	Task Group Energy, Industry and Waste Handling
ER	Emission Registration (system)
ERT	Expert Review Team
ERU	Emission Reduction Unit
ETS	Emission Trading System
EU	European Union
EWL	European Waste List
EZ	Ministry of Economic Affairs
EZK	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 wastewater treatment plant
IPCC	Intergovernmental Panel on Climate Change
KP	Kyoto Protocol
KP-LULUCF	Land use, land use change and forestry according the Kyoto Protocol definitions
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
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
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 September 2019

Sector	ID# concept ARR	Adressing/Not resolved/New from 2019 review	Issue and/or problem classification[a[, b]]	Recommendation made in previous review report	ERT assessment and rationale	NLD Response in NIR /CRF 2021	Paragraph or table number in: NIR, CRF and or Methodology report (MR)
IPP U	I.6	Not Resolved	2.A.4 Other process uses of carbonates (2.A.4.b soda ash)– CO_2	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.	Not resolved. The ERT noted that the description of the methodology for this category in the NIR (p. 123) is the same as that in previous NIRs and there is no information about actions taken to improve the completeness and accuracy of the estimates. The ERT also noted that the Netherlands uses a long extrapolation period to assess the latest emissions, which could decrease accuracy. The ERT believes that this issue should be considered further in future reviews to confirm that there is not an underestimation of emissions. The ERT considers that this issue could potentially be resolved by investigating EU ETS data.	In par. 4.2.6 it was announced that we will endeavour to find out in which chemical industries soda ash is used, and to investigate whether EU-ETS data could be used to improve the data in the inventory. This text stays the same in the 2021 submission, as we did not succeed in this investigation so far.	Par. 4.2.6

Sector	ID# concept ARR	Adressing/Not resolved/New from 2019 review	Issue and/or problem classification[a[, b]]	Recommendation made in previous review report	ERT assessment and rationale	NLD Response in NIR /CRF 2021	Paragraph or table number in: NIR, CRF and or Methodology report (MR)
IPP U	I.8	Not Resolved	2.B.1 Ammonia production - CO2	Estimate emissions from ammonia production, taking into account CO2 emissions and sequestration from urea production by collecting new AD (annual urea production, urea imports and exports, and urea application to soils) through research and/or consultation with industry and statistical agencies in order to improve the accuracy and comparability of emission estimates.	Not resolved. The Netherlands reported in its NIR (p.131) that data on urea production and use are still not available. During the review, the Party confirmed that it was not able to implement the recommendation because of the lack of available data on urea production and use. The ERT noted that the accuracy of the estimates has therefore not improved.	Emission timeseries is recalculated, now taking into account the CO_2 storage in urea, and described in the NIR	paragraph 4.3.2
IPP U	I.27	New	2.F.1 Refrigeration and air conditioning		The Party reported emissions from subcategories 2.F.1.a (commercial refrigeration), 2.F.1.d (transport	Corrected in CRF, text added to paragraph 4.7.1	NIR paragraph 4.7.1

Sector	ID# concept ARR	Adressing/Not resolved/New from 2019 review	Issue and/or problem classification[a[, b]]	Recommendation made in previous review report	ERT assessment and rationale	NLD Response in NIR /CRF 2021	Paragraph or table number in: NIR, CRF and or Methodology report (MR)
			– HFCs		refrigeration) and 2.F.1.f (stationary air conditioning) as not occurring for the years 1990–2012. However, the methodology report of Peek et al. (2019) reports that emissions from category 2.F.1 have been occurring in the Netherlands since 1995 (section 2.2.3.9, p.64)…… …The ERT recommends that the Netherlands (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; and (2) revise the description of the data-collection methods in the NIR such that clear information on the method currently being used is provided. In addition, the ERT		

