DENMARK'S NATIONAL INVENTORY REPORT 2015

Emission Inventories1990-2013 – Submitted under the United Nations Framework Convention on Climate Change and the Kyoto Protocol

Scientific Report from DCE – Danish Centre for Environment and Energy No. 171 2015

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Data sheet

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Abstract: This report is Denmark's National Inventory Report 2014. The report contains information on Denmark's emission inventories for all years' from 1990 to 2013 for CO_2, CH_4, N_2O, HFCs, PFCs and SF_6, NO_x, CO, NMVOC, SO_2

Keywords: Emission Inventory; UNFCCC; IPCC; CO_2; CH_4; N_2O; HFCs; PFCs; SF_6

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List of abbreviations

BAT	Best Available Techniques
CH_4	Methane
CHP	Combined Heat and Power
CHR	Central Husbandry Register
CLRTAP	Convention on Long-Range Transboundary Air Pollution
CO	Carbon monoxide
CO_2	Carbon dioxide
COPERT	COmputer Programme to calculate Emissions from Road Transport
CORINAIR	CORe INventory on AIR emissions
CRF	Common Reporting Format
DAAS	Danish Agricultural Advisory Service
DAFA	Danish AgriFish Agency
DCA	Danish Centre for food and Agriculture
DCE	Danish Centre for Environment and energy
DEA	Danish Energy Agency
DEPA	Danish Environmental Protection Agency
DSt	Statistics Denmark
EEA	European Environment Agency
EF	Emission Factor
EIONET	European Environment Information and Observation Network
EMEP	European Monitoring and Evaluation Programme
ENVS	Department of ENVironmental Science, Aarhus University
EU ETS	European Union Emission Trading Scheme
FSE	Full Scale Equivalent
GE	Gross Energy
GHG	Greenhouse gas
GWP	Global Warming Potential
HCB	Hexachlorobenzene
HFCs	Hydrofluorocarbons
IDA	Integrated Database model for Agricultural emissions
IEF	Implied Emission Factor
IPCC	Intergovernmental Panel on Climate Change
KCA	Key Category Analysis
LPG	Liquefied Petroleum Gas
LRTAP	Long-Range Transboundary Air Pollution
LTO	Landing and Take Off
LULUCF	Land Use, Land-Use Change and Forestry
MCF	Methane Conversion Factor
MSW	Municipal Solid Waste
N_2O	Nitrous oxide
NF_3	Nitrogen trifluoride
NFI	National Forest Inventory
NFR	Nomenclature For Reporting
NH_3	Ammonia
NIR	National Inventory Report
NMVOC	Non-Methane Volatile Organic Compounds
NO_x	Nitrogen Oxides
PFCs	Perfluorocarbons
QA	Quality Assurance
QC	Quality Control

SCR	Selective Catalytic Reduction
SF_6	Sulphur hexafluoride
SNAP	Selected Nomenclature for Air Pollution
SO_2	Sulphur dioxide
SWDS	Solid Waste Disposal Sites
UNECE	United Nations Economic Commission for Europe
UNFCCC	United Nations Framework Convention on Climate Change
VS	Volatile Solids
WWTP	WasteWater Treatment Plant

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- HMN Naturgas for providing detailed data on distribution of natural gas
- NGF Nature Energy Distribution A/S for providing detailed data on distribution of natural gas
- .
- Torben Ahlmann-Laursen, Aalborg Portland, for providing information on production statistics.
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Executive summary

ES.1 Background information on greenhouse gas inventories and climate change

According to Decision 13/CP.20 of the Conference of the Parties to the UNFCCC, CRF Reporter version 5.0.0 was not functioning in order to enable Annex I Parties to submit their CRF tables for the year 2015. In the same Decision, the Conference of the Parties reiterated that Annex I Parties in 2015 may submit their CRF tables after April 15, but no longer than the corresponding delay in the CRF Reporter availability. "Functioning" software means that the data on the greenhouse emissions/removals are reported accurately both in terms of reporting format tables and XML format.

CRF reporter version 5.10 still contains issues in the reporting format tables and XML format in relation to Kyoto Protocol requirements, and it is therefore not yet functioning to allow submission of all the information required under Kyoto Protocol.

Recalling the Conference of Parties invitation to submit as soon as practically possible, and considering that CRF reporter 5.10 allows sufficiently accurate reporting under the UNFCCC (even if minor inconsistencies may still exist in the reporting tables, as per the Release Note accompanying CRF Reporter 5.10), the present report is the official submission for the year 2015 under the UNFCCC. The present report is not an official submission under the Kyoto Protocol, even though some of the information included may relate to the requirements under the Kyoto Protocol.

ES.1.1 Reporting

This report is Denmark's National Inventory Report (NIR) 2015 for submission to the United Nations Framework Convention on Climate Change and the Kyoto Protocol, due April 15, 2015. The report contains detailed information about Denmark's inventories for all years from 1990 to 2013. The structure of the report is in accordance with the UNFCCC guidelines on reporting and review. The main difference between Denmark's NIR 2015 report to the European Commission, due March 15, 2015, and this report to UNFCCC is reporting of territories. The NIR 2015 to the EU Commission was for Denmark, while this NIR 2015 to the UNFCCC is for Denmark, Greenland and the Faroe Islands. The suggested outline provided by the UNFCCC secretariat has been followed to include the necessary information under the Kyoto Protocol. The report includes detailed and complete information on the inventories for all years from year 1990 to the year 2013, in order to ensure transparency.

The annual emission inventories for the years from 1990 to 2013 are reported in the Common Reporting Format (CRF). Within this submission separate CRF's are available for Denmark (EU), Greenland, the Faroe Islands, for Denmark and Greenland (KP) as well as for Denmark, Greenland and the Faroe Islands (UNFCCC). The CRF spreadsheets contain data on emissions, activity data and implied emission factors for each year. Emission trends are given for each greenhouse gas and for total greenhouse gas emissions in CO_2 equivalents.

The issues addressed in this report are: Trends in greenhouse gas emissions, description of each emission category of the CRF, uncertainty estimates, explanations on recalculations, planned improvements and procedure for quality assurance and control. The information presented in Chapters 2-9 and Chapter 11 refers to Denmark (EU) only. Specific information regarding the submission of Greenland and the Faroe Islands is included in Chapter 16 and Annex 8, respectively. Chapter 17 contains information on the aggregated submission of Denmark and Greenland under the Kyoto Protocol (e.g. on trends, uncertainties and key category analysis).

This report itself does not contain the full set of CRF tables. The full set of CRF tables is available at the EIONET, Central Data Repository, kept by the European Environmental Agency:
http://cdr.eionet.europa.eu/dk/Air_Emission_Inventories

In the report English notation is used: "." (full stop) for decimal sign and mostly space for division of thousands. The English notation for division of thousand as "," (comma) is not used due to the risk of being misinterpreted by Danish readers.

ES.1.2 Institutions responsible

On behalf of the Ministry of the Environment and the Ministry of Climate, Energy and Building, the Danish Centre for Environment and Energy (DCE), Aarhus University, is responsible for the calculation and reporting of the Danish national emission inventory to EU and the UNFCCC (United Nations Framework Convention on Climate Change) and UNECE CLRTAP (Convention on Long Range Transboundary Air Pollution) conventions. Hence, DCE prepares and publishes the annual submission for Denmark to the EU and UNFCCC of the National Inventory Report and the greenhouse gas (GHG) inventories in the Common Reporting Format, in accordance with the UNFCCC guidelines. Further, DCE is responsible for reporting the national inventory for the Kingdom of Denmark to the UNFCCC. DCE is also the body designated with overall responsibility for the national inventory under the Kyoto Protocol for Greenland and Denmark. Furthermore, DCE participates when reporting issues are discussed in the regime of UNFCCC and EU (Monitoring Mechanism).

The work concerning the annual greenhouse gas emission inventory is carried out in cooperation with Danish ministries, research institutes, organisations and companies. The Government of Greenland is responsible for finalising and transferring the inventory for Greenland to DCE. The Faroe Islands Environmental Agency is responsible for finalising and transferring the inventory for the Faroe Islands to DCE.

ES.1.3 Greenhouse gases

The greenhouse gases reported are those under the UN Climate Convention:

- Carbon dioxide CO_2
- Methane CH_4
- Nitrous oxide N_2O
- Hydrofluorocarbons HFCs
- Perfluorocarbons PFCs
- Sulphur hexafluoride SF_6

The global warming potential (GWP) for various greenhouse gases has been defined as the warming effect over a given time frame of a given weight of a specific substance relative to the same weight of CO_2. The purpose of this measure is to be able to compare and integrate the effects of the individual greenhouse gases on the global climate. Typical lifetimes in the atmosphere of greenhouse gases are very different, e.g. approximately 12 and 120 years for CH_4 and N_2O, respectively. So the time perspective clearly plays a decisive role. The life frame chosen is typically 100 years. The effect of the various greenhouse gases can then be converted into the equivalent quantity of CO_2, i.e. the quantity of CO_2 giving the same effect in absorbing solar radiation. According to the IPCC and their Fourth Assessment Report, which UNFCCC has decided to use as reference, the global warming potentials for a 100-year time horizon are:

- Carbon dioxide (CO_2): 1
- Methane (CH_4): 25
- Nitrous oxide (N_2O): 298

Based on weight and a 100-year period, CH_4 is thus 25 times more powerful a greenhouse gas than CO_2 and N_2O is 298 times more powerful than CO_2. Some of the other greenhouse gases (hydrofluorocarbons, perfluorocarbons and sulphur hexafluoride) have considerably higher global warming potentials. For example, sulphur hexafluoride has a global warming potential of 22 800. The values for global warming potential used in this report are those prescribed by UNFCCC. The indirect greenhouse gases reported are nitrogen oxides (NO_x), carbon monoxide (CO), non-methane volatile organic compounds (NMVOC) and sulphur dioxide (SO_2). Since no GWPs are assigned to these gases, they do not contribute to GHG emissions in CO_2 equivalents.

ES.2 Summary of national emission and removal trends

Summary ES.2-4 refers to the inventory for Denmark only. The inventories for Greenland, Denmark and Greenland and the Faroe islands are described in Chapter 16 and 17 and Annex 8, respectively.

ES.2.1 Greenhouse gas emissions inventory

The greenhouse gas emissions are estimated according to the IPCC guidelines and guidance and are aggregated into six main sectors. According to decisions made under the UNFCCC and the Kyoto Protocol the greenhouse gas emissions are estimated according to the IPCC 2006 guidelines and the IPCC 2000 good practice guidance. The greenhouse gases include CO_2, CH_4, N_2O, HFCs, PFCs, SF_6 and NF_3 Figure ES.1 shows the estimated total greenhouse gas emissions in CO_2 equivalents from 1990 to 2013. The emissions are not corrected for electricity trade or temperature variations. CO_2 is the most important greenhouse gas contributing in 2013 to national total in CO_2 equivalents excluding LULUCF (Land Use and Land Use Change and Forestry) with 76.3 % followed by N_2O with 9.4 %, CH_4 12.7 % and F-gases (HFCs, PFCs and SF_6) with 1.7 %. Seen over the time series from 1990 to 2013 these percentages have been increasing for CH_4 and F-gases and decreasing for N_2O. The percentages for CO_2 show larger fluctuations during the time series. Stationary combustion plants, Transport and Agriculture represent the largest contributing categories to emissions of greenhouse gases, followed by Industrial processes and product use, Waste and Fugitive emissions, see Figure ES.1. The net CO_2 emission by LULUCF in 2013 is 4.4 % of the total emission in CO_2 equivalents excl. LULUCF. The national total greenhouse gas emission in CO_2 equivalents excluding LULUCF has decreased by 21.2 % from 1990 to 2013 and 25.1 % including LULUCF. Comments to the overall trends for the individual greenhouse gases etc. seen in Figure ES.1 are given in the sections below.

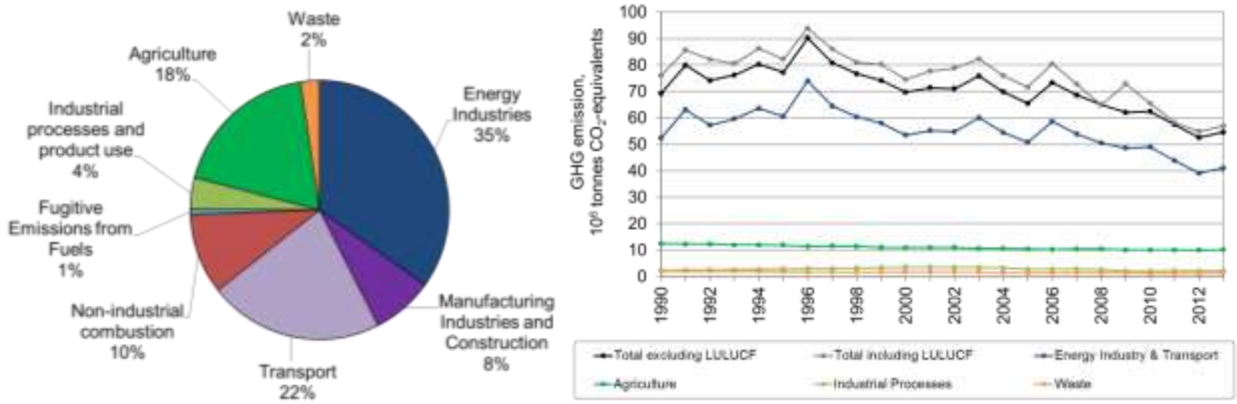


Figure ES.1 Greenhouse gas emissions in CO_2 equivalents distributed on main sectors (excl. LULUCF) for 2013 and time series for 1990 to 2013, Where data are given with or without LULUCF.

ES.2.2 KP-LULUCF activities

Net emissions from Afforestation, Reforestation and Deforestation (ARD) activities in 2013 were 79 kt CO_2 equivalents. Net removals from Forest Management (FM) were 2 350 kt CO_2 equivalents (Table ES.1).

For Cropland Management (CM) the net emissions in 2013 were 4 163 kt CO_2 equivalents compared to a net emission in 1990 of 5 444 kt CO_2 equivalents.

For Grazing land Management (GM) the net emissions in 2013 were 602 kt CO_2 equivalents compared to a net emission in 1990 of 796 kt CO_2 equivalents.

Table ES.1 Emissions and removals in 2013 for activities relating to Article 3.3 and Article 3.4.

	Net CO_2 emissions/ removals	CH_4	N_2O	Net CO_2e emissions/ removals
		Kt		
A. Article 3.3 activities				79.28
A.1. Afforestation and Reforestation	40.02	IE.NE.NO	IE.NO	40.02
A.2. Deforestation	37.95	0.00	0.00	39.27
B. Article 3.4 activities				2414.53
B.1. Forest Management	-2.384.50	0.00	0.12	-2.350.06
B.2. Cropland Management	4.161.73	NO	0.00	4162.84
B.3. Grazing Land Management	593.80	0.27	0.00	601.76
B.4. Revegetation	NA	NA	NA	NA
B.5. Wetland drainage and rewetting	NA	NA	NA	NA

ES.3 Overview of source and sink category emission estimates and trends

ES.3.1 Greenhouse gas emissions inventory

Energy

The largest source of CO_2 emission is the energy sector, which includes the combustion of fossil fuels such as oil, coal and natural gas.

The emission of CO_2 from Energy Industries has decreased by 28.2 % from 1990 to 2013. The relatively large fluctuation in the emission is due to inter-country electricity trade. Thus, the high emissions in 1991, 1994, 1996, 2003 and 2006 reflect a large electricity export and the low emissions in 1990, 1992 and 2005, 2008 and 2011-2013 are due to a large import of electricity. The main reason for this decrease owe to decreasing fuel consumption, mainly for coal and natural gas. This decrease is partly due to increasing import of electricity and partly to increasing production of wind power and other renewable energy sources.

The increasing emission of CH_4 during the nineties is due to the increasing use of gas engines in decentralised cogeneration plants. The CH_4 emissions from this sector have been decreasing from 2001 to 2013 due to the liberalisation of the electricity market. The CO_2 emission from the transport sector increased by 11.5 % from 1990 to 2013, mainly due to increasing road traffic.

Industrial processes and product use

The GHG emissions from industrial processes and product use, i.e. emissions from processes other than fuel combustion, amount in 2013 to 3.9 % of the total emission in CO_2 equivalents (excl. LULUCF). The main sources are cement production, refrigeration, foam blowing and calcination of limestone. The CO_2 emission from cement production – which is the largest source contributing in 2013 with 1.6 % of the national total – decreased by 1.7 % from 1990 to 2013. The second largest source has previously been N_2O from the production of nitric acid. However, the production of nitric acid/fertiliser ceased in 2004 and therefore the emission of N_2O also ceased.

The emission of HFCs, PFCs and SF_6 has increased by 167.7 % from 1995 until 2013, largely due to the increasing emission of HFCs. The use of HFCs, and especially HFC-134a, has increased several fold and thus HFCs have become the dominant F-gases, contributing 70.1 % to the F-gas total in 1995, rising to 84.7 % in 2013. HFC-134a is mainly used as a refrigerant. However, the use of HFC-134a is now stabilising. This is due to Danish legislation, which in 2007 banned new HFC-based refrigerant stationary systems. However, in contrast to this trend is the increasing use of air conditioning systems in mobile systems.

The major source to N_2O emissions from the IPPU sector is Other product manufacture and use, contributing 99 % of the sectoral N_2O emission in 2013.

Agriculture

The agricultural sector contributes in 2013 with 18.6 % of the total greenhouse gas emission in CO_2 equivalents (excl. LULUCF) and is the most important sector regarding the emissions of N_2O and CH_4. In 2013, the contribution of N_2O and CH_4 to the total emission of these gases was 86.7 % and 77.9 %, respectively. The N_2O emission from agriculture decreased by 28.8 %

from 1990 to 2013. The main reason for the decrease is a legislative demand for an improved utilisation of nitrogen in manure. This result in less nitrogen excreted per livestock unit produced and a considerable reduction in the use of fertilisers. From 1990 to 2013, the emission of CH_4 from enteric fermentation has decreased due to decreasing numbers of cattle. However, the emission from manure management has increased due to changes in stable management systems towards an increase in slurry-based systems. Altogether, the emission of CH_4 for the agricultural sector has decreased by 2.6 % from 1990 to 2013.

Land Use and Land Use Change and Forestry (LULUCF)

The LULUCF sector alters between being a net sink and a net source of GHG. In 2013 LULUCF was a net source with 4.4 % of the total GHG emission excluding LULUCF. In 2012 LULUCF was a net source equivalent to 4.3 % of the total GHG emission (excluding LULUCF). The overall trend in the LULUCF sector without Forestry is a decrease of 27 % since 1990.

In 2013 Forest Land was a large sink of 2 310 CO_2 equivalents, while Cropland, Grassland, Wetlands and Settlements was net sources contributing with 4 104 kt CO_2 equivalents, 592 kt CO_2 equivalents, 41 kt CO_2 equivalents and 79 kt CO_2 equivalents, respectively.

Waste

The waste sector contributes in 2013 with 2.4 % to the national total of greenhouse gas emissions (excl. LULUCF), 15.7 % of the total CH_4 emission and 3.8 % of the total N_2O emission. The sector comprises solid waste disposal on land, wastewater handling, waste incineration without energy recovery (e.g. incineration of animal carcasses) and other waste (e.g. composting and accidental fires).

The GHG emission from the sector has decreased by 36.4 % from 1990 to 2013. This decrease is a result of (1) a decrease in the CH_4 emission from solid waste disposal sites (SWDS) by 52.4 % due to the increasing use of waste for power and heat production, and (2) a decrease in emission of N_2O from wastewater (WW) handling systems of 26.7 % due to upgrading of WW treatment plants. These decreases are counteracted by an increase in CH_4 from WW of 13.3 % due to increasing industrial load to WW systems. In 2013 the contribution of CH_4 from SWDS was 12.2 % of the total CH_4 emission. The CH_4 emission from WW amounts in 2013 to 1.6 % of the total CH_4 emissions. The emission of N_2O from WW in 2013 is 1.4 % of national total of N_2O. Since all incinerated waste is used for power and heat production, the emissions are included in the 1A CRF category.

ES.3.2 KP-LULUCF activities

In 2013 the activities under Article 3.3 was a net source of 79 kt CO_2 equivalents and the activities under Article 3.4 was a net source of 2 415 kt CO_2 equivalents. A short overview of KP-LULUCF is given in Chapter ES.2.2 and a more detailed description is given in Chapter 11.

ES.4 Other information

ES.4.1 Quality assurance and quality control

A plan for Quality Assurance (QA) and Quality Control (QC) in greenhouse gas emission inventories is included in the report. The plan is in accordance with the guidelines provided by the UNFCCC (Good Practice Guidance and

Uncertainty Management in National Greenhouse Gas Inventories and Guidelines for National Systems). ISO 9000 standards are also used as an important input for the plan.