Sector	ID# concept ARR	Adressing/Not resolved/New from 2019 review	Issue and/or problem classification[a[, b]]	Recommendation made in previous review report	ERT assessment and rationale	NLD Response in NIR /CRF 2021	Paragraph or table number in: NIR, CRF and or Methodology report (MR)
					encourages the Party to investigate the reasons for any discrepancies between data from the stock model and refrigerant registration system.		
LULUCF	L.2	Addressing	4. General (LULUCF) – CO_2	Correct the notation key “NE” to “NO” for those pools in which the Party considers no CSC occurs, provide estimates for those pools and categories for which it believes zero carbon change does not apply, or provide the justification for reporting “NE” for the pools in which the amount of CSC is insignificant in line with paragraph 37 of the UNFCCC Annex I inventory reporting guidelines.	Addressing. The Netherlands significantly improved its use of notation keys by including references in table 6.1 of the NIR (referring to the relevant sections of the NIR) and a background paper where the justifications are provided. However, the ERT noted that the notation key used for CSC in litter under other land converted to forest land in CRF table 4.A was changed to “NO” rather than retained as a justified “NE”, which is inconsistent with NIR table 6.1 and the other subcategories of land converted to forest land. During the review, the Party explained that the above-mentioned use of “NO”	This has been corrected in the NIR2020	

Sector	ID# concept ARR	Adressing/Not resolved/New from 2019 review	Issue and/or problem classification[a[, b]]	Recommendation made in previous review report	ERT assessment and rationale	NLD Response in NIR /CRF 2021	Paragraph or table number in: NIR, CRF and or Methodology report (MR)
					appeared to be an error and would be corrected in the next submission. The ERT noted that, at their 16th meeting, GHG inventory lead reviewers in 2019 recommended that the correct notation key for a tier 1 assumption of carbon stock equilibrium is “NA”; however, this is considered as a separate recommendation (see ID# L.18 in table 5 ARR2019).		
LULUCF	L.4	Addressing	4. General (LULUCF) – CO_2	(a) Add to the NIR an explanation for the lack of AD before 1990, and extend the description by adding graphs showing the problem of extrapolation of the AD back from 1990; (b) Make further efforts or explore alternative ways to derive appropriate data (e.g. through	Addressing. The Netherlands partially explained the grounds on which pre-1990 AD are inadequate in the NIR (pp.194–195). However, the information and assertions are not supported by statistical data (e.g. graphs), and the ERT did not note any planned improvements regarding the derivation of appropriate data, as recommended. The ERT therefore reiterates the conclusions of previous ERTs,	In the NIR 2021, the Netherlands has included a 1970 land-use map, taking into consideration the land-use changes between 1970-1990.	NIR sections 6.1.3, and 6.3. NIR Table 6.3. MR chapter 3.

Sector	ID# concept ARR	Adressing/Not resolved/New from 2019 review	Issue and/or problem classification[a[, b]]	Recommendation made in previous review report	ERT assessment and rationale	NLD Response in NIR /CRF 2021	Paragraph or table number in: NIR, CRF and or Methodology report (MR)
				extrapolation based on surrogate data).	that the non-consideration of land use prior to 1990 is not consistent with the 2006 IPCC Guidelines (vol. 4, equation 2.5). During the review, the Party explained that older spatial information is available, including topographic maps, but previous attempts to include these maps in the inventory resulted in inconsistencies in the time series. The ERT considers that such data could still be of use as surrogate data, or that the Party could explore interpolation with Landsat observation data, which are available in a time series since 1972 on a 25 m grid, given that the Netherlands appears to have the geospatial capabilities to analyse and utilize a data set of this resolution.		

Sector	ID# concept ARR	Adressing/Not resolved/New from 2019 review	Issue and/or problem classification[a[, b]]	Recommendation made in previous review report	ERT assessment and rationale	NLD Response in NIR /CRF 2021	Paragraph or table number in: NIR, CRF and or Methodology report (MR)
LULUCF	L.13	Not Resolved	4.C.1 Grassland remaining grassland – CO_2	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.	Not resolved. The Netherlands improved transparency regarding the allocation of areas and estimates of emissions/removals for grassland in section 6.6.1 of the NIR, however, the misallocation of areas and the estimates of emissions/removals between grassland remaining grassland and land converted to grassland is still present. Lands converted to grassland within the past 20 years continue to be allocated to grassland remaining grassland if a transition between “nature” and “grassland vegetation” occurs. During the review, the Party explained that its subcategory “nature under grassland” has the same soil and biomass carbon stock as grassland, thus conversions between	We are adressing this recommend-dation. However, changing this allocation is not easy in the LULUCF bookkeeping model that we currently use. Currently a new implementation of the model is being program-med in java. This implementation will solve this allocation issue. The model ondergoes last QA tests and it is foreseen that it will be used for the 2022 submission. The total emissions will not change, except that now about 1 kt CO2 is reported under GL remaining GL while it should be reported	NIR section 6.6.1