The plan comprises a framework for documenting and reporting emissions in a way that emphasize transparency, consistency, comparability, completeness and accuracy. To fulfil these high criteria, the data structure describes the pathway, from the collection of raw data to data compilation and modelling and finally reporting.

As part of the Quality Assurance (QA) activities, emission inventory sector reports are being prepared and sent for review to national experts not involved in the inventory development. To date, the reviews have been completed for the stationary combustion plants sector, the fugitive emissions from fuels sector, the transport sector, the solvents and other product use sector and the agricultural sector. In order to evaluate the Danish emission inventories, a project where emission levels and emission factors are compared with those in other countries has been conducted.

ES.4.2 Completeness

The Danish greenhouse gas emission inventories include all sources identified by the revised IPPC guidelines.

Please see Annex 5 for more information.

ES.4.3 Recalculations and improvements

The main improvements of the inventories are:

Energy

Stationary Combustion

For stationary combustion plants, the emission estimates for the years 1990-2012 have been updated according to the latest energy statistics published by the Danish Energy Agency. The update included both end use and transformation sectors as well as a source category update. The changes in the energy statistics are largest for the years 2010, 2011 and 2012.

A time series for the CH_4 emission factor for residential wood combustion have been added for 1990-2000. This cause an increased CH_4 emission estimated for residential plants in 1990-2000.

The consumption of wood in residential plants in 2012 is 4% lower in the revised energy statistics than in the energy statistics applied last year. This causes a lower emission of CH_4 reported for 2012 this year.

The increased CO_2 emission from residential plants is related to improved fuel data disaggregation between the transport sector and stationary combustion plants.

Mobile sources

The following recalculations and improvements of the emission inventories have been made since the emission reporting in 2014.

Road transport

Based on the updated version of COPERT IV version 11 launched in 2014, fuel consumption and NO_x , VOC, CO and PM emission factors for euro 5 and 6 gasoline and diesel passenger cars and light duty vehicles have been updated in the model. Updated Euro V and VI fuel consumption and NO_x, VOC, CO and PM emission factors for heavy duty vehicles have been included in the calculations also.

For N_2O and NH_3, Euro 5/6 and V/VI emission factors are also updated for passenger cars/light duty vehicles (only N_2O) and heavy duty vehicles.

Further a new Euro 6c technology class has been added for diesel passenger cars and light duty vehicles.

The amount of diesel sold for road transport reported by the Danish Energy Agency has been slightly changed in 2012.

Very small changes in mileage data has been made for the years 1985-2012 based on new information from DTU Transport.

The percentage emission change interval and year of largest percentage differences (low %; high %, year) for the different emission components are: CO_2 (0 %; 0.2 %, 2011), CH_4 (-0.1 %; 0.4 %, 2012) and N_2O (-21.7 %; 0 %, 2006).

Navigation

Recreational craft have been regrouped in the Danish inventory. These vessels have now been removed from the navigation sector and included under Other (1A5b), the latter sector according to its sector subtitle also comprise recreational craft. Further, small amounts of LPG and kerosene previously included in the navigation sector has now been transferred to stationary sources.

The following largest percentage differences (in brackets) for domestic navigation are noted for: CO_2 (-20 %), CH_4 (-72 % and N_2O (-12 %).

Agriculture/forestry

The baseline emission factors of NO_x, TSP, CO and VOC and the transient factors for fuel consumption, NO_x, TSP, CO and VOC for diesel machinery has been slightly changed in the calculation model used to estimate the emissions from Danish non road mobile machinery. Further, the CH_4 fraction of VOC has been updated. The changes are made based on new emission knowledge published by IFEU (1999) for baseline emission factors and CH_4 fractions, and IFEU (2014) for transient factors.

The number of agricultural tractors has been regrouped into finer engine size intervals for all inventory years. The total number of agricultural tractors and harvesters has been updated for the years 2006-2012 based on new stock data from Statistics Denmark for the year 2013.

The following largest percentage differences (in brackets) for agriculture/forestry are noted for: The following largest percentage differences (in brackets) are noted for: CO_2 (0.5 %), CH_4 (100 % and N_2O (0.6 %).

Fisheries

Small amounts of LPG and kerosene previously included in the navigation sector has now been transferred to stationary sources.

The following largest percentage differences (in brackets) for fisheries are noted for: CO_2 (-0.8 %), CH_4 (-8.9 % and N_2O (0.1 %).

Industry
The baseline emission factors of NOx, TSP, CO and VOC and the transient factors for fuel consumption, NOx, TSP, CO and VOC for diesel machinery has been slightly changed in the calculation model used to estimate the emissions from Danish non road mobile machinery. Further, the CH_4 fraction of VOC has been updated. The changes are made based on new emission knowledge published by IFEU (1999) for baseline emission factors and CH_4 fractions, and IFEU (2014) for transient factors.

The following largest percentage differences (in brackets) for industrial non road machinery are noted for: CO_2 (0.6 %), CH_4 (14 % and N_2O (0.1 %).

Civil aviation
The model used for calculating civil aviation emissions has been updated by replacing the previous fuel consumption and emission factors for representative aircraft types (46 types) with a new and more comprehensive list of aircraft types (79 types) provided by Eurocontrol and published in the EMEP/EEA guidebook (EMEP/EEA, 2014).

The following largest percentage differences (in brackets) for civil aviation are noted for: CO_2 (32 %), CH_4 (44 % and N_2O (-8.9 %).

Military
Recreational craft have been regrouped in the Danish inventory. These vessels have now been removed from the navigation sector and included under Other (1A5b), the latter sector according to its sector subtitle also comprises recreational craft.

The following largest percentage differences (in brackets) for military are noted for: CO_2 (108 %), CH_4 (1780 %) and N_2O (93 %).

Fugitive emissions
In the emission inventory reported in 2015 for the years 1990-2013 the following recalculations regarding fugitive emissions from fuels have been applied:

Exploration of oil and natural gas
Exploration has been included as a new source in the emission inventory as activity data has now been made available by the Danish Energy Agency. Emissions only occur in years with exploration and appraisal wells (E/A wells) (1990-2000, 2002, 2005, 2009 and 2013). The largest E/A productions occurred in 1990 and 2002, contributing 3.8 % and 4.0 % to the fugitive CO_2 emission, 0.6 % and 1.0 % to the fugitive CH_4 emission, and 2.6 % and 3.9 % to the fugitive N2O emission.

Refineries
The methodology for estimating CH_4 from one refinery has been changed, resulting in an increase of the CH_4 emissions for the years 1994-2003 and a decrease for the years 2004-2012. The refinery report annual VOC emissions based on results from measurement campaigns, the last in carried out in 2006. In previous inventories, the split between CH_4 and NMVOC given by the refinery has been use. This methodology has been changed, as the CH4 share was much higher than for the other Danish refinery, and also much higher than corresponding shares found in a literature study. The CH_4 share of VOC has been changed to 10 % for all years, as given by the other Danish refinery and supported by shares of 10-20 % found for Swedish refineries. Previously, the shares were 1 % (1994-2003), 20 % (2004-2005), and 44 % (2006-2012). The largest decrease of the CH_4 emissions is estimated for the years 2006-2012 (1 611 tonnes per year), corresponding 17 % - 35 % of the total fugitive CH_4 emissions (17 % in 2006 and 35 % in 2012).

Gas transmission and distribution
Activity data has been updated for one town gas distribution company for the year 2012. The change of 0.22 tonnes CH_4 has insignificant impact on the total fugitive emissions (< 0.01%).

Venting
Activity data and direct CH_4 emission has been corrected for one gas storage plant for 2012 according to the annual environmental report. The change of 0.002 tonnes CH_4 is insignificant for the total fugitive CH_4 emissions (< 0.01%).

Flaring in refineries
The CO_2 emission factor has been updated for 1994-2006 to the average of first five years with ETS data available (2007-2011) for two refineries. For a third refinery that was closed down in 1996 the CO_2 emission factor has been updated for the years 1994-1996 according to the 2013 EMEP/EEA Guidebook. The changes of the emissions are largest in 1994 with an increase of 3 kt CO_2, corresponding 0.5 % of the total fugitive emission.

Flaring in oil and gas extraction
The implied emission factor for CO_2 has been updated for the years 1990-2007 to the average of ETS data for the years 2008-2012 instead of the previously applied average of the years 2008-2010. The increase of the CO_2 emission factor is 1 %, and the increase of the emissions is 2.9 kt CO_2 (1990) to 10.4 kt CO_2 (1999), corresponding to 0.6 % and 0.9 % of the total fugitive CO_2 emissions, respectively.

Flaring in gas storage and treatment plants
CH_4 emissions are updated according to the environmental report for the gas treatment plant for 2012. CH_4 has been changed from 0.502 tonnes to 0.027 tonnes. The decrease of the CH_4 emissions accounts for 0.01 % of the total fugitive emissions.

Flaring in gas transmission and distribution
Flaring in gas transmission and distribution has been included as a new source in the emission inventory, only occurring in the years 2011-2013. The gas transmission company inform that they have started using a mobile flare in large construction works, and also one distribution company is flaring gas. The largest emissions occur in 2012 with 0.1 kt CO_2 and 0.7 ktonnes CH_4, corresponding 0.05 % and 0.02 % of the total fugitive emissions.

Industrial Processes

Lime production
The activity data for lime no longer includes slaked lime and imported burnt lime. Personal communication with the industry made it clear that the inclusion of slacked lime resulted in a double counting, because statistical data on the production of burned lime also includes lime that is later slacked. Also, imported burned lime was by mistake included for 2010-2011 for Faxe Kalk. This recalculation related to slacked lime results in a decreased emission of between 5 % (1999) and 18 % (1991). The double counting of hydrated lime was only a problem for the years 1990-2010 (where EU-ETS data was not available/used) and the inclusion of imported burned lime only affected 2011-2012 (where EU-ETS data was used). The result of these recalculations has been an increase of the implied emission factor, and that the implied emission factors for 1990-2010 now matches the level of those for 2011-2013.

The EU-ETS data from Faxe Kalk for 2006-2010 have been included in this year's inventory; this change has only caused minor recalculation.

The stoichiometric emission factor for lime production has been corrected from 0.7857 to 0.7850 kg CO_2 per kg CaO for the entire time series.

The CO_2 emissions from lime production in the sugar industry have been moved from the CRF category "2H2 Food and Beverages Industry" (previously "2D2 Food and Drink"; IPCC, 1997), to the CRF category "2A2 Lime Production" (IPCC, 2006).

Glass production
A new methodology for calculating emissions from container glass production for 1990-2005 was used in this year's inventory. The resulting recalculations are between -1 % (1995) and +22 % (1998); average for 1990-2005 is an increase of 2 %. More detailed data was found for dolomite in 2006-2007, causing a decrease in emissions of 22 % and 25 % for the two years respectively.

Better estimates for the activity data for container glass in 1998-2012 were calculated for this year's inventory. This change has no influence on the emission but creates more stable implied emission factor.

The consumption of dolomite in the production of glass wool in 1990-2005 has been added as a raw material carbonate; as a result emissions from this production have increased with between 16 % (1999) and 37 % (2000); average for 1990-2005 is 29 %.

In last year's submission, the CO_2 emission from glass wool production in 2009 was mistakenly reported as 2977 Mg, this has now been corrected to 1428 Mg causing a 52 % decrease from this production in 2009.

Ceramics
The methodologies for calculating emissions from both bricks and expanded clay products have been changed for 1990-2005 in this year's inventory. Previously, emissions were based on a number of unverifiable assumptions. Now the historical years are based on the actual implied emission factors provided by EU-ETS (2006-2013).

This recalculation has resulted in increased emissions from brickworks of 3-10 % (8 % in average) and from expanded clay producers of 9 %.

<u>Other uses of soda ash</u>
The source category of other uses of soda ash is new in this year's inventory.

Flue gas desulphurisation
All activity data from this source category were reassessed and multiple recalculations were performed. Some recalculations were simple corrections of typing errors and some were more general. During the reassessment of flue gas desulphurisation at waste incineration plants, four facilities were removed from this part of the inventory because their desulphurisation is dry or semi-dry technology. It was also discovered that waste incineration plants (being power and gypsum producing) are included in the data from Energinet.dk (2014) and have therefore previously been double counted.

Mineral wool production
The CO_2 emission from mineral wool production was reassessed and found to be underestimated in last year's inventory. The surrogate data used to extrapolate emissions back in time was changed from energy consumption to raw material consumption. Emissions are now also calculated for 1995-2002 based on surrogate data instead of kept constant. Emissions have more than doubled for some years.

Chemical industry
The process related CO_2 emission from production of catalysts/fertilisers was recalculated for the years 1990-1996 leading to a small increase; the production for these years is now calculated as the average production for 1997-2001.

Metal industry
A correction was made for the activity data for steel production in 1992, this recalculation has resulted in small increases in emissions for 1992 and the extrapolated/interpolated years 1990-1991 and 1993.

For magnesium production, activity data are now calculated from the consumption of SF_6 and the default IPCC (2006) emission factor is applied, however this change has no influence on the emission.

CO_2 emissions related to the production of secondary lead are new in this year's inventory.

Non-energy products from fuels and solvent use
The amount of solvent, which is added to the asphalt in "cutback", is comprised in Solvent use (CRF 2D3 Other), with an emission fac-tor of approximately unity. This amount was previously included in Road paving with asphalt (CRF 2D3 Other) as "cutback". In the improved inventory NMVOC emissions from "cutback" asphalt in Road paving (CRF 2D3 Other) only include emissions from the asphalt fraction.

A change in allocation of amounts from Statistics Denmark (2014) has caused an increase in activity data for Asphalt roofing (CRF 2D3 Other), e.g. 2012: from 75.5 kt to 131 kt, and a relatively small increase for Road paving (CRF 2D3 Other), e.g. for 2012: from 3223 kt to 3233 kt.

CH_4 emissions from Road paving with asphalt (CRF 2D3 Other) have been included.

CH_4 emissions from use of candles (CRF 2D2 Paraffin wax use) have been included.

CO_2 emissions from the use of urea in fuel consumption has been included in Urea used in catalysts (CRF 2D3 Other).

Other product manufacture and use
For "Medical applications of N_2O" emissions have been extrapolated back to 1990. A recalculation of the activity data for 2000-2004 has caused the emission for these years to increase drastically because last year's submission only included 1-2 distributors (out of four) for these years. Minor corrections were made for 2005-2012.

The category of "N_2O used as propellant for pressure and aerosol products" is new in this year's inventory.

CH_4 emissions have been included for use of fireworks, tobacco and charcoal for barbeques.

Agriculture
Changes have been made in the number of animals due to updated numbers in the statistics. These changes are of minor importance compared to the changes caused by the change to the 2006 IPCC Guidelines.

LULUCF
In the updated land use matrix that now includes mapping of three years: 1990, 2005 and 2011, significant changes have been noted related to land use and land use changes. This includes increased afforestation in areas without support from public funds. This includes establishment of minor forests areas, to improve hunting options and to produce biomass. Some forest areas have been established through natural succession, a method now approved by the Forest Act (from 2005). In the previous reporting, mainly afforestation based on subsidies were expected and included in the reporting.

Recalculations have been made due to the update to the IPCC 2006 Guidelines. Furthermore was there, by a mistake used a wrong EF for organic soils. Elsgaard et al. (2012) is used for documentation of the EF. In the previous submission was by mistake the Net Ecosystem Exchange (NEE) figures used instead of the net ecosystem carbon balances (NECB) figures. Overall has the recalculations increased the emission from CL.

Waste

A review of plant specific data was initiated with the purpose of identifying process emissions from the biogas production at wastewater treatment plants. Data on biogas lost via venting is scarce but based on a review of plant level environmental account data reported voluntary by the WWTPs an EF value of 1.3 % of the gross energy production were applied in this year´s inventory. This has led to a small decrease in the methane lost by venting ranging between 2.9-6.4 %.

The main reason for the increase in the methane emission from sector 5.D. Wastewater treatment and discharge are to be found in the change in the default COD value for the 10 % of the population not connected to the collective sewer system from 45.625 to 56.575 kg COD/person/year (IPCC, 1996; IPCC, 2006), which results in an increase in the methane emission from septic tanks of 29.2%. Likewise, the use of COD data in place of BOD data for the influent organic matter (TOW) have resulted in an increase in the methane emission from the sewer system and biotanks of 0-30 %.

Only a minor update in the influent N for the year 2011 resulting in a small increase in the N_2O emission of 0.24 %, while no methodological changes have occurred.

KP-LULUCF

A recalculation for KP-LULUCF has been performed as part of the switch in guidelines as well as the changes indicated for LULUCF.

Sammenfatning

S.1 Baggrund for opgørelse af drivhusgasemissioner og klimaændringer

I følge "Decision 13/CP.20 of the Conference of the Parties to the UNFCCC", var CRF Reporter version 5.0.0 ikke funktionel således at Annex I Parties var i stand til at rapportere deres CRF tabeller for år 2015. I samme Beslutning gentog "Conference of the Parties" at Annex I Parties i 2015 må rapportere deres CRF tabeller senere end 15. April, men ikke senere end den tilsvarende forsinkelse i adgangen til en funktionel CRF Reporter. "Funktionel" software betyder at data for drivhusgas emissioner/optag rapporteres korrekt både i rapporteringsformat og XML format.

CRF Reporter version 5.10 har stadig udeståender i forhold til rapporteringsformat og XML format i relation til betingelser under rapportering til Kyotoprotokollen., og CRF Reporter er dermed endnu ikke funktionel således at der kan rapporteres informationer i henhold til Kyotoprotokollen.

Jævnfør "Conference of Parties" invitation til at rapportere så tidligt som praktisk muligt, og i betragtning af at CRF Reporter 5.10 muliggør tilstrækkelig korrekt rapportering under klimakonventionen (til trods for små uoverensstemmelser stadig kan optræde i rapporteringstabellerne, jævnfør "Release Note", der ledsager CRF Reporter 5.10), er den nuværende rapportering den officielle rapportering for år 2015 under klimakonventionen (UNFCCC). Den nuværende rapportering er ikke en officiel rapportering under Kyotoprotokollen, til trods for at den indeholdte information kan relatere til kravene under Kyotoprotokollen.

S.1.1 Rapporteringen

Denne rapport er Danmarks årlige rapport – den såkaldte Nationale Inventory Report (NIR) for 2015. Rapporten beskriver drivhusgasopgørelsen som blev fremsendt til FN's konvention om klimaændringer (UNFCCC) og Kyotoprotokollen den 15. april 2015. Rapporten indeholder detaljerede informationer om Danmarks drivhusgasudslip for alle år fra 1990 til 2013. Rapportens struktur er i overensstemmelse med UNFCCC's retningslinjer for rapportering og review. Hovedforskellen mellem Danmarks NIR 2015 som blev fremsendt til EU-Kommissionen til den 15. marts 2015, og denne rapport til UNFCCC vedrører det territorium rapporteringen omfatter. NIR 2015 til EU-Kommissionen var for Danmark, mens NIR 2015 til UNFCCC er for Danmark, Grønland og Færøerne. For at sikre at opgørelserne er sammenhængende og gennemskuelige indeholder rapporten detaljerede oplysninger om opgørelsesmetoder og baggrundsdata for alle årene fra 1990 og til 2013.

Denne emissionsopgørelse for årene 1990 til 2013, er som tidligere årlige opgørelser, rapporteret i formatet Common Reporting Format (CRF) som Klimakonventionen foreskriver anvendt. Emissionsopgørelsen i CRF foreligger med denne rapportering således, at der er separate CRF for Danmark (EU), Grønland, Færøerne, for Danmark og Grønland (KP) samt for Danmark, Grønland og Færøerne (Klimakonventionen). CRF-tabellerne indeholder oplysninger om emissioner, aktivitetsdata og emissionsfaktorer for hvert år, emissionsudvikling for de enkelte drivhusgasser samt den totale drivhusgasemission i CO_2-ækvivalenter.

Følgende emner er beskrevet i rapporten: Udviklingen i drivhusgasemissionerne, metoder mv. som anvendes til opgørelserne i de emissionskategorier som findes i CRF-formatet, usikkerheder, genberegninger, planlagte forbedringer og procedure for kvalitetssikring og –kontrol. Teksten i kapitel 2-9 og kapitel 11 omhandler kun Danmark som omfattet af EU. Oplysninger om emissionsopgørelsen for Grønland og Færøerne er inkluderet i henholdsvis kapitel 16 og annex 8. Kapitel 17 indeholder informationer for den samlede aflevering for Danmark og Grønland under Kyotoprotokollen (f.eks. om udviklingen i emissioner over tid, usikkerheder og identifikation af nøglekategorier).

Denne rapport indeholder ikke det fulde sæt af CRF-tabeller. Det fulde sæt af CRF-tabeller er tilgængelige på EIONET, som er det Europæiske Miljøagenturs rapporterings-internetsite:
http://cdr.eionet.europa.eu/dk/Air_Emission_Inventories

Med hensyn til gengivelsen af tal i CRF-formatet, gøres opmærksom på at det er med dansk notation: "," (komma) for decimaladskillelse og "." (punktum) til adskillelse af tusinder. I rapporten er den engelske notation brugt: "." (punktum) for decimaltegn og for det meste mellemrum for adskillelse af tusinder. Den engelske notation for adskillelse af tusinder med "," (komma) er for det meste ikke brugt på grund af risikoen for fejltolkninger for danske læsere.

S.1.2 Ansvarlige institutioner

DCE - Nationalt Center for Miljø og Energi ved Aarhus Universitet er på vegne af Miljøministeriet samt Klima-, Energi- og Bygningsministeriet ansvarlig for udregning og afrapportering af den nationale emissionsopgørelse til EU og til UNFCCC (FN's konvention om klimaændringer) såvel som til UNECE-konventionen om langtransporteret grænseoverskridende luftforurening. Som følge heraf er DCE ansvarlig for udførelse og publicering af opgørelserne af drivhusgasemissioner og den årlige rapportering til EU og UNFCCC for Danmark. DCE er den centrale institution for Danmarks nationale system til drivhusgasopgørelser under Kyotoprotokollen. Ydermere er DCE ansvarlig for rapportering af drivhusgasemissionsopgørelser til Klimakonventionen for Kongeriget Danmark (Færøerne, Grønland og Danmark), samt Danmarks og Grønlands samlede rapportering til Kyotoprotokollen. DCE deltager desuden i arbejdet i regi af Klimakonventionen og Kyotoprotokollen, hvor retningslinjer for rapportering diskuteres og vedtages og i EU's moniteringsmekanisme for opgørelse af drivhusgasser, hvor retningslinjer for rapportering til EU reguleres.

Arbejdet med de årlige opgørelser udføres i samarbejde med andre danske ministerier, forskningsinstitutioner, organisationer og private virksomheder. Grønlands Klima- og Infrastrukturstyrelse er ansvarlig for levering af opgørelser for Grønland til DCE. Færøernes miljømyndighed (Umhvørvisstovan) er ansvarlig for de færøske opgørelser.

S.1.3 Drivhusgasser

Til Klimakonventionen rapporteres følgende drivhusgasser:

- Kuldioxid CO_2
- Metan CH_4
- Lattergas N_2O

- Hydrofluorcarboner HFC'er
- Perfluorcarboner PFC'er
- Svovlhexafluorid SF_6

Det globale opvarmningspotentiale, på engelsk Global Warming Potential (GWP), udtrykker klimapåvirkningen over en nærmere angivet tid af en vægtenhed af en given drivhusgas relativt til samme vægtenhed af CO_2. Drivhusgasser har forskellige karakteristiske levetider i atmosfæren, således for CH_4 ca. 12 år og for N_2O ca. 120 år. Derfor spiller tidshorisonten en afgørende rolle for størrelsen af GWP. Typisk vælges 100 år. Herefter kan effekten af de forskellige drivhusgasser omregnes til en ækvivalent mængde CO_2, dvs. til den mængde CO_2 der vil give samme klimapåvirkning. Til rapporteringen til Klimakonventionen er vedtaget at anvende GWP-værdier for en 100-årig tidshorisont, som ifølge IPCC's fjerde vurderingsrapport er:

- Kuldioxid, CO_2: 1
- Metan, CH_4: 25
- Lattergas, N_2O: 298

Regnet efter vægt og over en 100-årig periode er metan således ca. 25 og lattergas ca. 298 gange så effektive drivhusgasser som kuldioxid. For andre drivhusgasser der indgår i rapporteringen, de såkaldte F-gasser (HFC, PFC, SF_6, NF_3) findes væsentlig højere GWP-værdier. Under Klimakonventionen er der ligeledes vedtaget GWP-værdier for disse baseret på IPCC's anbefalinger. Således har f.eks. SF_6 en GWP-værdi på 22 800. I denne rapport anvendes de GWP-værdier, som UNFCCC har vedtaget.

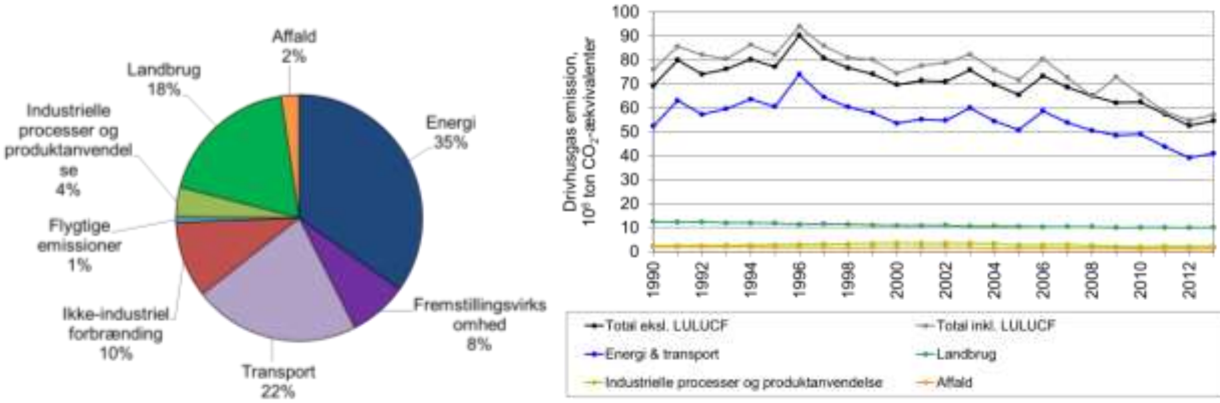
Endvidere rapporteres de indirekte drivhusgasser Kvælstofilte (NO_x), Kulilte (CO), Ikke-metan flygtige organiske forbindelser (NMVOC) og Svovldioxid (SO_2). Da der ikke tilskrives disse gasser GWP-værdier, medregnes disse ikke i drivhusgasemissioner i CO_2-ækvivalenter.

S.2 Udviklingen i drivhusgasemissioner og optag

Sammenfatning S.2.-4. omhandler alene opgørelsen for Danmark. Opgørelsen for Grønland, Danmark og Grønland samt for Færøerne beskrives i kapitel 16 og 17 samt i Annex 8.

S.2.1 Drivhusgasemissionsopgørelse

De danske opgørelser af drivhusgasemissioner følger metoderne som beskrevet i IPCC's retningslinjer. I den forbindelse skal nævnes at det under Klimakonventionen og Kyotoprotokollen er vedtaget at IPCC's 1996 retningslinjer og IPCC's 2000 anvisninger skal anvendes. Opgørelserne er opdelt i seks overordnede sektorer, 1. energi, 2. industrielle processer og produktanvendelse, 3. landbrug, 6. arealanvendelse for skove og jorder (Land Use Land Use Change and Forestry: LULUCF), 5. affald og 6. andet. Drivhusgasserne omfatter CO_2, CH_4, N_2O og F-gasserne: HFC'er, PFC'er, SF_6 og NF_3. I Figur S.1 ses de estimerede drivhusgasemissioner for Danmark i CO_2-ækvivalenter for perioden 1990 til 2013. Figuren viser Danmarks totale udledning med og uden LULUCF-sektoren (Land Use and Land Use Change and Forestry). Til venstre i figur S.1 ses det relative bidrag til Danmarks totale udledning (uden LULUCF) i 2013 for sektorerne 1. – 3. og 5. For sektor 1. energi er vejtrafik vist særskilt. Sektor 4. LULUCF indgår ikke i denne figur da sektoren omfatter kilder der bidrager med både optag og udledninger.



Figur S.1 Danske drivhusgasemissioner. Bidrag til total emission fra hovedsektorer for 2013 og tidsserier i CO_2-ækvivalenter for 1990-2013, hvor data er angivet med og uden LULUCF.

I overensstemmelse med retningslinjerne for opgørelserne er emissionerne ikke korrigerede for handel med elektricitet med andre lande og temperatursvingninger fra år til år. CO_2 er den vigtigste drivhusgas og bidrager i 2013 med 76,3 % af den nationale totale udledning uden LULUCF-sektoren, efterfulgt af CH_4 med 12,7 % og N_2O med 9,4 %, mens HFC'er, PFC'er og SF_6 kun udgør 1,7 % af de totale emissioner uden LULUCF-sektoren. Set over perioden 1990-2013 så har disse procenter været stigende for CH_4 og F-gasser og faldende for N_2O. For CO_2 har procenterne fluktueret mere gennem perioden. Netto CO_2-optaget fra LULUCF er i 2013 4,4 % af den nationale totale emission eksklusiv LULUCF. Med hensyn til sektorerne (figur S.1) så bidrager energi ekskl. vejtransport (hovedsageligt stationære forbrændingsanlæg), transport og landbrug mest i 2013 (Figur S.1). De nationale totale drivhusgasemissioner i CO_2-ækvivalenter er faldet med 21,2 % fra 1990 til 2013, hvis nettobidraget fra skovenes og jordernes udledninger og optag af CO_2 (LULUCF) ikke indregnes, og faldet med 25,1 % hvis LULUCF indregnes.

S.2.2 KP-LULUCF-aktiviteter

Den samlede udledning af drivhusgasser i skov omfattet af Kyotoprotokollens artikel 3.3 udgør 79 kt CO_2-ækvivalenter i 2013. Nettooptaget fra skov plantet før 1990 under Kyotoprotokollens artikel 3.4 udgør 2 350 kt CO_2-ækvivalenter i 2013 (tabel S.1).

Nettoemissionen fra landbrugsarealer under artikel 3.4 udgør 4 163 kt CO_2-ækvivalenter i 2013. Til sammenligning var nettoemissionen fra samme kilde 5 444 kt CO_2-æqvivalenter i 1990.

Det samlede emission fra permanente græsarealer under artikel 3.4 udgør 602 kt CO_2-ækvivalenter i 2013. I 1990 var den tilsvarende emission på 796 kt CO_2-ækvivalenter.

Tabel S.1 Emissioner og optag i 2013 for aktiviteter under Kyotoprotokollens artikel 3.3 og 3.4.

	Netto CO_2 emission/ optag	CH_4	N_2O	Netto CO_2-ækvivalent emission/ optag
		kt		
A. Aktiviteter under artikel 3.3				79.28
A.1. Skovrejsning	40.02	IE.NE.NO	IE.NO	40.02
A.2. Skovrydning	37.95	0.00	0.00	39.27
B. Aktiviteter under artikel 3.4				2414.53
B.1. Forvaltning af skov plantet før 1990	-2.384.50	0.00	0.12	-2.350.06
B.2. Forvaltning af landbrugsarealer	4.161.73	NO	0.00	4162.84
B.3. Forvaltning af permanente græsarealer	593.80	0.27	0.00	601.76
B.4. Gentilplantning	NA	NA	NA	NA
B.5. Dræning og genetablering af vådområder	NA	NA	NA	NA

S.3 Oversigt over drivhusgasemissioner og optag fra sektorer

S.3.1 Drivhusgasemissionsopgørelse

Energi

Udledningen af CO_2 stammer altovervejende fra forbrænding af kul, olie, benzin og naturgas på kraftværker, i beboelsesejendomme, industri og vejtransport. CO_2-emissionen fra energisektorerne faldt med 28,2 % fra 1990 til 2013. De relative store udsving i emissionerne fra år til år skyldes handel med elektricitet med andre lande, herunder særligt de nordiske. De høje emissioner i 1991, 1994, 1996, 2003 og 2006 er et resultat af stor eksport af elektricitet, mens de lave emissioner i 1990, 1992, 2005, 2008 og 2011-2013 skyldes import af elektricitet. Den væsentligste årsag til dette fald skyldes faldende brændselsforbrug, hovedsageligt for kul og naturgas. Faldet skyldes delvist stigende import af elektricitet og stigende produktion af vindkraft.

Udledningen af CH_4 fra energiproduktion har været stigende på grund af øget anvendelse af gasmotorer, som har en stor CH_4-emission i forhold til andre forbrændingsteknologier. Anvendelsen af gasmotorer er dog blevet mindre siden liberaliseringen af elmarkedet, hvilket har ført til lavere CH_4-emissioner fra energisektoren. Transportsektorens CO_2-emissioner er steget med 11,5 % siden 1990 hovedsagelig på grund af voksende vejtrafik.

Industrielle processer og produktanvendelse

Emissionen fra industrielle processer og produktanvendelse – hvilket vil sige andre processer end forbrændingsprocesser – udgør i 2013 3,9 % af de totale danske drivhusgasemissioner. De vigtigste kilder er cementproduktion, kølesystemer, opskumning af plast og kalcinering af kalksten. CO_2-emissionen fra cementproduktion - som er den største kilde - bidrager med 1,6 % af den totale emission i 2013. Emissionen fra cementproduktion er dog faldet med 1,7 % fra 1990 til 2013. Den anden største kilde har tidligere været N_2O fra produktion af salpetersyre. Produktionen af salpetersyre stoppede i midten af 2004, hvilket betyder, at N_2O-emissionen er nul for denne kilde fra 2005.

Emissionen af HFC'ere, PFC'ere og SF_6 er i perioden fra 1995 og til 2013 steget med 167,7 %, hovedsageligt på grund af stigende emissioner af HFC'ere. Anvendelsen af HFC'ere, og specielt HFC-134a, er steget kraftigt, hvilket har betydet, at andelen af HFC'ere af den samlede F-gas-emission steg fra 70,1 %

i 1995 og til 84,7 % i 2013. HFC'er anvendes primært inden for køleindustrien. Anvendelsen er dog nu stagnerende, som et resultat af dansk lovgivning, der forbyder anvendelsen af nye HFC-baserede stationære kølesystemer fra 2007. I modsætning til denne udvikling ses et stigende brug af airconditionsystemer i køretøjer. Den samlede effekt er, at emissionen forventes at falde fremover.

Landbrug

Landbrugssektoren bidrager i 2013 med 18,6 % til den totale drivhusgasemission i CO_2-ækvivalenter og er den vigtigste sektor hvad angår emissioner af N_2O og CH_4. I 2013 var landbrugets bidrag til de totale emissioner af N_2O og CH_4 henholdsvis 86,7 % og 77,9 %. Fra 1990 til 2013 ses et fald på 28,8 % i N_2O-emissionen fra landbrug. Dette skyldes mindre brug af kvælstofhandelsgødning og bedre udnyttelse af kvælstof i husdyrgødningen, hvilket resulterer i mindre emissioner pr. produceret dyreenhed. Emissioner af CH_4 fra husdyrenes fordøjelsessystem er faldet fra 1990 til 2013 grundet et faldende antal kvæg. På den anden side har en stigende andel af gyllebaserede staldsystemer bevirket at emissionerne fra husdyrgødning er steget. I alt er CH_4-emissionerne fra landbrugssektoren faldet med 2,6 % fra 1990 til 2013.

Arealanvendelse - skove og jorder (LULUCF)

LULUCF-sektoren skifter mellem at udgøre et nettooptag og en nettoudledning. I 2013 udgør LULUCF et nettooptag svarende til 4,4 % af den samlede drivhusgasudledning, eksklusiv LULUCF. I 2012 udgjorde LULUCF et nettooptag svarende til 4,3 % af den samlede drivhusgasudledning eksklusiv LULUCF. Siden 1990 er LULUCF sektoren eksklusiv skov faldet med 36 %.

I 2013 bidrager arealer med skov med et optag på 2 310 kt CO_2-ækvivalenter, mens dyrkede jorder, græsning, vådområder og bebyggelse bidrager med emissioner på henholdsvis 4 104 kt CO_2-ækvivalenter, 592 kt CO_2- ækvivalenter, 1 kt CO_2- ækvivalenter og 79 kt CO_2- ækvivalenter.

Affald

Affaldssektoren udgør i 2013 2,4 % af den danske totalemission, 15,7 % af den totale CH_4-emission og 3,8 % af den totale N_2O-emission. Sektoren omfatter lossepladser, spildevandshåndtering, affaldsforbrænding uden energiudnyttelse (f.eks. kremeringer af dyr), og andet affald (f.eks. kompostering og ildebrande). Da al traditionel affaldsforbrænding bruges til produktion af elektricitet og varme, er emissionerne herfra inkluderet i CRF-kategorien 1A.

Drivhusgasemissionen fra sektoren er faldet med 36,4 % fra 1990 til 2013. Reduktionen skyldes især (1) et fald i CH_4-emissionen fra lossepladser på 52,4 % pga. reducerede mængder affald, der går til deponi, og (2) et fald i N_2O-emissionen fra spildevandshåndtering på 26,7 % pga. fornyelse af spildvandsanlæggene. Disse fald er delvist modvirket af en stigning i CH_4-emissionen fra spildevandshåndtering på 13,3 % pga. en stigning i det industrielle spildevand. I 2013 bidrog lossepladser med 12,2 % af den totale nationale CH_4-emission. CH_4-emissionen fra spildevandshåndtering udgør i 2013 1,6 % af den totale nationale CH_4-emission. Emissionen af N_2O fra spildevandshåndtering udgør i 2013 1,4 % af den totale nationale N_2O-emission. Da al affaldsforbrænding udnyttes til el- og varmeproduktion, indgår emissionerne i CRF kategorien 1A.

S.3.2 KP-LULUCF-aktiviteter

I 2013 udgjorde aktiviteterne under Kyotoprotokollens artikel 3.3 en nettoudledning på 79 kt CO_2- ækvivalenter mens aktiviteterne under artikel 3.4 udgjorde et nettoemission på 2 415 kt CO_2- ækvivalenter. En kort oversigt over KP-LULUCF findes i kapitel S.2.2 mens en mere detaljeret redegørelse findes i kapitel 11.

S.4 Andre informationer

S.4.1 Kvalitetssikring og - kontrol

Rapporten indeholder en plan for kvalitetssikring og -kontrol af emissionsopgørelserne. Kvalitetsplanen bygger på IPCC's retningslinjer og ISO 9000 standarderne. Planen skaber rammer for dokumentation og rapportering af emissionerne, så opgørelserne er gennemskuelige, konsistente, sammenlignelige, komplette og nøjagtige. For at opfylde disse kriterier, understøtter datastrukturen arbejdsgangen fra indsamling af data til sammenstilling, modellering og til sidst rapportering af data.

Som en del af kvalitetssikringen, udarbejdes der for emissionskilderne rapporter, der detaljeret beskriver og dokumenterer anvendte data og beregningsmetoder. Disse rapporter evalueres af personer uden for Aarhus Universitet, der har høj faglig ekspertise indenfor det pågældende område, men som ikke direkte er involveret i arbejdet med opgørelserne. Indtil nu er rapporter for stationære forbrændingsanlæg, transport og landbrug blevet evalueret. Desuden er der gennemført et projekt, hvor de danske opgørelsesmetoder, emissionsfaktorer og usikkerheder sammenlignes med andre landes, for yderligere at verificere rigtigheden af opgørelserne.

S.4.2 Fuldstændighed i forhold til IPCC's retningslinjer for kilder og gasser

De danske opgørelser af drivhusgasemissioner indeholder alle de kilder, der er beskrevet i IPCC's retningsliner.

I annex 5 er der flere informationer om fuldstændigheden af den danske drivhusgasopgørelse.

S. 4.3 Genberegninger og forbedringer

De vigtigste forbedringer af opgørelserne er:

Energi

Stationær forbrænding

Den seneste officielle energistatistik er implementeret i opgørelsen for årene 1990-2012. Opdateringen omfatter både slutforbrug og konverteringssektoren samt opdatering af kilde kategorier. Ændringerne i energistatistikken er størst for årene 2010-2012.

Der er tilføjet en tidsserie for CH_4 emissionsfaktorer for forbrænding af træ i husholdninger for årene 1990-2000. Dette har medført en stigning for CH_4 emissionerne for husholdninger i 1990-2000.

Træforbruget i husholdninger i 2012 er 4 % lavere end det reviderede estimat i den seneste energistatistik. En opdatering af dette medfører et fald for CH_4 emissionen for 2012.

Stigningen i CO_2 emissionen fra husholdninger er relateret til forbedrede opdeling af brændselsdata mellem transportsektoren og stationær forbrænding.

Mobile kilder

Vejtransport

Baseret på den opdaterede version af COPERT IV, der blev lanceret i 2014, er brændselsforbrug samt emissionsfaktorerne for NO_x, VOC, CO og PM opdateret for Euro 5 og 6 for benzin og diesel personbiler og varebiler. Opdaterede Euro V og Euro VI brændselsforbrug og emissionsfaktorer for NO_x, VOC, CO og PM for lastbiler er ligeledes tilføjet til modellen.