Sector	**ID# concept ARR**	**Adressing/Not resolved/New from 2019 review**	**Issue and/or problem classification[a[, b]]**	**Recommendation made in previous review report**	**ERT assessment and rationale**	**NLD Response in NIR /CRF 2021**	**Paragraph or table number in: NIR, CRF and or Methodology report (MR)**
					these categories do not involve CSC. The ERT noted that this explanation is not relevant to concerns regarding application of the 2006 IPCC Guidelines (chapter 3.3 on land representation), as per previous review recommendations.	under the various converted to GL categories. This is explicitly indicated in the NIR Chapter 6.6.1.	
LULUCF	L.20	New	4.A.1 Forest land remaining forest land – CO_2		The Party reported using EFISCENb for modelling CSCs in living biomass in forests from 2014 onward in the absence of updated NFI data (p.198 of NIR). During the review, in consideration of ID# L.6 in table 3, the Party explained how EFISCEN ensures time-series	For improving transparency information on initilisation and calibration of the EFISCEN model are now included in Annex 6 of the methodological background report	MR Annex 6

Sector	ID# concept ARR	Adressing/Not resolved/New from 2019 review	Issue and/or problem classification[a[, b]]	Recommendation made in previous review report	ERT assessment and rationale	NLD Response in NIR /CRF 2021	Paragraph or table number in: NIR, CRF and or Methodology report (MR)
					consistency for living biomass by referring the ERT to the methodology report of Arets et al. (2019, section 4.2.1), which describes calibration of the model using data from the sixth NFI. However, it was not clear to the ERT how calibration ensures proper time-series consistency. According to the 2006 IPCC Guidelines (vol. 1, section 5.3.3.1), when using the overlap method to combine two estimation techniques (as appears to be the case in the Netherlands), it is preferable to include multiple years when evaluating the relationship between two models, because comparing only one year may lead to bias and it is not possible to evaluate trends. The ERT could identify evidence of only a single year used in overlap, 2013, for	(Arets et al. 2020) with the NIR 2020.	

Sector	ID# concept ARR	Adressing/Not resolved/New from 2019 review	Issue and/or problem classification[a[, b]]	Recommendation made in previous review report	ERT assessment and rationale	NLD Response in NIR /CRF 2021	Paragraph or table number in: NIR, CRF and or Methodology report (MR)
					calibration with NFI data. The ERT recommends that the Netherlands provide in the NIR information regarding the use and calibration of EFISCEN, including evidence that the model is able to reproduce observed trends before 2013 in the CSC of living biomass.		
LULUCF	L.25	New	4.G.2 Paper and paperboard – CO_2		The Party reported in CRF table 4.Gs1 that carbon has not been accumulating in the paper products pool since 1994. However, AD on domestic production, imports and exports of paper and paper products were reported in CRF table 4.Gs2. During the review, the Party explained that the calculation of the share of wood pulp used in paper and paper product production arising from domestic sources (using equation 2.8.2 of the Kyoto	From the NIR 2021 onwards the Netherlands directly uses data and information collected by PROBOS as part of the Joint Forest Sector Questionaire collected.	NIR sections 6.1.3 and 6.10