Emissionsfaktorer for N_2O og NH_3 for Euro 5/6 og V/VI er opdateret for personbiler/varebiler (kun N_2O) og lastbiler. Desuden er den nye Euro 6c teknologi tilføjet for diesel personbiler og varebiler.

Mængden af solgt diesel til vejtransport opgjort af Energistyrelsen er opdateret jf. mindre ændringer siden 2012.

Meget små korrektioner af antal kørte kilometer er tilføjet for årene 1985-2012 baseret på ny information fra DTU Transport.

Minimum og maksimum procentvis difference og år for numerisk maksimum difference (min. %, maks. %, år med maks. %) for emissionskomponenterne er: CO_2 (0 %; 0.2 %, 2011), CH_4 (-0.1 %; 0.4 %, 2012) and N_2O (-21.7 %; 0 %, 2006).

Søfart

Lystbåde er omgrupperet i den danske emissionsopgørelse. Fartøjerne er flyttet fra søfart-sektoren og nu inkluderet under "Andet" (1A5b), hvoraf sidstnævnte sektor ifølge dennes undertitel inkluderer lystfartøjer. Desuden er de mindre mængder LPG og petroleum, som tidligere var inkluderet under søfart nu overført til stationær forbrænding.

De følgende maksimale procentvise ændringer for national søfart (i parenteser) som følge af genberegningen er: CO_2 (-20 %), CH_4 (-72 %) and N_2O (-12 %).

Landbrug/skovbrug

Der er foretaget mindre ændringer for basis emissionsfaktorer for NO_x, TSP, CO og VOC og de slidafhængige faktorer for brændselsforbrug, NO_x, TSP, CO og VOC for diesel maskinel i beregningsmodellen anvendt til estimering af emissioner fra ikke-vejgående maskiner. Desuden er CH_4 fraktionen af VOC blevet opdateret. Ændringerne er baseret på ny viden om emissioner publiceret i IFEU (1999) for basis emissionsfaktorer og i IFEU (2014) for slidafhængige faktorer.

Antallet af landbrugstraktorer er omgrupperet i finere motorstørrelsesintervaller for alle opgørelsesårene. Det totale antal traktorer og mejetærskere er opdateret for årene 2006-2012 baseret på nye bestandsdata fra Danmarks Statistik for år 2013.

De følgende maksimale procentvise ændringer for landbrug/skovbrug (i parenteser) som følge af genberegningen er: CO_2 (0.5 %), CH_4 (100 %) and N_2O (0.6 %).

Fiskeri

Små mængder LPG og petroleum, som tidligere var inkluderet under søfart nu overført til stationær forbrænding. De følgende maksimale procentvise ændringer for fiskeri (i parenteser) som følge af genberegningen er: CO_2 (-0.8 %), CH_4 (-8.9 %) and N_2O (0.1 %).

Industri

Der er foretaget mindre ændringer for basis emissionsfaktorer for NO_x, TSP, CO og VOC og de slidafhængige faktorer for brændselsforbrug, NO_x, TSP, CO og VOC for diesel maskinel i beregningsmodellen anvendt til estimering af emissioner fra ikke-vejgående maskiner. Desuden er CH_4 fraktionen af VOC blevet opdateret. Ændringerne er baseret på ny viden om emissioner publiceret i IFEU (1999) for basis emissionsfaktorer og i IFEU (2014) for slidafhængige faktorer.

De følgende maksimale procentvise ændringer for ikke-vejgående maskiner i industrien (i parenteser) som følge af genberegningen er: CO_2 (0.6 %), CH_4 (14 %) and N_2O (0.1 %).

Luftfart

Modellen der anvendes til beregning af emissioner for luftfart er blevet opdateret, og de tidligere brændselsforbrug og emissionsfaktorer for de repræsentative flytyper (46 typer) er opdateret til en ny og mere fyldestgørende liste af flytyper (79 flytyper), udarbejdet af Eurocontrol og publiceret i EMEP/EEA guidebogen (EMEP/EEA, 2014). Maksimum emissionsdifference er: CO_2 (32 %), CH_4 (44 %) and N_2O (-8.9 %).

Militær

Lystbåde er omgrupperet i den danske emissionsopgørelse. Fartøjerne er flyttet fra søfart-sektoren og nu inkluderet under "Andet" (1A5b), hvoraf sidstnævnte sektor ifølge dennes undertitel inkluderer lystfartøjer. Maksimum emissionsdifference er: CO_2 (108 %), CH_4 (1780 %) and N_2O (93 %).

Flygtige emissioner

I forbindelse med rapporteringen i 2015 er der foretaget en række genberegninger som specificeret nedenfor.

Udvinding af olie og naturgas

Udvinding er inkluderet som en ny kilde i emissionsopgørelsen, da aktivitetsdata er blevet tilgængelige via Energistyrelsen. Emissioner optræder kun i de år, hvor der er foregået udvindings- og efterforskningsboringer (1990-2000, 2002, 2005, 2009 og 2013). De største prøveproduktioner foregik i 1990 og 2002, og bidrager med 3,8 % og 4,0 % af den samlede flygtige CO_2 emission, 0,6 % og 1,0 % af den samlede flygtige CH_4 emission og 2,6 % og 3,9 % af den samlede flygtige N_2O emission.

Raffinaderier

Metoden til estimering af CH_4 emissioner fra ét raffinaderi er ændret, resulterende i en stigning af CH_4 emissionen for årene 1994-2003 og et fald for årene 2004-2012. Raffinaderiet rapporterer årlige VOC emissioner baseret på målekampagner, den seneste udført i 2006. I tidligere opgørelser er raffinaderiets oplysning om fordeling mellem CH_4 og NMCOV anvendt. Denne metode er ændret, da CH_4 andelen var markant højere end for det andet danske raffinaderi, og også markant højere end tilsvarende andele fundet gennem internationale litteraturstudie. CH_4 andelen af VOC er ændret til 10

% for alle år, svarende til andelen for det andet danske raffinaderi, og understøttet af andele på 10-20 % for svenske raffinaderier. Tidligere er der anvendt 1 % (1994-2003), 20 % (2004-2005) og 44 % (2006-2012). Det største fald i CH_4 emissionen er estimeret for årene 2006-2012 (1611 ton per år), svarende til 17 % - 35 % af den samlede flygtige CH_4 emission (17 % i 2006 og 35 % i 2012).

Transmission og distribution af naturgas

Aktivitetsdata er opdateret for ét bygasdistributionsselskab for år 2012. Ændringen på 0,22 ton CH_4 er ubetydelig i forhold til den samlede flygtige CH_4 emission (< 0,01 %).

Venting

Aktivitetsdata og CH_4 emission er opdateret for et gaslager for 2012 i overensstemmelse med det grønne regnskab. Ændringen på 0,002 ton CH_4 er ubetydelig i forhold til den samlede flygtige CH_4 emission (< 0,01 %).

Flaring på raffinaderier

CO_2 emissionsfaktoren er opdateret for årene 1994-2006 til gennemsnittet af de første fem år med ETS data (2007-2011) for to raffinaderier. For et tredje raffinaderi, der lukkede i 1996, er CO_2 emissionsfaktoren opdateret for årene 1994-1996 til standardfaktoren angivet i 2013 EMEP/EEA Guidebook. Ændringen af emissionerne er størst for 1994 med en stigning på 3 kton CO_2, svarende til 0,5 % af den samlede flygtige CO_2 emission.

Flaring ved olie- og gasudvinding

Den afledte emissionsfaktor for CO_2 er opdateret for årene 1990-2007 til gennemsnittet for ETS data for årene 2008-2012, fremfor som tidligere gennemsnittet for 2008-2010. Stigningen af CO_2 emissionsfaktoren er 1 % og stigningen af emissionen er mellem 2,9 kton CO_2 (1990) og 10,4 kton CO_2 (1999), svarende til 0,6 % og 0,9 % af den samlede flygtige CO_2 emission.

Flaring på gasbehandlingsanlæg og gaslagre

CH_4 emissionen er opdateret i henhold til miljørapporten for gasbehandlingsanlægget for 2012. CH_4 er ændret fra 0,502 ton til 0,027 ton. Faldet i CH_4 emission udgør 0,01 % af den samlede flygtige CH_4 emission.

Flaring ved olie- og gasudvinding

Flaring ved transmission og distribution er inkluderet som en ny kilde i emissionsopgørelsen, kun optrædende i årene 2011-2013. Gastransmissionsselskabet oplyser at de er begyndt at anvende en mobil flare ved større arbejder på transmissionsnettet, og også et af distributionsselskaberne benytter flaring. Den største emissions optræder i 2012 med 0,1 kton CO_2 og 0,7 kton CH_4, svarende til 0,05 % og 0,02 % af den samlede flygtige emission.

Industrielle processer

Produktion af kalk

Aktivitetsdata for kalk indeholder læsket kalk og importeret brændt kalk. Personlig kommunikation med industrien har afklaret at inkludering af læsket kalk resulterer i en dobbelttælling, da statistiske data for produktion af brændt kalk også inkluderer kalk der efterfølgende læskes. Desuden var importeret kalk ved en fejl inkluderet for 2010-2011 for Faxe Kalk. Genberegningen relateret til læsket kalk medfører et fald af emissionen mellem 5 5 (1999) og 18 % (1991). Dobbelttællingen af læsket kalk var kun et problem for årene 1990-2010 (hvor EU-ETS data ikke var tilgængelige/anvendt) og inkludering af importeret brændt kalk påvirkede kun årene 2011-2012 (hvor EU_ETS data blev anvendt). Genberegningerne har medført en stigning af den afledte emissionsfaktor, samt at den afledte emissionsfaktor for 1990-2010 nu svarer til den for 2011-2013.

EU-ETS data for Faxe Kalk for 2006-2010 er inkluderet i opgørelsen, hvilket medfører en ubetydelig genberegning.

Den støkiometriske emissionsfaktor for kalkproduktion er rettet fra 0,7857 til 0,7850 kg CO_2 per kg CaO for hele tidsserien.

CO_2 emissionen fra kalkproduktion i sukkerindustrien er flyttet fra CRF kategori "2H2 Food and Beverages Industry" (tidligere "2D2 Food and Drink"; IPCC, 1997), til CRF kategori "2A2 Lime Production" (IPCC, 2006).

Glasproduktion

En ny metode til estimering af emissioner fra produktion af beholderglas er implementeret for årene 1990-2005. Genberegningen har medført ændringer mellem -1 % (1995) og + 22 % (1998); gennemsnittet for 1990-2005 er en stigning på 2 %. Mere detaljerede data er inddraget for dolomit for årene 2006-2007, hvilket har medført et fald af emissionen på hhv. 22 % og 25 % for de to år.

Bedre estimater for aktivitetsdata for beholderglas for 1998-2012 er inddraget i opgørelsen. Denne ændring har ingen indflydelse på emissionen, men bidrager til en mere stabil afledt emissionsfaktor.

Forbruget af dolomit i produktion an glasuld i årene 1990-2005 er tilføjet som et nyt råmateriale. Genberegningen har medført en stigning af emissionen mellem 16 % (1999) og 37 % (2000); den gennemsnitlige ændring for 1990-2005 er 29 %.

I den seneste emissionsopgørelse blev CO_2 emissionen fra produktion af glasuld fejlagtigt opgjort til 2977 ton, hvilket er rettet til 1428 ton, svarende til et fald på 52 % fra produktionen in 2009.

Keramik

Metoden til estimering af emissioner fra tegl og ekspanderede lerprodukter er opdateret for årene 1990-2005. Tidligere er estimaterne baseret på udokumenterede antagelser, hvilket er ændret så de historiske år nu er baseret på aktuelle afledte emissionsfaktorer fra EU-ETS data (2006-2013). Genberegningen har medført en stigning i emissionen fra teglværker på 3 % - 10 % (gennemsnitligt 8 %), og fra produktion af ekspanderede lerprodukter på 9 %.

Anden anvendelse af kalcineret soda

Denne kategori er ny i dette års emissionsopgørelse.

Afsvovling af røggas

Alle aktivitetsdata fra denne kilde er revideret og flere genberegninger er udført. Nogle genberegninger er simple korrektioner af fejl, andre er af mere generel karakter. Under revideringen af afsvovling af røggas på affaldsforbrændingsanlæg er fire anlæg fjernet fra denne del af emissionsopgørelsen, da der anvendes tør eller semitør afsvovlingsteknologi. Det er desuden afdækket at affaldsforbrændingsanlæg (kraft- og gipsproducerende) er inkluderet i data fra Energinet.dk (2014) og derfor tidligere er talt dobbelt.

Mineraluldsproduktion

CO_2 emissionen fra mineraluldsproduktion er revideret og der er afdækket en underestimering i seneste års opgørelse. Surrogatdata anvendt til ekstrapolation af emissioner tilbage i tiden er ændret fra energiforbrug til råmaterialeforbrug. Emissionerne er nu også estimeret for årene 1995-2002 baseret på surrogatdata frem for at holde emissionen konstant. Emissionerne er mere end fordoblet for nogle år.

Kemisk industri

Den procesrelaterede CO_2 emission fra produktion af katalysatorer/kunstgødning er genberegnet for årene 1990-1996, hvilket har medført en mindre stigning; produktionen for disse år er nu estimeret som gennemsnittet for 1997-2001.

Metalindustri

Aktivitetsdata for stålproduktion er rettet for 1992, hvilket har resulteret i en mindre stigning af emissionen for 1992 og de ekstrapolerede/interpolerede år 1990-1991 og 1993.

Aktivitetsdata for magnesiumproduktion er nu estimeret baseret på forbruget af SF_6, og standardemissionsfaktorer fra IPCC (2006) er anvendt, hvilket dog ikke har indflydelse på emissionen.

CO_2 emissionen fra sekundær blyproduktion er tilføjet som ny kilde i dette års opgørelse.

Ikke-energi produkter fra brændsler og anvendelse af opløsningsmidler

Mængden af opløsningsmidler der tilsættes asfalt i "cutback" er omfattet i sektoren "Solvent use" (CRF 2D3 Other), med en emissionsfaktor på ca 1. Mængden var tidligere inkluderet i "Road paving with asphalt" (CRF 2D3 Other) som "cutback". I den forbedrede opgørelse omfatter NMVOC fra "cutback" asfalt i "Road paving" (CRF 2D3 Other) kun emissioner fra asfaltfraktionen.

En ændring i allokering af mængder i fra Danmarks statistik (2014) har medført en stigning i aktivitetsdata for "Asphalt roofing" (CRF 2D3 Other) (fx fra 75,5 kton til 131 kton for 2012), og en lille stigning for "Road paving" (CRF 2D3 Other) (fx fra 3223 kton til 3233 kton for 2012).

CH_4 emission fra "Road paving" (CRF 2D3 Other) er inkluderet.

CH_4 emission fra stearinlys (CRF 2D2 Paraffin wax use) er inkluderet.

CO_2 emission fra anvendelse af urea i ureabaserede katalysatorer er inkluderet i "Urea used in catalysts" (CRF 2D3 Other).

Anden produktfremstilling og –anvendelse

For "Medical applications of N_2O"er emissionerne ekstrapoleret tilbage til 1990. Genberegning af aktivitetsdata for 2000-2004 har medført en stor stigning af emissionen for disse år, da seneste års opgørelse kun omfattede 1-2 distributører (ud af fire). Mindre korrektioner er tilføjet for årene 2005-2012.

Landbrug

Der er lavet genberegninger for antal dyr jf. opdaterede antal i statistikkerne. Ændringerne er af begrænset betydning sammenlignet med ændringerne der skyldes omlægning til 2006 IPCC Guidelines.

Arealanvendelse (LULUCF)

I den opdaterede arealanvendelsesmatrice, der nu omfatter årene 1990, 2005 og 2011, er der observeret markante ændringer af arealanvendelse og arealanvendelsesændringer. Dette omfatter skovrejsning på arealer uden støtteordninger, herunder etablering af mindre skovarealer for at fremme jagtmuligheder og til produktion af biomasse. Nogle skovarealer er etableret ved naturlig succession; en metode nu anerkendt af skovloven (fra 2005). I den seneste opgørelse var antagelsen at skovrejsning hovedsageligt var baseret på tilskud, og disse var inddraget i opgørelsen.

Genberegninger er tilføjet i overensstemmelse med IPCC 2006 Guidelines. Desuden var der tidligere ved en fejl anvendt en forkert emissionsfaktor for organiske jorde. Elsgaard et al. (2012) er anvendt som dokumentation for emissionsfaktoren. I den seneste rapportering var der ved en fejl anvendt ”Net Ecosystem Exchange” (NEE) data i stedet for ”Net ecosystem carbon balances” (NECB) data. Samlet set har genberegningerne medført en stigning af emissionen fra arealer med afgrøder.

Affald

Anlægsspecifikke data er gennemgået med det formål at identificere procesemissioner fra biogasproduktion på rensningsanlæg for spildevand. Data for biogastab ved venting er begrænset, men baseret på en gennemgang af data fra anlægsspecifikke miljøregnskaber, frivilligt rapporteret af selskaberne, er der opstillet en emissionsfaktor på 1,3 % af bruttoenergiproduktionen, som er inkluderet i emissionsopgørelsen. Dette har medført et mindre fald i mængden af CH_4 tabt ved venting på 2,9 % - 6,4 %.

Hovedårsagen til stigningen i CH_4 emissionen fra CRF sektor 5.D (”Wastewater treatment and discharge”) er ændring til standard COD værdi, for de 10 % af befolkningen, der ikke er tilsluttet det offentlige kloaksystem, fra 45 625 kg COD/person/år til 56 575 kg COD/person/år (IPCC, 1996; IPCC, 2006), hvilket resulterer i en stigning i CH_4 emissionen fra septiktanke på 29,2 %. Tilsvarende har anvendelsen af COD data i stedet for BOD data for organisk materiale i indløbsspildevand (TOW) medført en stigning af CH_4 emissionen fra kloaksystemet og biotanke på 0 % - 30 %.

Der er lavet en opdatering for N i indløbsspildevan for 2011, resulterende i en mindre stigning af N_2O emissionen på 0,24 %. Der er ikke foretaget ændringer til den anvendte metode.

KP-LULUCF

Genberegning for KP-LULUCF er udført som et led i overgangen til 2006 IPCC Guidelines, så vel som beskrevet for LULUCF.

1 Introduction

1.1 Background information on greenhouse gas inventories and climate change

According to Decision 13/CP.20 of the Conference of the Parties to the UNFCCC, CRF Reporter version 5.0.0 was not functioning in order to enable Annex I Parties to submit their CRF tables for the year 2015. In the same Decision, the Conference of the Parties reiterated that Annex I Parties in 2015 may submit their CRF tables after April 15, but no longer than the corresponding delay in the CRF Reporter availability. "Functioning" software means that the data on the greenhouse emissions/removals are reported accurately both in terms of reporting format tables and XML format.

CRF reporter version 5.10 still contains issues in the reporting format tables and XML format in relation to Kyoto Protocol requirements, and it is therefore not yet functioning to allow submission of all the information required under Kyoto Protocol.

Recalling the Conference of Parties invitation to submit as soon as practically possible, and considering that CRF reporter 5.10 allows sufficiently accurate reporting under the UNFCCC (even if minor inconsistencies may still exist in the reporting tables, as per the Release Note accompanying CRF Reporter 5.10), the present report is the official submission for the year 2015 under the UNFCCC. The present report is not an official submission under the Kyoto Protocol, even though some of the information included may relate to the requirements under the Kyoto Protocol.

1.1.1 Annual report

This report is Denmark’s National Inventory Report (NIR) 2015 for submission to the United Nations Framework Convention on Climate change and the Kyoto Protocol, due April 15, 2015. The report contains detailed information about Denmark’s inventories for all years from 1990 to 2013. The structure of the report is in accordance with the UNFCCC guidelines on reporting and review. The main difference between Denmark’s NIR 2015 report to the European Commission, due March 15, 2014, and this report to UNFCCC is reporting of territories. The NIR 2015 to the EU Commission was for Denmark, while this NIR 2015 to the UNFCCC is for Denmark, Greenland and the Faroe Islands. The report includes detailed and complete information on the inventories for all years from year 1990 to the year 2013, in order to ensure transparency.

Due to the delay in the provision of a functioning CRF software by the UNFCCC, it was not possible to submit the national inventory be the due date.

The issues addressed in this report are trends in greenhouse gas emissions, a description of each IPCC category, uncertainty estimates, recalculations, planned improvements and procedures for quality assurance and control.

The annual emission inventories for the years from 1990 to 2013 are reported in the Common Reporting Format (CRF) as requested in the reporting guidelines. The CRF-spreadsheets contain data on emissions, activity data and implied emission factors for each year. Emission trends are given for each greenhouse gas and for the total greenhouse gas emissions in CO_2 equivalents.

According to the instrument of ratification, the Danish government has ratified the UNFCCC on behalf of Denmark, Greenland and the Faroe Islands. The Danish government has ratified the Kyoto Protocol on behalf of Denmark and Greenland. In the first commitment period under the Kyoto Protocol, Greenland had a reduction commitment. However, for the second commitment period a territorial exemption will be made in the ratification of the Doha Amendment, so that Greenland in the second commitment period does not have a commitment.

The information in the sectoral chapters in this report relates to Denmark only, while information for Greenland is included in Chapter 16 and for the Faroe Islands in Annex 7. Chapter 17 contains information (e.g. on trends, uncertainties and key category analysis) on the aggregated submission of Denmark and Greenland under the Kyoto Protocol.

This report itself does not contain the full set of CRF Tables. The full set of CRF tables is available at the EIONET, Central Data Repository, kept by the European Environmental Agency:
http://cdr.eionet.europa.eu/dk/Air_Emission_Inventories/Submission_UNFCCC

1.1.2 Greenhouse gases

The greenhouse gases to be reported under the Climate Convention are:

- Carbon dioxide CO_2
- Methane CH_4
- Nitrous Oxide N_2O
- Hydrofluorocarbons HFCs
- Perfluorocarbons PFCs
- Sulphur hexafluoride SF_6
- Nitrogen trifluoride NF_3

The main greenhouse gas responsible for the anthropogenic influence on the heat balance is CO_2. The atmospheric concentration of CO_2 has increased from a pre-industrial value of about 280 ppm to 379 ppm in 2005 (an increase of about 35 %), and exceeds now the natural range of 180-300 ppm over the last 650 000 years as determined by ice cores (IPCC, Fourth Assessment Report, 2007). The main cause for the increase in CO_2 is the use of fossil fuels, but changing land use, including forest clearance, has also been a significant factor. The greenhouse gases CH_4 and N_2O are very much linked to agricultural production; CH_4 has increased from a pre-industrial atmospheric concentration of about 715 ppb to 1774 ppb in 2005 (an increase of about 140 %) and N_2O has increased from a pre-industrial atmospheric concentration of about 270 ppb to 319 ppb in 2005 (an increase of about 18 %) (IPCC, Fourth Assessment Report, 2007). Changes in the concentrations of greenhouse gases are not related in simple terms to the effect on the heat balance, however. The various gases absorb radiation at different wavelengths and with different efficiency. This must be considered in assessing the effects of changes in the concentrations of various gases. Furthermore, the lifetime of the gases in the atmosphere needs to be taken into account – the longer they remain in the atmosphere, the greater the overall effect. The global warming potential (GWP) for various gases has been defined as the warming effect over a given time of a given weight of a specific substance relative to the same weight of CO_2. The purpose of this measure is to be able to compare and integrate the effects of individual substances on the global climate. Typical lifetimes in the atmosphere of substances are very different, e.g. 12 and 120 years approximately for CH_4 and N_2O, respectively. So the time perspective clearly plays a decisive role. The time frame chosen is typically 100 years. The effect of the various greenhouse gases can, then, be converted into the equivalent quantity of CO_2, i.e. the quantity of CO_2 giving the same effect in absorbing solar radiation. According to the IPCC and their Fourth Assessment Report, which UNFCCC has decided to use as reference for reporting for inventory years throughout the commitment period 2013-2020, the global warming potentials for a 100-year time horizon are:

- Carbon dioxide (CO_2): 1
- Methane (CH_4): 25
- Nitrous oxide (N_2O): 298

Based on weight and a 100-year period, methane is thus 25 times more powerful a greenhouse gas than CO_2, and N_2O is 298 times more powerful. Some of the other greenhouse gases (hydrofluorocarbons, perfluorocarbons and sulphur hexafluoride) have considerably higher global warming potential values. For example, sulphur hexafluoride has a global warming potential of 22 800.

The indirect greenhouse gases reported are nitrogen oxides (NO_x), carbon monoxide (CO), non-methane volatile organic compounds (NMVOC) and sulphur dioxide (SO_2).

1.1.3 The Climate Convention and the Kyoto Protocol

At the United Nations Conference on Environment and Development in Rio de Janeiro in June 1992, more than 150 countries signed the UNFCCC (the Climate Convention). On the 21st of December 1993, the Climate Convention was ratified by a sufficient number of countries, including Denmark, for it to enter into force on the 21st of March 1994. One of the provisions of the treaty was to stabilise the greenhouse gas emissions from the industrialised nations by the end of 2000. At the first conference under the UN Climate Convention in March 1995, it was decided that the stabilisation goal was inadequate. At the third conference in December 1997 in Kyoto in Japan, a legally binding agreement was reached committing the industrialised countries to reduce the six greenhouse gases by 5.2 % by 2008-2012 compared with the base year. For F-gases, the countries can choose freely between 1990 and 1995 as the base year. On May 16, 2002, the Danish parliament voted for the Danish ratification of the Kyoto Protocol. Denmark (including Greenland and excluding the Faroe Islands) is, thus, under a legal commitment to meet the requirements of the Kyoto Protocol, when it came into force on the 16th of February 2005. Hence, Denmark (including Greenland) is committed to reduce greenhouse gases with 8 %. The European Union is under the KP committed to reduce emissions of greenhouse gases by 8 %. However, within the EU member states have made a political agreement – the Burden Sharing Agreement – on the contributions to be made by each member state to the overall EU reduction level of 8 %.

Under the Burden Sharing Agreement, Denmark (excluding Greenland and the Faroe Islands) had to reduce emissions by an average of 21 % in the period 2008-2012 compared with the base year emission level.

For the second commitment period, the EU has a target of 20 % reduction compared to the base year. The reduction commitment within the EU distinguishes between the emissions covered by the EU Emission Trading System (ETS) and the non-ETS emissions. For the ETS there is a reduction of 24 % in allowances. For the non-ETS emissions each Member State has a separate target set out in the Effort Sharing Decision, (ESD) (Decision No 406/2009/EC). In the ESD, Denmark has a reduction commitment of 20 % in 2020 compared to the emission level in 2005.

In accordance with the Kyoto Protocol, Denmark's base year emissions include the emissions of CO_2, CH_4 and N_2O in 1990 in CO_2 equivalents and Denmark has chosen 1995 as the base year for the emissions of HFCs, PFCs and SF_6 and NF_3.

1.1.4 The role of the European Union

The European Union (EU) is a party to the UNFCCC and the Kyoto Protocol. Therefore, the EU has to submit similar datasets and reports for the collective 15 EU Member States under the burden sharing. The EU imposes some additional guidelines and obligations to these EU Member States through Decision No. 280/2004/EC concerning a mechanism for monitoring community greenhouse gas emissions and for implementing the Kyoto Protocol (EU monitoring mechanism). In 2013 a new regulation was agreed regarding the reporting of information related to greenhouse gases in the EU, the regulation is Regulation (EU) No 525/2013. As mentioned above the ESD is the legal framework for Member States reduction commitments in the non-ETS sectors.

1.1.5 Background information on supplementary information required under KP article 7.1

For the LULUCF activities under Article 3, paragraphs 3 and 4, of the Kyoto Protocol Denmark has chosen annual accounting. Article 3.3 covers direct, human induced afforestation (A), reforestation (R) and deforestation (D) activities, and accounting of these activities is mandatory. Under Article 3.4 Denmark elected the activities Forest Management (FM), Cropland Management (CM) and Grazing Land Management (GM) for accounting in the first Commitment Period (CP) and hence these activities are mandatory for the second commitment period.

1.2 A description of the institutional arrangement for inventory preparation

On behalf of the Ministry of the Environment and the Ministry of Climate, Energy and Building the Danish Centre for Environment and Energy (DCE) is responsible for the calculation and reporting of the Danish national emission inventory to the EU, the UNFCCC (United Nations Framework Convention on Climate Change) and UNECE CLRTAP (Convention on Long-Range Transboundary Air Pollution). Hence, DCE prepares and publishes the annual submission for Denmark to the EU and UNFCCC of the National Inventory Report and the GHG inventories in the Common Reporting Format, in accordance with the UNFCCC guidelines. Furthermore, DCE is responsible for reporting the national inventory for the Kingdom of Denmark to the UNFCCC. DCE is also the body designated with overall responsibility for the national inventory under the Kyoto Protocol for Greenland and Denmark.

The work concerning the annual greenhouse gas emission inventory is carried out in cooperation with Danish ministries, research institutes, organisations and companies. The Government of Greenland is responsible for finalising and transferring the inventory for Greenland to DCE. The Faroe Islands Environmental Agency is responsible for finalising and transferring the inventory for the Faroe Islands to DCE.

There are now data agreements in place with both Greenland and the Faroe Islands ensuring the data delivery. These agreements contain deadlines for when DCE is to receive the data and documentation.

DCE has been and is engaged in work in connection with meetings of the Conference of the Parties (COP) to the UNFCCC and the Conference of the Parties serving as the Meeting of the Parties (COP/MOP) to the Kyoto protocol and its subsidiary bodies, where the reporting rules are negotiated and settled. Furthermore, DCE participates in the EU Monitoring Mechanism, Working Group 1 (WG1), where the guidelines, methodologies etc. on inventories to be prepared by the EU Member States are regulated.

The main experts responsible for the sectoral inventories and the corresponding chapters and annexes in this report are:

Project leader		**Ole-Kenneth Nielsen (okn@envs.au.dk)**
Sector	Sub-sector	Responsible expert(s)
Energy	Stationary combustion:	Malene Nielsen
	Transport and other mobile sources	Morten Winther
	Fugitive emissions:	Marlene Plejdrup
Industrial processes and product use	Industrial processes	Katja Hjelgaard
	Product use	Patrik Fauser
Agriculture		Mette Hjorth Mikkelsen
		Rikke Albrektsen
LULUCF	Forestry	Vivian Kvist Johannsen,
		Thomas Nord-Larsen,
		Inge Stupak Møller
		Lars Vesterdal
	Harvested wood products	Erik Schou
		Kjell Suadicani
LULUCF	Cropland, grassland, wetlands, settlements	Steen Gyldenkærne
Waste		Marianne Thomsen
Greenland		Lene Baunbæk
Faroe Islands		Maria Gunnleivsdóttir Hansen

The work concerning the annual greenhouse emission inventory is carried out in cooperation with other Danish ministries, research institutes, organisations and companies:

Danish Energy Agency, the Ministry of Energy, Utilities and Climate: Annual energy statistics in a format suitable for the emission inventory work and fuel-use data for the large combustion plants. Company reports submitted under EU ETS.

Danish Environmental Protection Agency, the Ministry of the Environment and Food: Database on waste and emissions of F-gases.

Danish Nature Agency, the Ministry of the Environment and Food: Database on Danish waste water quality parameters.

Statistics Denmark, the Ministry of Social Affairs and the Interior: Statistical yearbook, sales statistics for manufacturing industries and agricultural statistics.

Danish Centre for Food and Agriculture (DCA), Aarhus University: Data on use of mineral fertiliser, feeding stuff consumption and nitrogen turnover in animals.

Department of Transport, Technical University of Denmark: Number of vehicles grouped in categories corresponding to the EU classification, mileage (urban, rural, highway), trip speed (urban, rural, highway).

Danish Centre for Forest, Landscape and Planning, University of Copenhagen: Background data for Forestry and CO_2 uptake by forest. Responsible for preparing estimates of emissions/removals for reporting under KP article 3.3 and for reporting FM under article 3.4.

Civil Aviation Agency of Denmark, the Ministry of Transport and Building: City-pair flight data (aircraft type and origin and destination airports) for all flights leaving major Danish airports.

Danish Railways, the Ministry of Transport and Building: Fuel-related emission factors for diesel locomotives.

Danish companies: Audited green accounts and direct information gathered from producers and agency enterprises.

Formerly, the provision of data was on a voluntary basis, but more formal agreements are now prepared. This is the case for e.g. the Danish Energy Agency, where the data agreement specifies the data needed and the deadlines for when DCE is to receive the data.

Additionally DCE receives data from Greenland and the Faroe Islands in order to report for the Kingdom of Denmark:

Statistics Greenland: Complete CRF tables for Greenland and documentation for the inventory process.

The Faroe Islands Environmental Agency: Complete CRF tables for the Faroe Islands and documentation for the inventory process.

The complete emission inventories for the three different submissions (EU, Kyoto Protocol and UNFCCC) by Denmark are compiled by DCE and along with the documentation report (NIR) sent for official approval. In recent years the responsibility for official approval has changed. Previously it was the Danish Environmental Protection Agency (Ministry of the Environment) now it is the Danish Energy Agency (Ministry of Climate, Energy and Building). This means that the emission inventory is finalised no later than March 15, whereupon the official approval is done prior to the reporting deadlines under the UNFCCC and the Kyoto Protocol.

1.3 Brief description of the process of inventory preparation. Data collection and processing, data storage and archiving

The background data (activity data and emission factors) for estimation of the Danish emission inventories is collected and stored in central databases located at the Department of Environmental Science (ENVS), Aarhus University. The databases are in Access format and handled with software developed by the European Environmental Agency and developed originally by the former National Environmental Research Institute (NERI), but is now maintained and further developed by ENVS. As input to the databases, various sub-models are used to estimate and aggregate the background data in order to fit the format and level in the central databases. The methodologies and data sources used for the different sectors are described in Chapter 1.4 and Chapters 3 to 9. As part of the QA/QC plan (Chapter 1.6), the data structure for data processing supports the pathway from collection of raw data to data compilation, modelling and final reporting.

For each submission, databases and additional tools and submodels are frozen together with the resulting CRF-reporting format. This material is placed on central institutional servers, which are subject to routine back-up services. Material, which has been backed up, is archived safely. A further documentation and archiving system is the official journal for DCE. In this journal system, correspondence, both in-going and out-going, is registered, which in this case involves the registration of submissions and communication on inventories with the UNFCCC Secretariat, the European Commission, review teams, etc.

Figure 1.1 shows a schematic overview of the process of inventory preparation. The figure illustrates the process of inventory preparation from the first step of collecting external data to the last step, where the reporting schemes are generated for the UNFCCC and EU (in the CRF format (Common Reporting Format)) and to the United Nations Economic Commission for Europe/Cooperative Programme for Monitoring and Evaluation of the Long-range Transmission of Air Pollutants in Europe (UNECE/EMEP) (in the NFR format (Nomenclature For Reporting)). For data handling, the software tool is CollectER (Pulles et al., 1999) and for reporting the software tool is the CRF reporter tool developed by the UNFCCC Secretariat together with additional tools originally developed by NERI, but now maintained and further developed by ENVS. Data files and programme files used in the inventory preparation process are listed in Table 1.1.

Table 1.1 List of current data structure; data files and programme files in use.

QA/QC Level	Name	Application type	Path	Type	Input sources
4 store	CFR Submissions (UNFCCC and EU)	External report	U:\ST_ENVS-Luft-Emi\Inventory\AllYears\8_AllSectors\Level_4a_Storage\	MS Excel, xml	CRF Reporter
4 store	NFR Report	External report	U:\ST_ENVS-Luft-Emi\Inventory\AllYears\8_AllSectors\Level_4a_Storage\	xls	NRF Report N8 Process
3 process	CRF Reporter	Management tool	Working path: local machine Archive path: U:\ST_ENVS-Luft-Emi\Inventory\AllYears\8_AllSectors\Level_3b_Processes	(exe + mdb)	National Compliler and Importer2CRF(xml) and IDAtoCRF(xml)
3 process	NRF Report N8 Process	Helptool	U:\ST_ENVS-Luft-Emi\Inventory\AllYears\8_AllSectors\Lev	Excel	NERIRep and Report Template (xls)

			el_3b_Processes\NFR		
3 process	Importer2CRF	Help tool	U:\ST_ENVS-Luft-Emi\Inventory\AllYears\8_AllSectors\Level_3b_Processes	MS Access	CRF Reporter, CollectEr2CRF, and excel files
3 process	CollectER2CRF	Help tool	U:\ST_ENVS-Luft-Emi\Inventory\AllYears\8_AllSectors\Level_3b_Processes	MS Access	NERIRep
3 proces	IDA2CRF	Help tool	U:\ST_ENVS-Luft-Emi\Inventory\AllYears\8_AllSectors\Level_3b_Processes	MS Access	IDA_backend
2 process 3 store	NERIRep	Help tool	Working path: I:\ROSPROJ\LUFT_EMI\DMURep	MS Access	CollectER databases; dk1972.mdb..dkxxxx.mdb and IDA_backend
2 process	CollectER	Management tool	Working path: local machine Archive path: U:\ST_ENVS-Luft-Emi\Inventory\AllYears\8_AllSectors\Level_2b_Processes	(exe +mdb)	Sector Expert
2 store	dk1980.mdb.dkxxxx.mdb	Datastore	U:\ST_ENVS-Luft-Emi\Inventory\AllYears\8_AllSectors\Level_2a_Storage	MS Access	CollectER
1 process	IDA	Management	U:\ST_ENVS-Luft-Emi\Agriculture\InventoryAgricultureData	MS Access	Sector Expert
1 store	IDA_Backend	Datastore	U:\ST_ENVS-Luft-Emi\Agriculture\InventoryAgricultureData	MS Access	IDA

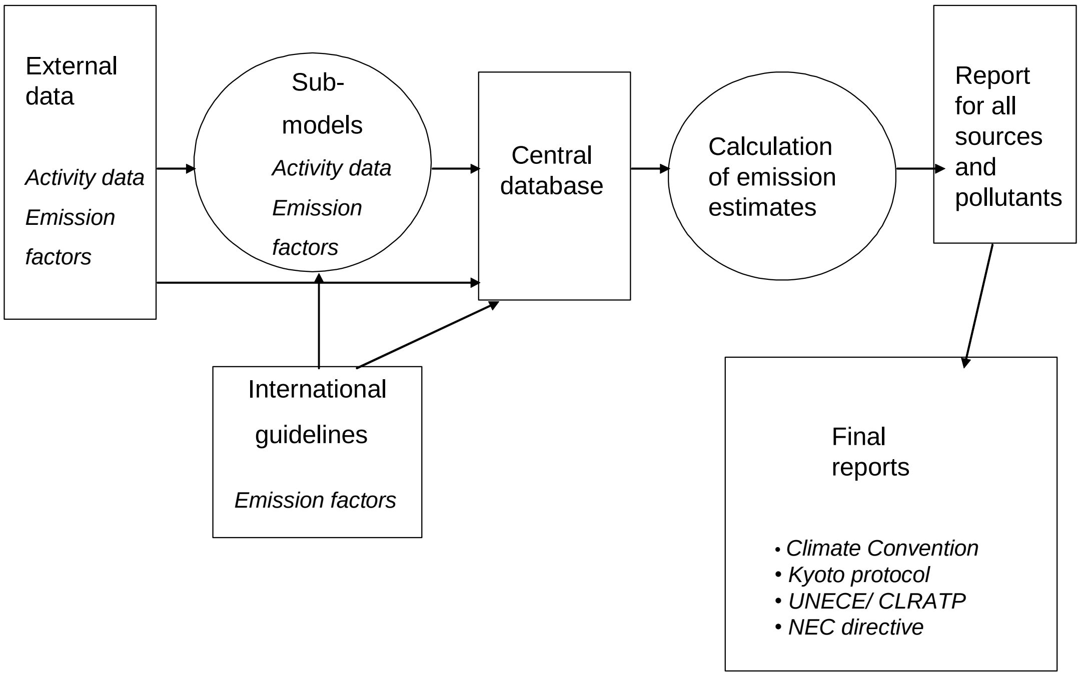


Figure 1.1 Schematic diagram of the process of inventory preparation.

Denmark has different geographical definitions for different submissions. Under the European Union only mainland Denmark is included. For the reporting under the Kyoto Protocol the submission includes Denmark and Greenland, while the reporting under the UNFCCC includes Denmark, Greenland and the Faroe Islands.

Due to the different geographical scopes of the Danish inventory submissions it is necessary to operate three independent installations of the CRF Reporter software on different virtual computers.

For the preparation of the Danish submission under the Kyoto Protocol the full Danish CRF is aggregated with the Greenlandic CRF and for the UNFCCC reporting this is also aggregated with the CRF of the Faroe Islands. The process of aggregation requires additional software tools and two additional installations of CRF Reporter. The process of aggregating the KP inventory is described in Chapter 17.