Sector	ID# concept ARR	Adressing/Not resolved/New from 2019 review	Issue and/or problem classification[a[, b]]	Recommendation made in previous review report	ERT assessment and rationale	NLD Response in NIR /CRF 2021	Paragraph or table number in: NIR, CRF and or Methodology report (MR)
					Protocol Supplement) has been negative since 1993 and as a consequence the domestic production of paper and paper products has been set to zero for 1994 onward. The Party provided the source statistics supporting these calculations. The ERT noted that in 2017 pulp production was 37,400 t whereas pulp exports were 1,045,400 t. This suggests either a significant re-exporting practice, which should be explained in the NIR, or an inconsistent inclusion of recycled paper in export data but not in production data. The Party explained that data from FAOSTAT, the statistical database of FAO (see http://www.fao.org/faostat/en/#home) were used as the source data, but did not go into details on the reasoning behind developments over time		

Sector	ID# concept ARR	Adressing/Not resolved/New from 2019 review	Issue and/or problem classification[a[, b]]	Recommendation made in previous review report	ERT assessment and rationale	NLD Response in NIR /CRF 2021	Paragraph or table number in: NIR, CRF and or Methodology report (MR)
					or on the relationships among reported production, imports and exports, which the ERT considers a lack of necessary QC in the consideration of source data. The ERT notes the Party's access to country-specific data on wood products from Probos, a Dutch source of statisticsthat provides information to FAO (see ID# KL.16 below), which could provide a more reliable source of production and trade data on wood pulp. The ERT recommends that the Netherlands apply QC procedures to its 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. The ERT also recommends that the Party include in the NIR a table		

Sector	ID# concept ARR	Adressing/Not resolved/New from 2019 review	Issue and/or problem classification[a[, b]]	Recommendation made in previous review report	ERT assessment and rationale	NLD Response in NIR /CRF 2021	Paragraph or table number in: NIR, CRF and or Methodology report (MR)
					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.		
Agri-culture	A.16	New	3. General (agriculture) –CH4 and N2O		The Party reported that milk production data for the period 1990–1999 were based on CBS dairy statistics and milk production data for 2000 onward were based on preliminary data from the Dutch Dairy Board (p.22 of the document "Standardised calculation methods for animal manure and nutrients"). The Party did not explain how the two data sets have been assessed and/or manipulated to ensure consistency in milk production data for the entire	The only difference between the statistics for 1990-1999 and 2000-present is that the data is provided directly by the RVO instead of first going to the dairy board. The dataset on dairy production is updated yearly with the final production figures. Only figures on the milk consumed on the farm are	

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					time series. The Party also did not note whether the preliminary data from the Dutch Dairy Board are updated with the final milk production figures each year in the NIR. The ERT noted that owing to the lack of clarity in this information, there is a potential issue of consistency in the time series for AD and possible inaccuracies owing to data not being updated. During the review, the Party explained that both data sets contain data gathered via a questionnaire from dairy factories. A correction is made by CBS for the milk withheld by the farmer (e.g. for own consumption). Even though two different organizations gathered the data, their content is the same and therefore the time series is consistent. The Party	sometimes preliminary; however this constitutes less than 0,1% of the milk production, and is thus negligible.	

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					confirmed that the data set is updated yearly with the relevant production figures. The ERT recommends that the Netherlands include in the NIR the explanation on how the two data sets on milk production, that based on CBS dairy statistics and that based on Dutch Dairy Board data, have been assessed and/or manipulated to ensure consistency in milk production data for the entire time series. The ERT also recommends that the Party confirm that the data set on milk porduction is updated yearly with the final production figures and that the previous year's estimates are recalculated accordingly, if appropriate.		
Agri-culture	A.19	New	3. General (agriculture)		The Party reported in its NIR (p.162, 170, 176, 178) that there are no category-specific QA/QC and verification	Efforts are made to include more sector-specific QA/QC information in the	see new paragraph 2.5 in methodology report

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					procedures for the agriculture sector as all procedures are included in the general QA/QC procedures discussed in chapter 1. The ERT determined, however, there appear to be no category-specific procedures in chapter 1. The ERT noted that the lack of category-specific QA/QC procedures is not good practice and is not in accordance with the 2006 IPCC Guidelines (vol. 1, chap. 6). During the review, the Party explained that the Pollutant Release and Transfer Register has a general QA/QC approach, including verification of any methodology changes, data integrity checks and collegial cross-checking. The NIR and CRF tables are peer reviewed and subject to a system of audits performed by the national inventory entity. Both	methodology report (see for example a new paragraph 2.5 in methodology report for agriculture (Van der Zee, 2021).	for agriculture (Van der Zee, 2021)