1.4 Brief general description of methodologies and data sources used

Denmark's air emission inventories are based on the Revised 1996 Intergovernmental Panel on Climate Change (IPCC) Guidelines for National Greenhouse Gas Inventories (IPCC, 1996), the Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories (IPCC, 2000), the Good Practice Guidance for Land Use, Land-Use Change and Forestry (IPCC, 2003) and the CORINAIR methodology. CORINAIR (COoRdination of INformation on AIR emissions) is a European air emission inventory programme for national sector-wise emission estimations, harmonised with the IPCC guidelines. To ensure estimates are as timely, consistent, transparent, accurate and comparable as possible, the inventory programme has developed calculation methodologies for most subsectors and software for storage and further data processing (EMEP-/CORINAIR, 2007).

A thorough description of the CORINAIR inventory programme used for Danish emission estimations is given in Illerup et al. (2000). The CORINAIR calculation principle is to calculate the emissions as activities multiplied by emission factors. Activities are numbers referring to a specific process generating emissions, while an emission factor is the mass of emissions per unit activity. Information on activities to carry out the CORINAIR inventory is largely based on official statistics. The most consistent emission factors have been used, either as national values or default factors proposed by international guidelines.

A list of all subsectors at the most detailed level is given in Illerup et al. (2000) together with a translation between CORINAIR and IPCC codes for sector classifications.

1.4.1 Stationary Combustion Plants

Stationary combustion plants are part of the CRF emission sources *1A1 Energy Industries*, *1A2 Manufacturing Industries* and *1A4 Other sectors*.

The Danish emission inventory for stationary combustion plants is based on the CORINAIR system described in Illerup et al. (2000). The emission inventory for stationary combustion is based on activity rates from the Danish energy statistics. General emission factors for various fuels, plants and sectors have been determined. Some large plants, such as power plants, are registered individually as large point sources and plant-specific emission data are used.

The fuel consumption rates are based on the official Danish energy statistics prepared by the Danish Energy Agency (DEA). DCE aggregates fuel consumption rates to SNAP categories. The fuel consumption of the NFR category 1A4 Manufacturing industries and construction is disaggregated to subsectors according to the DEA data prepared and reported to Eurostat.

For each of the fuel and SNAP categories (sector and e.g. type of plant), a set of general emission factors has been determined. Some emission factors refer to the EMEP/EEA guidebook and some are country specific and refer to Danish legislation, Danish research reports or calculations based on emission data from a considerable number of plants.

Some of the large plants, such as e.g. power plants and municipal waste incineration plants are registered individually as large point sources and emission data from the actual plants are used. This enables use of plant specific emission factors that refer to emission measurements stated in annual environmental reports, etc. At present, the emission factors for CH_4 and N_2O are, however, not plant-specific, whereas emission factors for SO_2 and NO_X often are. For CO_2 it was possible to use data reported under the EU-ETS in the emission inventory from 2006. Therefore it was possible to derive some plant specific CO_2 emission factors for coal and oil fired power plants.

The CO_2 from incineration of the plastic part of municipal waste is included in the Danish inventory.

In addition to the detailed emission calculation in the national approach, CO_2 emission from fuel combustion is aggregated using the reference approach. In 2012, the CO_2 emission inventory based on the reference approach and the national approach, respectively, differ by 0.97 %.

Please refer to Chapter 3.2 and Annex 3A for further information on the emission inventory for stationary combustion plants.

1.4.2 Transport

The emissions from transport, referring to SNAP category 07 (road transport) and the sub-categories in 08 (other mobile sources), are made up in the IPCC categories: 1A2f (Industry-other), 1A3a (Civil aviation), 1A3b (road transport), 1A3c (Railways), 1A3d (Navigation), 1A4a (Commercial and Institutional), 1A4b (Residential), 1A4c (Agriculture/forestry/fisheries) and 1A5 (Other).

An internal DCE model with a structure similar to the European COPERT IV emission model (EMEP/EEA, 2009) is used to calculate the Danish annual emissions for road traffic. The emissions are calculated for operationally hot engines, during cold start and fuel evaporation. The model also includes the emission effect of catalyst wear. Input data for vehicle stock and mileage is obtained from DTU Transport and Statistics Denmark, and is grouped according to average fuel consumption and emission behaviour. For each group, the emissions are estimated by combining vehicle type and annual mileage figures with hot emission factors, cold:hot ratios and evaporation factors (Tier 2 approach).

For air traffic, from 2001 onwards estimates are made on a city-pair level, using flight data provided by the Danish Civil Aviation Agency (CAA-DK) for flights between Danish airports and flights between Denmark and Greenland/Faroe Islands), and LTO and distance-related emission factors from the CORINAIR guidelines (Tier 2 approach). For previous years, the background data consists of LTO/aircraft type statistics from Copenhagen Airport and total LTO numbers from CAA-DK. With appropriate assumptions, consistent time series of emissions are produced back to 1990 and include the findings from a Danish city-pair emission inventory in 1998.

Off-road working machines and equipment are grouped in the following sectors: inland waterways (pleasure craft), agriculture, forestry, industry, and household and gardening. The sources for stock and operational data are various branch organisations and key experts. In general, the emissions are calculated by combining information on the number of different machine types and their respective load factors, engine sizes, annual working hours and emission factors (Tier 2 approach).

The inventory for navigation consists of regional ferries, local ferries and other national sea transport (sea transport between Danish ports and between Denmark and Greenland/Faroe Islands). For regional ferries, the fuel consumption and emissions are calculated as a product of number of round trips per ferry route (Statistics Denmark), sailing time per round trip, share of round trips per ferry, engine size, engine load factor and fuel consumption/emission factor. The estimates take into account the changes in emission factors and ferry specific data during the inventory period.

For the remaining navigation categories, the emissions are calculated simply as a product of total fuel consumption and average emission factors. For each inventory year, this emission factor average comprises the emission factors for all present engine production years, according to engine life times.

Please refer to Chapter 3.3 and Annex 3B for further information on emissions from transport.

1.4.3 Fugitive emissions from fuels

Fugitive emissions from oil (1.B.2.a)

Fugitive emissions from oil are estimated according to the methodology described in the Emission Inventory Guidebook (EMEP/EEA, 2009). The sources include offshore extraction of oil and gas, onshore oil tanks, onshore and offshore loading of ships, and gasoline distribution. Activity data is given in the Danish Energy Statistics by the Danish Energy Agency. The emission factors are based on the figures given in the guidebook except in the case of onshore oil tanks and gasoline distribution where national values are included.

The VOC emissions from petroleum refinery processes cover non-combustion emissions from feed stock handling/storage, petroleum products processing, and product storage/handling. SO_2 is also emitted from non-combustion processes and includes emissions from product processing and sulphur-recovery plants. The emission calculations are based on information from the Danish refineries.

Fugitive emissions from natural gas (1.B.2.b)

Inventories of NMVOC emission from transmission and distribution of natural gas and town gas are based on annual environmental reports from the Danish gas transmission company and annual reports for the gas distribution companies. The annual gas composition is based on Energinet.dk.

Fugitive emissions from flaring (1.B.2.c)

Emissions from flaring offshore, in gas treatment and storage plants, and in refineries are included in the inventory. Emissions calculations are based on annual reports from the Danish Energy Agency and environmental reports from gas storage and treatment plants and the refineries. Calorific values are based on the reports for the EU ETS for offshore flaring, on annual gas quality data from Energinet.dk, and on additional data from the refineries. Emission factors are based on the Emission Inventory Guidebook (EMEP/EEA, 2009).

Please refer to Chapter 3.5 for further information on fugitive emissions from fuels.

1.4.4 Industrial processes and product use

Energy consumption associated with industrial processes and the emissions thereof are included in the Energy sector of the inventory. This is due to the overall use of energy balance statistics for the inventory.

There is only one producer of cement in Denmark, Aalborg Portland Ltd. The activity data for the production of cement clinker is obtained from the company and the CO_2 emission is from the company report to EU-ETS. The methodology is approved by the Danish Energy Agency and the yearly emission estimate is in accordance with the methodology.

The reference for the activity data for production of lime, hydrated lime, expanded clay products and bricks, is the production statistics from the manufacturing industries, published by Statistics Denmark.

Limestone is used for the refining of sugar as well as for wet flue gas cleaning at power plants and waste incineration plants. The reference for the activity data is Statistics Denmark for sugar, Energinet.dk for gypsum from power plants combined with specific information on consumption of $CaCO_3$ at specific power plants and National Waste Statistics for gypsum from waste incineration. The emission factors are based on stoichiometric relations between consumption of $CaCO_3$ and gypsum generation as well as consumption of lime for sugar refining and precipitation with CO_2. This information is supplemented with company reports to EU-ETS.

The reference for the activity data for asphalt roofing is Statistics Denmark for consumption of roofing materials, combined with technical specifications for roofing materials produced in Denmark. The emission factors are default factors.

For road paving with asphalt the reference for the activity data is Statistics Denmark for consumption of asphalt and cut-back asphalt. The emission factors are default factors for consumption of asphalt and an estimated emission factor for cut-back asphalt based on the statistics on the emission of NMVOC compiled by the industrial organisations in question.

The reference for activity data for the production of glass and glass wool are obtained from the producers published in their environmental reports. Emission factors are based on stoichiometric relations between raw materials and CO_2 emissions. This information is supplemented with company reports to EU-ETS.

The production of lime and yellow bricks gives rise to CO_2 emissions. The emission factors are based on stoichiometric relations, assumption on $CaCO_3$ content in clay as well as a default emission factor for expanded clay products. This information is supplemented with company reports to EU-ETS.

There was one producer of nitric acid in Denmark. The data in the inventory relies on information from the producer. The producer reported emissions of NO_x and NH_3 as measured emissions and emissions of N_2O for 2003 as estimated emissions. The emission of N_2O in 2005 and forward is not occurring as the nitric acid production was closed down in the middle of 2004.

There is one producer of catalysts in Denmark. The data in the inventory relies on information published by the producer in environmental reports.

There was one steelwork in Denmark. The activity data as well as data on consumption of raw materials (coke) has been published by the producer in environmental reports. Emission factors are based on stoichiometric relations between raw materials and CO_2 emission. The electro steelwork was closed in 2005.

The inventory on F-gases (HFCs, PFCs and SF_6) is based on work carried out by the Danish Consultant Company "Planmiljø". Their yearly report (DEPA, 2014) documents the inventory data up to the year 2012. The methodology is implemented for the whole time series 1990-2012, but full information on activities only exists since 1995.

Please refer to Chapter 4 for further information on industrial processes.

The approach for calculating the emissions of Non-Methane Volatile Organic Carbon (NMVOC) from industrial and household use in Denmark focuses on single chemicals rather than activities. This leads to a clearer picture of the influence from each specific chemical, which enables a more detailed differentiation on products and the influence of product use on emissions. The procedure is to quantify the use of the chemicals and estimate the fraction of the chemicals that is emitted as a consequence of use.

Outputs from the inventory are: a list where the approximately 40 most predominant NMVOCs are ranked according to emissions to air; specification of emissions from industrial sectors and from households - contribution from each chemical to emissions from industrial sectors and households; tidal (annual) trend in NMVOC emissions, expressed as total NMVOC and single chemical, and specified in industrial sectors and households.

This emission inventory includes N_2O emissions from the use of anaesthesia for 2000 onwards. Five companies sell N_2O in Denmark and only one company produces N_2O. Due to confidentiality no data on produced amount are available and thus the emissions related to N_2O production are unknown. An emission factor of one is assumed for all use, which equals the sold amount to the emitted amount.

Emissions from other product use such as fireworks, tobacco and charcoal for grilling are included in the inventory. Activity data on consumption of fireworks, tobacco and charcoal are obtained from Statistics Denmark. The emission factors used refer to international literature.

Please refer to Chapter 4 and Annex 3C for further information on the emission inventory for solvent and other product use.

1.4.5 Agriculture

The calculation of emissions from the agricultural sector is based on methods described in the IPCC Guidelines (IPCC, 1996) and the Good Practice Guidance (IPCC, 2000). Activity data for livestock is on a one-year average basis from the agricultural statistics published by Statistics Denmark (2013). Data concerning the land use and crop yield is also from the agricultural statistics. Data concerning the feed consumption and nitrogen excretion is based on information from the Danish Centre for Food and Agriculture (Aarhus University). The CH_4 Implied Emission Factors for Enteric Fermentation and Manure Management are based on a Tier 2/CS approach for all animal categories except for poultry which are based on a Tier 1 approach. All livestock categories in the Danish emission inventory are based on an average of certain subgroups separated by differences in animal breed, age and weight class. The emissions from enteric fermentation for fur farming are estimated to be not applicable.

Emission of N_2O is closely related to the nitrogen balance. Thus, quite a lot of the activity data is related to the Danish calculations for ammonia emission (Mikkelsen et al., 2011). National standards are used to estimate the amount of ammonia emission. When estimating the N_2O emission the IPCC standard value is used for all emission sources. The emission of CO_2 from Agricultural Soils is included in the LULUCF sector.

A model-based system is applied for the calculation of the emissions in Denmark. This model (IDA – Integrated Database model for Agricultural emissions) is used to estimate emission from both greenhouse gases and ammonia. A more detailed description is published in Mikkelsen et al. (2011). The emissions from the agricultural sector are mainly related to livestock production. IDA works on a detailed level and includes around 38 livestock categories, and each category is subdivided according to housing type and manure type. The emissions are calculated from each subcategory and the emissions are aggregated in accordance with the livestock category given in the CRF.

To ensure data quality, both data used as activity data and background data used to estimate the emission factor are collected, and discussed in cooperation with specialists and researchers in different institutions. Thus, the emission inventory will be evaluated continuously according to the latest knowledge. Furthermore, time series of both emission factors and emissions in relation to the CRF categories are prepared. Any considerable variations in the time series are explained.

The uncertainties for assessment of emissions from enteric fermentation, manure management, agricultural soils and field burning of agricultural residue have been estimated based on a Tier 1 and Tier 2 approach. The most significant uncertainties are related to the emissions of N_2O from agricultural soils.

A more detailed description of the methodology for the agricultural sector is given in Chapter 5 and Annex 3D.

1.4.6 Land Use, Land Use Change and Forestry

A complete Land Use Change matrix based on satellite imaging of the whole Danish land area together with cadastral information has been prepared for the six major area classes. This has improved the coverage and the quality of the inventory substantially.

CO_2 emissions from cropland and grassland are based on census data from Statistics Denmark as regards size of area and crop yield combined with GIS-analysis on land use from the EU agricultural subsidiary system. This gives a very high accuracy for land use. All applicable pools are reported for Cropland and Grassland. The emission from mineral soils for cropland is estimated with a three-pooled dynamical soil carbon model (C-TOOL). C-TOOL was initialised in 1980. The model is run for each region corresponding to former counties in Denmark. Emissions from organic soils in cropland are based on new nationally developed emission factors. For grassland IPCC Tier 1b values are used. National models have been developed for wooden perennial crops in cropland based on land use statistics from Statistic Denmark. These are of minor importance. Sinks in hedgerows are calculated based on a nationally developed model. The area with hedgerows is estimated from information on hedgerows established with financial support from the Danish Government and aerial photos. Emissions from liming are calculated from annual sales data collected by the Danish Agricultural Advisory Centre, combined with the acid neutralisation capacity for each lot produced.

For wetlands emissions are reported from peat extraction areas. Natural wetlands are not reported. A comprehensive programme for restoration of wetlands is implemented in Denmark. Other land uses converted to wetlands is therefore reported.

For the purpose of having estimates for the KP accounting other land uses converted to settlements is reported but not settlements remaining as settlements.

No estimates are made for other land remaining other land and no conversion of land to other land is occurring. For the purpose of having estimates for the KP accounting estimates for living biomass are provided for land converted from other land to other land uses.

1.4.7 Waste

For 5.A Solid waste disposal, only managed waste disposal sites are of importance and registered; i.e. unmanaged and illegal disposal of waste is considered to play a negligible role in the context of this category. The CH_4 emission at the Danish SWDSs is based on a First Order Decay (FOD) model according to an IPCC tier 2 approach (IPCC 1997, 2000 and 2006). Data on waste types and amounts deposited at solid waste disposal sites is according to the official registration collected by the Danish Environmental Protection Agency (DEPA, 2013). The model calculations are performed using landfill site characteristics and statistics on the amounts of waste fractions deposited each year. Improved documentation of the methodology, input parameter data including uncertainty analysis is described in Chapter 7.2.

Regarding 5.C Incineration and open burning of waste, all municipal, industrial, hazardous and medical waste incinerated is used for energy and heat production. This production is included in the energy statistics, hence emissions are included in the CRF under fuel combustion activities (CRF sector 1A), and more specifically waste incineration takes place in CRF sectors 1A1a, 1A2f and 1A4a. For the 2011 submission reporting in this category covers incineration of corpses and carcasses. The activity data are obtained from the National Association of Danish Crematoria and the three facilities incinerating carcasses.

For 5.D Wastewater treatment and discharge, country-specific methodologies are used for calculating the emissions of CH_4 and N_2O at wastewater treatment plants (WWTPs). Recent expert review teams (ERTs) in the UNFCCC review have requested better documentation of derived EF and national activity data, and improvements has been performed with respect to dividing the contributions to the net methane emission into specific treatment processes. Fugitive methane releases from the municipal and private WWTPs have been divided into contributions from 1) the sewer system, primary settling tank and biological N and P removal processes, 2) from anaerobic treatment processes in closed systems with biogas extraction and combustion for energy production and 3) septic tanks. N_2O formation and releases during the treatment processes at the WWTPs and from discharged effluent waste water are included. Documentation of the improved methodology, emission factors and activity data are described in Chapter 7.3.

In CRF category 5.E Other emissions from accidental fires have been reported.

Please refer to Chapter 7 and Annex 3F for further information on emission inventories for waste.

1.4.8 KP-LULUCF

Regarding the possibility of including in the first commitment period emissions and removals associated with land use, land-use change and forestry activities under Article 3.4 of the Kyoto Protocol, Denmark decided to include emissions and removals from Forest Management (FM), Cropland Management (CM) and Grazing land Management (GM).

The national system has identified land areas associated with the activities under Article 3.4 of the Kyoto Protocol in accordance with definitions, modalities, rules and guidelines relating to land use, land-use change and forestry activities under the protocol by satellite monitoring, use of the EU Land Parcel Information System (LPIS), detailed crop information data on field level, soil mapping and sample plots from the National Forest Inventory (NFI). All land converted from other activities into cropland and grassland is accounted for. No land can leave elected areas under art. 3.4.

The forest definition adopted in the NFI is identical to the FAO definition (TBFRA, 2000). It includes “wooded areas larger than 0.5 ha, that are able to form a forest with a height of at least 5 m and crown cover of at least 10 %”. The minimum width is 20 m. For afforestation the carbon stock change in the period 1990 - 2011 is calculated based on the area of afforestation, the information on species composition from the Forest Census 2000 and from the NFI. In the afforestation a steady increase in carbon stock is found. The estimates for the carbon pools in the afforestation are similar to previous estimates, with a slight increase due to the new knowledge on species composition, average carbon stock in those areas based on the NFI data and new data on the carbon stock in soils. Carbon stock change caused by deforestation is estimated based on the deforested area and the mean values of carbon stock in the total forest area. This is due to the fact that no specific knowledge is available on the carbon pools of the deforested areas. For Forest Management census and NFI data are used.

For cropland and grassland the same methodology is used in the KP reporting as used in the Convention reporting.

Please see Chapter 10 for further details.

1.4.9 Use of EU Emission Trading Scheme data

In 2004 the first guidelines for the monitoring and reporting of greenhouse gas emissions pursuant to the EU Emission Trading Scheme (ETS) Directive (2003/87/EC) were implemented (EU Commission, 2004). These were updated in 2007 and are available from the EU Commission website (EU Commission, 2007).

The Danish emission inventory only includes data from plants using higher tier methods as defined in the EU decision establishing guidelines for monitoring and reporting (EU Commission, 2007). In the Guidelines the specific methods for determining carbon contents, oxidation factor and calorific value are specified.

In the Danish inventory plant or activity based CO_2 emission factors have been derived for power plants combusting coal and oil, refinery gas and flare gas in refineries, fuel gas and flare gas at off-shore installations, cement production, production of brick and tiles and lime production. For all these sources the EU ETS reports are only used in the Danish inventory for plants using high tier methods. The EU ETS data have been applied for the years 2006 onwards.

The EU ETS reporting guidelines emphasizes the need for a high quality reporting through ensuring completeness, consistency, accuracy, transparency and faithfulness. The quality criteria as defined under the EU ETS reporting guidelines are in complete agreement with the principles in the IPCC good practice guidance. For all activities covered by the EU ETS installations are divided into three categories (A, B and C) depending on the annual CO_2 emission. A category A installation has an annual emission of less than 50 Gg CO_2, a category B installation has an annual emission of between 50 and 500 Gg CO_2 and a category C installation has an annual emission of more than 500 Gg CO_2. For each activity Table 1 of the EU ETS guidelines (EU Commission, 2007) specifies the minimum tier level for the different calculation parameters. An example for combustion installations is shown in Table 1.2, the full list for all activities is available in the EU ETS guidelines (EU Commission, 2007).

Table 1.2 Example of minimum requirements in EU ETS guidelines (EU Commission, 2007).

	Activity data						Emission factor			Oxidation factor		
	Fuel flow			Net calorific value								
Activity	A	B	C	A	B	C	A	B	C	A	B	C
Commercial standard fuels	2	3	4	2a/2b	2a/2b	2a/2b	2a/2b	2a/2b	2a/2b	1	1	1
Other gaseous and liquid fuels	2	3	4	2a/2b	2a/2b	3	2a/2b	2a/2b	3	1	1	1
Solid fuels	1	2	3	2a/2b	3	3	2a/2b	3	3	1	1	1

The determination of the variables needed for the emission calculation has to be done in accordance with international standards. It is not possible to list all the relevant standards here, but an overview is available in annex 1, chapter 13 of the EU ETS guidelines. There are also demands concerning sampling methods and frequency of analysis.

As an example the tier 3 regarding fuel flow for fuel combustion, corresponds to a determination of the fuel consumption with an maximum uncertainty of 2.5 % taking into account possible effects of stock change. Tier 4 has a maximum uncertainty of 1.5 %. These uncertainties are very low and are in line with what could be expected from a well-functioning energy statistics system. More information regarding the use of EU ETS data in the specific subsectors of the inventory is included in Chapter 3.2.5 (CHP plants), Chapter 3.5.2 (Refineries and off-shore installations) and Chapter 4.2.2 (Cement production and other mineral products).

The operators shall establish, document, implement and maintain effective data acquisition and handling activities. This means assigning responsibilities for the quality process, as well as quality assurance, reviews and validation of data. Furthermore an independent verification ensuring that emissions have been monitored in accordance with the EU ETS guidelines and that reliable and correct emission data are reported. There are also demands that records and documentation of the control activities must be stored for at least 10 years. The demands for the QA/QC system in the EU ETS guidelines are fully comparable to the requirements in the IPCC good practice guidance. Even so, DCE also performs QC checks of the data received as part of company reporting under EU ETS. This includes comparing the reported parameters with previous years, identifying outliers etc. In case DCE detects what is considered to be outliers DCE contacts the Danish Energy Agency, which is the regulating authority for the EU ETS system in Denmark.

1.5 Brief description of key categories

The key category analysis described in this section covers only Denmark. The aggregation used for the analysis is not directly suited for emissions from Greenland. If Greenlandic emissions were included in the analysis, they would not affect the overall results of the key category analysis. For a key category analysis covering Greenland refer to Chapter 16 and for Denmark and Greenland refer to Chapter 17.

All KCA have been carried out in accordance with IPCC Guidelines (IPCC, 2006).

The KCA for Denmark includes a total of 12 different analyses:

- Base year, reporting year and trend
- Including and excluding LULUCF
- Approach 1 and approach 2

The KCA is based on 210 emission source categories including 28 LULUCF source categories.

The 12 different KCA for Denmark point out 25-52 key source categories each and a total of 72 different key source categories. The number of key categories in each of the main sectors is: energy 40, IPPU 6, agriculture 14, LULUCF 9 and waste 3.

Approach 1 point out mainly the large emission sources as key categories and thus CO_2 emission from stationary and mobile combustion are important key categories. Approach 2 point out some of the sources with larger uncertainty rates.

Table 1.3 shows the 70 source categories that are key categories in at least one of the six key category analysis including LULUCF. The table includes ranking in the analysis. A similar table for the KCAs excluding LULUCF is included in Annex 1.

The categorisation and detailed results of each of the KCAs are included in Annex 1.

Table 1.3 Key categories for KCAs including LULUCF. The numbers show the ranking in each of the KCAs.

IPCC Source Categories (LULUCF included)		GHG	Level Approach 1	Level Approach 1	Trend Approach 1	Level Approach 2	Level Approach 2	Trend Approach 2
			1990	**2013**	**1990-2013**	**1990**	**2013**	**1990-2013**
Energy	1A Stationary combustion, Coal, ETS data	CO_2		1	2		39	25
Energy	1A Stationary combustion, Coal, no ETS data	CO_2	1	28	1	17		4
Energy	1A Stationary combustion, Fossil waste, ETS data	CO_2		13	8			30
Energy	1A Stationary combustion, Fossil waste, no ETS data	CO_2	22	21	26		40	
Energy	1A Stationary combustion, Petroleum coke, ETS data	CO_2		23	14			
Energy	1A Stationary combustion, Petroleum coke, no ETS data	CO_2	28		21			
Energy	1A Stationary combustion, Residual oil, ETS data	CO_2		30	19			
Energy	1A Stationary combustion, Residual oil, no ETS data	CO_2	7		7			36
Energy	1A Stationary combustion, Gas oil	CO_2	3	18	6	29		24
Energy	1A Stationary combustion, Kerosene	CO_2	29		23			
Energy	1A1b Stationary combustion, Petroleum refining, Refinery gas	CO_2	17	15	22			
Energy	1A Stationary combustion, Natural gas, onshore	CO_2	6	3	4		36	31
Energy	1A1c_ii Stationary combustion, Oil and gas extraction, Off shore gas turbines, Natural gas	CO_2	26	8	9			
Energy	1A4b_i Stationary combustion, Residential wood combustion	CH_4				32	28	29
Energy	1A4b_i/1A4c_i Stationary Combustion, Residential and agricultural straw combustion	CH_4				35		
Energy	1A1 Stationary Combustion, Solid fuels	N_2O				23	33	32
Energy	1A1 Stationary Combustion, Gaseous fuels	N_2O					25	23
Energy	1A1 Stationary Combustion, Waste	N_2O						42
Energy	1A1 Stationary Combustion, Biomass	N_2O					30	20
Energy	1A2 Stationary Combustion, Liquid fuels	N_2O				21	37	15
Energy	1A2 Stationary Combustion, Gaseous fuels	N_2O					42	50
Energy	1A4 Stationary Combustion, Liquid fuels	N_2O				30		26
Energy	1A4 Stationary Combustion, Gaseous fuels	N_2O					35	34
Energy	1A4b_i Stationary Combustion, Residential wood combustion	N_2O					20	14
Energy	1.A.2.g Industry (mobile)	CO_2	16	11	18	16	10	11
Energy	1.A.3.a Civil aviation	CO_2	34					
Energy	1.A.3.b Road Transport	CO_2	2	2	3	13	9	7
Energy	1.A.3.c Railways	CO_2	33	33				
Energy	1.A.3.d Navigation (large vessels)	CO_2	19	27				
Energy	1.A.4.a Commercial/Institutional (mobile)	CO_2		37			43	38
Energy	1.A.4.c ii Agriculture (mobile)	CO_2	12	10	30	19	16	35
Energy	1.A.4.c iii Fisheries	CO_2	21	26				
Energy	1.A.5.b Other (small boats)	CO_2		40				
Energy	1.A.2.g Industry (mobile)	N_2O				33	31	28
Energy	1.A.3.d Navigation (large vessels)	N_2O				27	38	48
Energy	1.A.4.c ii Agriculture (mobile)	N_2O				26	24	45
Energy	1.A.4.c iii Fisheries	N_2O				31	34	
Energy	1.B.2.c.2.ii Flaring, gas	CO_2	31	35				
Energy	1.B.2.c.2.ii Flaring, gas	N_2O				12	11	
IPPU	2A1 Cement production	CO_2	15	16	27			
IPPU	2D2 Paraffin wax use	CO_2						37
IPPU	2B2 Nitric acid production	N_2O	13		10	22		8
IPPU	2F1 Refrigeration and air conditioning	HFCs		19	11		14	3
IPPU	2F2 Foam blowing agents	HFCs				34		33
IPPU	2G2 SF6 and PFCs from other product use	SF6						43
Agriculture	3A Enteric Fermentation	CH_4	5	4	12	7	6	17
Agriculture	3B Manure Management	CH_4	10	7	13	15	12	16
Agriculture	3B Manure Management	N_2O	18	22		6	8	46
Agriculture	3B5 Atmospheric deposition	N_2O				25	26	
Agriculture	3Da1 Inorganic N fertilizer	N_2O	8	14	16	3	5	2
Agriculture	3Da2a Animal manure applied to soils	N_2O	14	12	24	5	2	5
Agriculture	3Da3 Urine and dung deposited by grazing animals	N_2O	32	36		20	21	40
Agriculture	3Da4 Crop Residues	N_2O	23	20	25	8	7	6
Agriculture	3Da5 Mineralization	N_2O		38		24	19	49
Agriculture	3Da6 Cultivation of organic soils	N_2O	27	29		11	13	41
Agriculture	3Db1 Atmospheric deposition	N_2O	30	39		18	23	22
Agriculture	3Db2 Leaching	N_2O	25	31		10	15	21

IPCC Source Categories (LULUCF included)		GHG	Level Approach 1	Level Approach 1	Trend Approach 1	Level Approach 2	Level Approach 2	Trend Approach 2
			1990	**2013**	**1990-2013**	**1990**	**2013**	**1990-2013**
Agriculture	3G Liming	CO_2	24	34	29	9	18	9
LULUCF	4.A.1 Forest land remaining forest land, Living biomass	CO_2		5	5		22	10
LULUCF	4.A.1 Forest land remaining forest land, Dead organic matter	CO_2		24	15			51
LULUCF	4.A.1 Forest land remaining forest land, Organic soils	CO_2		32		28	32	47
LULUCF	4.B.1 Cropland remaining cropland, Mineral soils	CO_2	11	9	28	4	4	13
LULUCF	4.B.1 Cropland remaining cropland, Organic soils	CO_2	4	6	20	2	1	12
LULUCF	4.C.1 Grassland remaining grassland, Organic soils	CO_2	20	25		14	17	
LULUCF	4.E.2 Other land uses converted to settlements	CO_2						39
LULUCF	4.G Harvested wood products	CO_2					41	27
LULUCF	4(III) Mineralization/immobilization	N_2O						44
Waste	5.A Solid waste disposal	CH_4	9	17	17	1	3	1
Waste	5.B.1 Composting	CH_4					27	19
Waste	5.B.1 Composting	N_2O					29	18

1.5.1 KP-LULUCF

See Chapter 10.9.1 for discussion on the key category analysis of KP-LULUCF.

1.6 Information on QA/QC plan including verification and treatment of confidential issues where relevant

1.6.1 Introduction

This section outlines the Quality Control (QC) and Quality Assurance (QA) plan for greenhouse gas emission inventories performed by DCE (Sørensen et al., 2005; Nielsen et al., 2013). The plan is in accordance with the guidelines provided by the IPCC (IPCC, 1996), and the Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories (IPCC, 2000). The ISO 9000 standards are also used as important input for the plan.

The QA/QC plan also covers Greenland. DCE receives the data corresponding to data processing level 3 and data storage level 4 and the data undergoes the same QA/QC procedure as the Danish data, some further QC checks are described in Chapter 17. The QA/QC specific to the Greenlandic emission inventory is described in Chapter 16.

1.6.2 Concepts of quality work

The quality planning is based on the following definitions as outlined by the ISO 9000 standards as well as the Good Practice Guidance (IPCC, 2000):

- Quality management (*QM*) Coordinates activity to direct and control with regard to quality.
- Quality Planning (*QP*) Defines quality objectives including specification of necessary operational processes and resources to fulfil the quality objectives.
- Quality Control (*QC*) Fulfils quality requirements.
- Quality Assurance (*QA*) Provides confidence that quality requirements will be fulfilled.

- Quality Improvement (*QI*) Increases the ability to fulfil quality requirements.

The activities are considered inter-related in this report as shown in Figure 1.2.

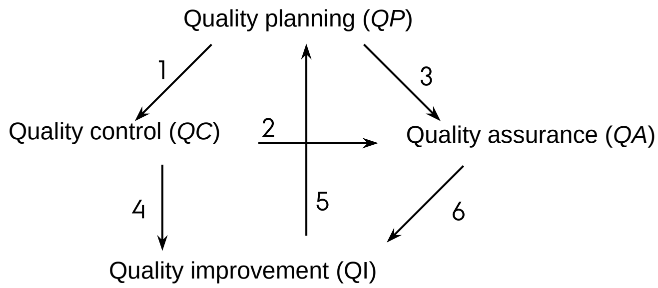


Figure 1.2 Interrelation between the activities with regard to quality. The arrows are explained in the text below this figure.

1: The *QP* sets up the objectives and, from these, measurable properties valid for the *QC*.

2: The *QC* investigates the measurable properties that are communicated to *QA* for assessment in order to ensure sufficient quality.

3. The *QP* identifies and defines measurable indicators for the fulfilment of the quality objectives. This yields the basis for the *QA* and has to be supported by the input coming from the *QC*.

4: The result from *QC* highlights the degree of fulfilment for every quality objective. It is thus a good basis for suggestions for improvements to the inventory to meet the quality objectives.

5: Suggested improvements in the quality may induce changes in the quality objectives and their measurability.

6: The evaluation carried out by external authorities is important input when improvements in quality are being considered.

1.6.3 Definition of quality

A solid definition of quality is essential. Without such a solid definition, the fulfilment of the objectives will never be clear and the process of quality control and assurance can easily turn out to be a fuzzy and unpleasant experience for the people involved. On the contrary, in case of a solid definition and thus a clear goal, it will be possible the make a valid statement of "good quality" and thus form constructive conditions and motivate the inventory work positively. A clear definition of quality has not been given in the UNFCCCC guidelines. In the Good Practice Guidance, Chapter 8.2, however, it is mentioned that:

"Quality control requirements, improved accuracy and reduced uncertainty need to be balanced against requirements for timeliness and cost effectiveness." The statement of balancing requirements and costs is not a solid basis for QC as long as this balancing is not well defined.

The resulting standard of the inventory is defined as being composed of accuracy and regulatory usefulness. The goal is to maximise the standard of the inventory and the following statement defines the quality objective:

The quality objective is only inadequately fulfilled if it is possible to make an inventory of a higher standard without exceeding the frame of resources.

1.6.4 Definition of Critical Control Points (*CCP*)

A Critical Control Point (*CCP*) is defined in this submission as an element or an action which needs to be taken into account in order to fulfil the quality objectives. Every *CCP* has to be necessary for the objectives and the *CCP* list needs to be extended if other factors, not defined by the *CCP* list, are needed in order to reach at least one of the quality objectives.

The objectives for the *QM*, as formulated by IPCC (2000), are to improve elements of transparency, consistency, comparability, completeness and confidence. In the IPCC guidelines (IPCC, 1996), the element "confidence" is replaced by "accuracy" and in this plan "accuracy" is used.

The objectives for the *QM* are used as *CCP*s, including the elements mentioned above. The following explanation is given by IPCC guidelines (IPCC, 1996) for each *CCP*:

Transparency means that the assumptions and methodologies used for an inventory should be clearly explained to facilitate replication and assessment of the inventory by users of the reported information. The transparency of the inventories is fundamental to the success of the process for communication and consideration.

Consistency means that an inventory should be internally consistent in all its elements with inventories of other years. An inventory is consistent if the same methodologies are used for the base and for all subsequent years and if consistent datasets are used to estimate emissions or removals from source or sinks. Under certain circumstances, an inventory using different methodologies for different years can be considered to be consistent if it has been recalculated in a transparent manner in accordance with the Intergovernmental Panel on Climate Change (IPCC) guidelines and good practice guidance.

Comparability means that estimates of emission and removals reported by Annex I Parties in inventories should be comparable among Annex I parties. For this purpose, Annex I Parties should use the methodologies and formats agreed upon by the COP for estimating and reporting inventories. The allocation of different source/sink categories should follow the split of *Revised 1996 IPCC Guidelines for national Greenhouse Gas Inventories* (IPCC, 1996) at the level of its summary and sectoral tables.

Completeness means that an inventory covers all sources and sinks, as well as all gases, included in the IPCC guidelines as well as other existing relevant source/sink categories, which are specific to individual Annex I Parties and, therefore, may not be included in the IPCC guidelines. Completeness also means full geographic coverage of sources and sinks of an Annex I Party.

Accuracy is a relative measure of the exactness of an emission or removal estimate. Estimates should be accurate and should systematically neither over- nor underestimate emissions nor removals. Uncertainties on estimates should be reduced if possible. Appropriate methodologies should be used in accordance with the *IPCC good practice guidance*, to promote data accuracy in inventories.

The robustness against unexpected disturbance of the inventory work has to be high in order to secure high quality, which is not covered by the *CCP*s above. The correctness of the inventory is formulated as an independent objective. This is so because the correctness of the inventory is a condition for all other objectives to be effective. A large part of the Tier 1 procedure given by the Good Practice Guidance (IPCC, 2000) is actually checks for miscalculations and, thus, supports the objective of correctness. Correctness, as defined here, is not similar to accuracy, because the correctness takes into account miscalculations, while accuracy relates to minimizing the always present data-value uncertainty.

Robustness implies arrangement of inventory work as regards e.g. inventory experts and data sources in order to minimize the consequences of any unexpected disturbance due to external and internal conditions. A change in an external condition could be interruption of access to an external data source and an internal change could be a sudden reduction in qualified staff, where a skilled person suddenly leaves the inventory work.

Correctness has to be secured in order to avoid uncontrollable occurrence of uncertainty directly due to errors in the calculations.

The different *CCP*s are not independent and represent different degrees of generality. E.g. deviation from *comparability* may be accepted if a high degree of *transparency* is applied. Furthermore, there may even be a conflict between the different *CCP*s. E.g. new knowledge may suggest improvements in calculation methods for better *completeness*, but the same improvements may to some degree violate the *consistency* and *comparability* criteria with regard to earlier years' inventories and the reporting from other nations. It is, therefore, a multi-criteria problem of optimisation to apply the set of *CCP*s in the aim for good quality.

1.6.5 Process-oriented QC

The strategy is based on a process-oriented principle (ISO 9000 series) and the first step is, thus, to set up a system for the process of the inventory work. The product specification for the inventory is a dataset of emission figures and the process, thereby, equates with the data flow in the preparation of the inventory.

The data flow needs to support the QC/QA in order to facilitate a cost-effective procedure. The flow of data has to take place in a transparent way by making the transformation of data detectable. It should be easy to find the original background data for any calculation and to trace the sequence of calculations from the raw data to the final emission result. Computer programming for automated calculations and checking will enhance the accuracy and minimize the number of miscalculations and flaws in input value settings. Especially manual typing of numbers needs to be minimized. This assumes, however, that the quality of the programming has been verified to ensure the correctness of the automated calculations. Automated value control is also one of the important means to secure accuracy. Realistic uncertainty estimates are necessary for securing accuracy, but they can be difficult to produce due to the uncertainty related to the uncertainty estimates themselves. It is, therefore, important to include the uncertainty calculation procedures into the data structure as far as possible. The QC/QA needs to be supported as far as possible by the data structure; otherwise the procedures can easily become troublesome and subject to frustration.

Both data processing and data storage form the data structure. The data processing is carried out using mathematical operations or models. The models may be complicated where they concern human activity or be simple summations of lower aggregated data. The data storage includes databases and file systems of data that are either calculated using the data processing at the lower level, using input to new processing steps or even using both output and input in the data structure. The measure for quality is basically different for processing and storage, so these need to be kept separate in a well-designed quality manual. A graphical display of the data flow is seen in Figure 1.3 and explained in the following.

The data storage takes place for the following types of data:

***External Data*:** a single numerical value of a parameter coming from an external source. These data govern the calculation of *Emission calculation input.*

***Emission calculation input*:** Data for input to the final emission calculation in terms of data for release source strength and activity. The data is directly applicable for use in the standardized forms for calculation. These data are calculated using external data or represent a direct use of *External Data* when they are directly applicable for *Emission Calculations*.