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					this entity and institutions contributing to the Pollutant Release and Transfer Register must approve the data set used in the estimations before its publication. The Party feels that given these mechanisms, additional category-specific procedures are not needed. The ERT, in part on the basis of the evidence provided by issues that have been raised during this review, does not agree with the Party's assessment. The 2006 IPCC Guidelines define QC as "a system of routine technical activities to assess and maintain the quality of the inventory as it is being compiled. It is performed by personnel compiling the inventory" (vol. 1, section 6.5), and state that "the inventory report should also include information on the		

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					implementation of a QA/QC plan" (vol. 1, section 8.4). The ERT recommends that the Netherlands 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 its QA/QC procedures, and if they do not already occur, develop a time line 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		

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					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. Noting that carrying out an extensive QA/QC process maybe resource-intensive and not feasible in the first year following this recommendation, the ERT also recommends that the Party document in its QA/QC plan when it expects to be able to implement each		

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					procedure. The QA/QC plan should be submitted as a supplementary document to the NIR in future submissions and be updated regularly. The ERT considers that documenting these details is important to aid future ERTs in understanding the QA/QC procedures of the Netherlands.		
Agri-culture	A.21	New	3.A.1 Cattle –CH4		The Party reported in the methodology report of Lagerwerf et al. submitted with the NIR (annex 7) that the model assumes that only female cattle graze (p.30), but also that the remainder of the energy requirement for the recoded production level is covered by the intake of grass from grazing (p.38). The first statement implies that male cattle do not graze, but the Party did not clarify where the remainder of their energy requirements comes from. The	This will be included in this years' update of the methodology report (Van der Zee, 2021)	

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					ERT noted that the conflicting information makes it unclear where feed for male cattle to meet their energy requirements comes from. During the review, the Party provided a summary of feed allocation to animals in the Netherlands, as follows: “It is known from statistical overviews how much feed is available. Part of this is allocated to grazing animals with a fixed ration, split into a ration for the stable period and for the grazing period (sheep, goats, young cattle). Animals with a fixed ration also have a fixed part of pasture in the pasture period. The feed materials that are left then go to dairy cows. In the stable period this is a ration without fresh grass, based on the feed requirement that in turn depends mainly on milk		

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					production. The cows eat the rest of the feed when they are in the stable. The feed requirement that still remains (grazing time or feeding fresh grass in the stable) is provided in the form of fresh grass. For animals such as male cattle that are kept in the stables all year round, a fixed ration is used, which means there is no ‘remainder of the energy requirement’. The latter applies only to dairy cows in the pasture period”. The complete explanation can be found in the paper on standardized calculation methods for animal manure and nutrients (CBS, 2012). The ERT recommends that the Netherlands review the methodology report for agriculture submitted with the NIR to remove the ambiguity about feeding requirements for		

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					male cattle. In addition, the ERT encourages the Party to include in the NIR the summary provided to the ERT during the review to help understanding of how emissions from animals are estimated in the Netherlands.		
Agri-culture	A.32	New	3.B.1 Cattle –CH4 and N2O		The Party reported in the methodology report of Lagerwerf et al. in annex 7 to the NIR that, for cattle, all of the manure is produced in animal housing, including during the summer months (p.25). However, on page 30, the paper indicates that this applies only to female cattle. The conflicting information	This will be included in this years' update of the methodology report (Van der Zee, 2021)	

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					makes it unclear where manure was produced for male cattle. During the review, the Party provided an overview of the fractions of manure produced in animal housing and on pasture. This information clarified that all manure from male cattle was produced in a housing system, while some manure from female cattle was produced while they were grazing. The ERT recommends that the Netherlands review its 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. The ERT encourages the Party to include, in the NIR or the		

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					methodology report, the summary table provided to the ERT during the review detailing the time series of fractions of cattle manure produced in animal housing and on pasture.		
KP-LULUCF activi-ties	KL.5	Addressing	FM – CO2, CH4 and N2O	In conducting technical corrections of the FMRL, address the recommendation made in the report of the technical assessment of the FMRL (FCCC/TAR/2011/NLD) and reflect historical emissions from natural disturbances (see also document FCCC/IRR/2016/NLD, table 3).	Addressing. The Netherlands has elected to account for activities under Article 3, paragraph 4, at the end of the commitment period and therefore, according to decision 2/CMP.7 (annex, para. 14), the technical correction shall be applied when accounting. While the ERT agrees that accounting is made at the end of the commitment period for Parties that chose to account at the end of the commitment period, the ERT considers that the reporting obligation applies to all annual submissions. During the review, the Party explained (NIR, section 11.5.2.3) that it	Technical correction has been carried out and is presented in the NIR 2021, with more details in (Schelhaas and Arets, 2021).	11.5.2.3

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					had transparently identified the need for technical corrections, and that the technical corrections would be quantifiably reported in a future NIR.		

KP-LULUCF activi-ties	KL.7	Addressing	Harvested wood products – CO_2	Provide in the NIR (1) information on the methodologies, parameters (e.g. half-lives) and assumptions used for the estimation of CO2 emissions from HWP; (2) an explanation of the treatment of HWP, including what is included or excluded as the emissions from HWP, and on which assumption their estimation is based in accounting those emissions; and, in particular, (3) information on the adherence to IPCC guidance in terms of the exclusion of imports and deforestation, inherent HWP, and the relationship between reporting under the Convention and the projection of	Addressing. The Netherlands has provided the description of the calculation of HWP in the NIR (section 6.10) which resolved the issue (1) and (2), however the ERT noted that information was missing, specifically related to decision 2/CMP.8 on inherited emissions, emissions accounted for in the first commitment period, and the exclusion of imported HWP. The Netherlands has now provided in the NIR an explanation for HWP emissions being accounted for in the first commitment period and for the exclusion of imported HWP (section 11.4.5). However, the Party did not explain how inherited emissions are consistent with the projection of HWP in the FMRL. The NIR states that “material inflow is included from 1990 onwards” (p.282), which suggests that inherited emissions for products produced prior to 1990 have not been taken into account. The ERT noted the	The technical correction has been carried out, which solves the issue of inconsistencies in HWP between FM and FMRL.	11.5.2.3

				HWP in the FMRL.	lack of AD on pre-1990 production in CRF table 4.Gs2. During the review, the Party explained that guidance in the Kyoto Protocol Supplement (section 2.8.3) identifies that data for FM must begin in 1990. The ERT considers that the provision for commencing in 1990 is only relevant to AR. For FM, the means of accounting for inherited emissions depends upon the construction of the FMRL and, unless an approach is taken that permits the exclusion of inherited emissions prior to the commencement of the commitment period, methods should make the best use of available AD, such as by using FAO data, which commences in 1961, or country-specific data, if available. The Party acknowledged that there is a methodological inconsistency between inherited emissions and the projection of HWP in the FMRL and that this would be addressed in a future technical correction. The ERT		

					considers that this planned improvement should be either implemented or more transparently explained in the next NIR (see ID# KL.16 in table 5).		

KP-LULUCF activi-ties	KL.16	New	Harvested wood products – CO_2		The Party identified errors in the FAO forest products statistics (see http://www.fao.org/forestry/statistics/en/) and made corrections to them using statistics provided by Probos, a Dutch source of statistics that provides information to FAO (NIR, p.283). The ERT noted that, in accordance with the 2006 IPCC Guidelines (vol. 4, figure 12.1), Parties should use country-specific data sources and methods wherever possible. During the review, the Party explained that it uses FAO data as they are available in English and stored in a single database, and because Probos supplies FAO with the data. The ERT recommends that the Netherlands consider full implementation of Probos as a country-specific data source or explain in the NIR why it has concluded that FAO data remain the superior source.	From the NIR 2021 onwards the Netherlands directly uses data and information collected by PROBOS as part of the Joint Forest Sector Questionaire collected.	NIR sections 11.3.2 and 11.4.5

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