***Emission Data*:** Estimated emissions based on the *emission calculation input.*

***Emission Reporting*:** Reporting of emission data in requested formats and aggregation level.

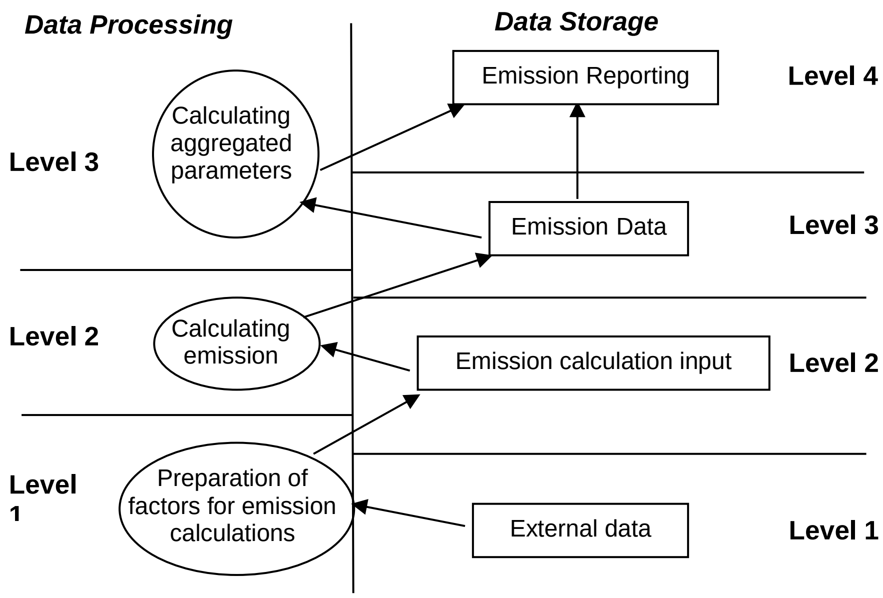


Figure 1.3 The general data structure for the emission inventory.

Key levels are defined in the data structure as:

Data storage Level 1, External data
Collection of external data for calculation of emission factors and activity data. The activity data are collected from different sectors and statistical surveys, typically reported on a yearly basis. The data consist of raw data, having an identical format to the data received and gathered from external sources. Level 1 data acts as a base-set, on which all subsequent calculations are based. If alterations in calculation procedures are made, they are based on the same dataset. When new data are introduced they can be implemented in accordance with the QA/QC structure of the inventory.

Data storage Level 2, Data directly usable for the inventory
This level represents data that have been prepared and compiled in a form that is directly applicable for calculation of emissions. The compiled data are structured in a database for internal use as a link between more or less raw data and data that are ready for reporting. The data are compiled in a way that elucidates the different approaches in emission assessment: (1) directly on measured emission rates, especially for larger point sources, (2) based on activities and emission factors, where the value setting of these factors are stored at this level.

Data storage Level 3, Emission data
The emission calculations are reported by the most detailed figures and divided in sectors. The unit at this level is typically mass pr yr for the country. For sources included in the SNAP system, the SNAP level 3 is relevant. Internal reporting is performed at this level to feed the external communication of results.

Data storage Level 4, Final reports for all subcategories
The complete emission inventory is reported to UNFCCC at this level by summing up the results from every subcategory.

Data processing Level 1 Compilation of external data
Preparation of input data for the emission inventory based on the external data sources. Some external data may be used directly as input to the data processing at level 2, while other data needs to be interpreted using more or less complicated models, which takes place at this level. The interpretation of activity data is to be seen in connection with availability of emission factors and vice versa. These models are compiled and processed as an integrated part of the inventory preparation.

Data processing Level 2 Calculation of inventory figures
The emission for every subcategory is calculated, including the uncertainty for all sectors and activities. The summation of all contributions from subsources makes up the inventory.

Data processing Level 3 Calculation aggregated parameters
Some aggregated parameters need to be reported as part of the final reporting. This does not involve complicated calculations but important figures, e.g. implied emission factors at a higher aggregated level to be compared in time series and with other countries.

1.6.6 Definition of Point of Measurements (*PM*)

The *CCP*s have to be based on clear measurable factors - otherwise the *QP* will end up being just a loose declaration of intent. Thus, in the following, a series of *Points for Measuring* (*PM*) is identified as building blocks for a solid

QC. Table 8.1 in Good Practice Guidance is a listing of such *PM*s. However, the listing in Table 1.2 is an extended and modified listing, in comparison to Table 8.1 in the Good Practice Guidance supporting all the *CCP*s. The *PM*s will be routinely checked in the QC reporting and, when external reviews take place, the reviewers will be asked to assess the fulfilment of the *PM*s using a checklist system. The list of *PM*s is continually evaluated and modified to offer the best possible support for the *CCP*s. The actual list used is seen in Table 1.2.

Table 1.2 The list of *PM*s as used.

Level	CCP	Id	Description	
Data Storage level 1	1. Accuracy	DS.1.1.1	General level of uncertainty for every dataset including the reasoning for the specific values	Sectoral
		DS.1.1.2	Quantification of the uncertainty level of every single data value, including the reasoning for the specific values.	Sectoral
	2. Comparability	DS1.2.1	Comparability of the data values with similar data from other countries, which are comparable with Denmark, and evaluation of the discrepancy.	Sectoral
	3.Completeness	DS.1.3.1	Documentation showing that all possible national data sources are included, by setting down the reasoning behind the selection of datasets.	Sectoral
	4.Consistency	DS.1.4.1	The origin of external data has to be preserved whenever possible without explicit arguments (referring to other PMs)	Sectoral
	6.Robustness	DS.1.6.1	Explicit agreements between the external institution holding the data and DCE about the conditions of delivery	Sectoral
		DS.1.6.2	At least two employees must have a detailed insight into the gathering of every external dataset.	General
	7.Transparency	DS.1.7.1	Summary of each dataset including the reasoning behind the selection of the specific dataset	Sectoral
		DS.1.7.2	The archiving of datasets needs to be easily accessible for any person in the emission inventory	General
		DS.1.7.3	References for citation for any external dataset have to be available for any single number in any dataset.	Sectoral
		DS.1.7.4	Listing of external contacts for every dataset	Sectoral
Data Processing level 1	1. Accuracy	DP.1.1.1	Uncertainty assessment for every data source as input to Data Storage level 2 in relation to type of variability. (Distribution as: normal, log normal or other type of variability)	Sectoral
		DP.1.1.2	Uncertainty assessment for every data source as input to Data Storage level 2 in relation to scale of variability (size of variation intervals)	Sectoral
		DP.1.1.3	Evaluation of the methodological approach using international guidelines	Sectoral
		DP.1.1.4	Verification of calculation results using guideline values	Sectoral
	2.Comparability	DP.1.2.1	The inventory calculation has to follow the international guidelines suggested by UNFCCC and IPCC.	Sectoral
	3.Completeness	DP.1.3.1	Assessment of the most important quantitative knowledge which is lacking.	Sectoral
		DP.1.3.2	Assessment of the most important cases where access is lacking with regard to critical data sources that could improve quantitative knowledge.	Sectoral
	4.Consistency	DP.1.4.1	In order to keep consistency at a high level, an explicit description of the activities needs to accompany any change in the calculation procedure	Sectoral
		DP.1.4.2	Identification of parameters (e.g. activity data, constants) that are common to multiple source categories and confirmation that there is consistency in the values used for these parameters in the emission calculations	General
	5.Correctness	DP.1.5.1	Shows at least once, by independent calculation, the correctness of every data manipulation	Sectoral
		DP.1.5.2	Verification of calculation results using time series	Sectoral
		DP.1.5.3	Verification of calculation results using other measures	Sectoral

Level	CCP	Id	Description	
		DP.1.5.4	Show one-to-one correctness between external data sources and the databases at Data Storage level 2	Sectoral
	6.Robustness	DP.1.6.1	Any calculation must be anchored to two responsible persons who can replace each other in the technical issue of performing the calculations.	General
	7.Transparency	DP.1.7.1	The calculation principle and equations used must be described	Sectoral
		DP.1.7.2	The theoretical reasoning for all methods must be described	Sectoral
		DP.1.7.3	Explicit listing of assumptions behind all methods	Sectoral
		DP.1.7.4	Clear reference to dataset at Data Storage level 1	Sectoral
		DP.1.7.5	A manual log to collect information about recalculations	Sectoral
Data Storage level 2	2.Comparability	DS.2.2.1	Comparison with other countries that are closely related to Denmark and explanation of the largest discrepancies	General
	5.Correctness	DS.2.5.1	Documentation of a correct connection between all data types at level 2 to data at level 1	Sectoral
		DS.2.5.2	Check if a correct data import to level 2 has been made	Sectoral
	6.Robustness	DS.2.6.1	All persons in the inventory work must be able to handle and understand all data at level 2.	General
	7.Transparency	DS.2.7.1	The time trend for every single parameter must be graphically available and easy to map	General
Data Processing level 2	1. Accuracy	DP.2.1.1	Documentation of the methodological approach for the uncertainty analysis	General
		DP.2.1.2	Quantification of uncertainty	General
	2.Comparability	DP.2.2.1	The inventory calculation has to follow the international guidelines suggested by UNFCCC and IPCC	General
	6.Robustness	DP.2.6.1	Any calculation at level 4 must be anchored to two responsible persons who can replace each other in the technical issue of performing the calculations.	General
	7.Transparency	DP.2.7.1	Reporting of the calculation principle and equations used	General
		DP.2.7.2	The reasoning for the choice of methodology for uncertainty analysis needs to be written explicitly.	General
Data Storage level 3	1. Accuracy	DS.3.1.1	Quantification of uncertainty	General
	5.Correctness	DS.3.5.1	Comparison with inventories of the previous years on the level of the categories of the CRF as well as on SNAP source categories. Any major changes are checked, verified, etc.	General
		DS.3.5.2	Total emissions, when aggregated to CRF source categories, are compared with totals based on SNAP source categories (control of data transfer).	General
		DS.3.5.3	Checking of time series of the CRF and SNAP source categories as they are found in the Corinair databases. Considerable trends and changes are checked and explained.	General
	7. Transparency	DS.3.7.1	The databases and other software used shall be clearly documented. The documentation should include a description that the appropriate data processing steps are correctly represented in the database; that data relationships are correctly represented in the database and that data fields are properly labelled and have the correct design specifications.	General

Level	CCP	Id	Description	
		DS.3.7.2	The documentation referred to under DS.3.7.1 should be archived at the same network folder as the program is located in.	General
Data Processing level 3	6. Robustness	DP.3.6.1	The process of generating the official submissions must be anchored by at least two responsible persons who can replace each other in the technical issue of generating CRF tables including of the aggregation of submissions for Denmark and Greenland.	General
	7. Transparency	DP.3.7.1	The databases and other software used shall be clearly documented. The documentation should include a description that the appropriate data processing steps are correctly represented in the database; that data relationships are correctly represented in the database and that data fields are properly labelled and have the correct design specifications.	General
	7. Transparency	DP.3.7.2	The documentation referred to under DP.3.7.1 should be archived at the same network folder as the program is located in.	General
Data Storage level 4	2.Comparability	DS.4.2.1	Description of similarities and differences in relation to other countries' inventories for the methodological approach.	General
	3.Completeness	DS.4.3.1	National and international verification including explanation of the discrepancies.	General
		DS.4.3.2	Check that the no sources where a methodology exists in the IPCC guidelines are reported as NE.	General
	4.Consistency	DS.4.4.1	The inventory reporting must follow the international guidelines suggested by UNFCCC and IPCC.	General
		DS.4.4.2	Check time series consistency of the reporting by Greenland and the Faroe Islands prior to aggregating the final submissions.	General
		DS.4.4.3	The IEFs from the CRF are checked both regarding level and trend. The level is compared to relevant emission factors to ensure correctness. Large dips/jumps in the time series are explained.	Sectoral
	5.Correctness	DS.4.5.1	Check that the aggregated submissions for Denmark under the Kyoto Protocol and the UNFCCC match the sum of the individual submissions.	General
		DS.4.5.2	Check that additional information and information related to land-use changes has been correctly aggregated compared to the individual submissions of Denmark and Greenland.	Sectoral
	6. Robustness	DS.4.6.1	The reporting to the UNFCCC must be anchored to two responsible persons who can replace each other in the technical issue of reporting to and communicating with the UNFCCC secretariat.	General
	7.Transparency	DS.4.7.1	Perform QA on the documentation report provided by the Government of Greenland.	General

1.6.7 Plan for the quality work

The IPCC uses the concept of a tiered approach, i.e. a stepwise approach, where complexity, advancement and comprehensiveness increase. Generally, more detailed and advanced methods are recommended in order to give guidance to countries which have more detailed datasets and more capacity, as well as to countries with less available data and manpower. The tiered approach helps to focus attention on the areas of the inventories that are relatively weak, rather than investing effort in irrelevant areas. Furthermore, the IPCC guidelines recommend using higher tier methods for key categories in particular. Therefore, the identification of key categories is crucial for planning quality work. However, there exist several issues regarding the listing of priority categories: (1) The contribution to the total emission figure (key source listing); (2) The contribution to the total uncertainty; (3) Most critical categories in relation to implementation of new methodologies and thus highest risk for miscalculations. All the points listed are necessary for different aspects of producing high quality work. These listings will be used to secure implementation of the full quality scheme for the most relevant categories. Verification in relation to other countries has been undertaken for priority categories.

1.6.8 Implementation of the QA/QC plan

The PMs listed in Table 1.2 are described for each sector in the QA/QC sections of Chapters 3-8, where a status with regard to implementation is also given. Some of the PMs are the same for all sectors and a common description for these PMs is given in Section 1.6.10, below. The focus has been on level 1 for both data storage and data processing as this is the most labour-intensive part. The quality system will be evaluated and adjusted continuously.

1.6.9 Archiving of data and documentations

The QA/QC work is supported by an inventory file system, where all data, models and QA/QC procedures and checks are stored as files in folders (Figure 1.4).

Figure 1.4 Schematic diagram of the folder structure in the inventory file system.

The inventory file system consists of the following levels: year, sector and the level for the process of the inventory work, as illustrated in Figure 1.4. The first level in the file system is year, which here means the inventory year and not the calendar year. The sector level contains the PMs relevant for the individual sectors i.e. the first levels (DS1 and DP1) (except the PMs described in Section 1.6.10), while the rest of the PMs (DS2-4 and DP2-3), are common for all sectors.

All data, models and other QA/QC related files are stored in the inventory file system and are accessible for all staff involved in the inventory work.

1.6.10 Common QA/QC PMs

The following PMs are common for all the sectors:

Data storage Level 1

Data Storage level 1	6. Robustness	DS.1.6.2	At least two employees must have a detailed insight into the gathering of every external dataset.

For all sectors: energy, industrial processes, solvent and other product use, agriculture, LULUCF and waste, two persons have detailed insight in data gathering and processing. A strong effort is continuously made to ensure the robustness of the inventory process.

Data Storage level 1	7. Transparency	DS.1.7.2	The archiving of datasets needs to be easily accessible for any person involved in the emission inventory.

All data, models and other QA/QC related files are stored in the inventory file system and are accessible for all inventory staff members. Refer to Section 1.6.9.

Data processing Level 1

Data Processing level 1	4. Consistency	DP.1.4.2	Identification of parameters (e.g. activity data, constants) that are common to multiple source categories and confirmation that there is consistency in the values used for these parameters in the emission calculations.

This PM is supported by the inventory file system where it is possible to compare and harmonise parameters that are common to multiple source categories.

Data Processing level 1	6.Robustness	DP.1.6.1	Any calculation must be anchored to two responsible persons who can replace each other in the technical issue of performing the calculations.

All data, models and other QA/QC related files are stored in the inventory file system and are accessible for all inventory staff members. Refer to Section 1.6.9.

Data storage Level 2

Data Storage level 2	2.Comparability	DS.2.2.1	Comparison with other countries that are closely related to Denmark and explanation of the largest discrepancies.

Systematic inter-country comparison has only been made on data storage level 4. Refer to DS 4.3.2.

Data Storage level 2	6.Robustness	DS.2.6.1	All persons in the inventory work must be able to handle and understand all data at level 2.

This PM is fulfilled for all sectors. The PM is supported by the inventory file system. Refer to Section 1.6.9.

Data Storage level 2	7.Transparency	DS.2.7.1	The time trend for every single parameter must be graphically available and easy to map.

Programs exist to make time series for all parameters. A tool for graphically showing time series has not yet been developed.

Data Processing Level 2

Data Processing level 2	1. Accuracy	DP.2.1.1	Documentation of the methodological approach for the uncertainty analysis

Refer to Chapter 1.7.

Data Processing level 2	1. Accuracy	DP.2.1.2	Quantification of uncertainty

Refer to Chapter 1.7 and the uncertainty sections in the sectoral chapters (Chapter 3-7).

Data Processing level 2	2.Comparability	DP.2.2.1	The inventory calculation has to follow the international guidelines suggested by UNFCCC and IPCC.

The emission calculations follow the international guidelines.

Data Processing level 2	6.Robustness	DS.2.6.1	All persons in the inventory work must be able to handle and understand all data at level 2.

At present the emission calculations are carried out using applications developed at DCE. The software development and programme runs are anchored to two inventory staff members.

Data Processing level 2	7.Transparency	DP.2.7.1	Reporting of the calculation principle and equations used.

Due to the uniform treatment of input data in the calculation routines used by the DCE software programmes, a central documentation of calculation principles, equations, theoretical reasoning and assumptions must be given, treating all national emission sources. This documentation still remains to be made, but is planned to be carried out in the future.

Data Processing level 2	7.Transparency	DP.2.7.2	The reasoning for the choice of methodology for uncertainty analysis needs to written explicitly.

Refer to Chapter 1.7 and the QA/QC sections in the sectoral chapters.

Data storage Level 3

Data Storage level 3	1. Accuracy	DS.3.1.1	Quantification of uncertainty

Refer to Chapter 1.7 and the QA/QC sections in the sector chapters.

Data Storage level 3	5.Correctness	DS.3.5.1	Comparison with inventories of the previous years on the level of the categories of the CRF as well as on SNAP source categories. Any major changes are checked, verified, etc.

Time series is prepared and checked, any major change is closely examined with the purpose of verifying and explaining changes from earlier inventories.

Data Storage level 3	5.Correctness	DS.3.5.2	Total emissions when aggregated to CRF source categories are compared with totals based on SNAP source categories (control of data transfer).

Total emission, when aggregated to IPCC and LRTAP reporting tables, is compared with totals based on SNAP source categories (control of data transfer).

Data Storage level 3	5.Correctness	DS.3.5.3	Checking of time series of the CRF and SNAP source categories as they are found in the Corinair databases. Considerable trends and changes are checked and explained.

Time series are prepared and checked, any major change is closely examined with the purpose of verifying and explaining fluctuations.

Data Storage level 3	7. Transparency	DS.3.7.1	The databases and other software used shall be clearly documented. The documentation should include a description that the appropriate data processing steps are correctly represented in the database; that data relationships are correctly represented in the database and that data fields are properly labelled and have the correct design specifications.

The databases used at data storage level 3 are documented. The documentation includes description of the queries and programming code used in the data processing. The documentation further includes information on all data fields in the database and the design specifications. Part of the detailed documentation is built into the database while the overall documentation is prepared as a separate documentation note.

Data Storage level 3	7. Transparency	DS.3.7.2	The documentation referred to under DS.3.7.1 should be archived at the same network folder as the program is located in.

The documentation prepared as part of DS.3.7.1 is archived in the same folder as the program is stored. For information on the file structure, please see Chapter 1.6.9.

Data Processing Level 3

Data Processing level 3	6. Robustness	DP.3.6.1	The process of generating the official submissions must be anchored by at least two responsible persons who can replace each other in the technical issue of generating CRF tables including of the aggregation of submissions for Denmark and Greenland.

The process of generating the official submissions including the aggregation of submissions to the UNFCCC and the Kyoto Protocol is currently anchored by two people within the team. In the future the goal is to have three team members capable of completing this task.

Data Processing level 3	7. Transparency	DP.3.7.1	The databases and other software used shall be clearly documented. The documentation should include a description that the appropriate data processing steps are correctly represented in the database; that data relationships are correctly represented in the database and that data fields are properly labelled and have the correct design specifications.

The databases used at data storage level 3 are documented. The documentation includes description of the queries and programming code used in the data processing. The documentation further includes information on all data fields in the database and the design specifications. Part of the detailed documentation is built into the database while the overall documentation is prepared as a separate documentation note.

Data Processing level 3	7. Transparency	DP.3.7.2	The documentation referred to under DS.3.7.1 should be archived at the same network folder as the program is located in.

The documentation prepared as part of DS.3.7.1 is archived in the same folder as the program is stored. For information on the file structure, please see Chapter 1.6.9.

Data Storage Level 4

Data Storage level 4	2.Comparability	DS.4.2.1	Description of similarities and differences in relation to other countries' inventories for the methodological approach

For each key source category, a comparison has been made between Denmark and the EU-15 countries (Fauser et al., 2007 & 2013). This is performed by comparing emission density indicators, defined as emission intensity value divided by a chosen indicator. The indicators are identical to the ones identified in the Norwegian verification inventory (Holtskog et al., 2000). The correlation between emissions and an independent indicator does not necessarily imply cause and effect, but in cases where the indicator is directly associated with the emission intensity value, such as for the energy sector, the emission density indicator is a measure of the implied emission factor and a direct comparison can be made. A qualitative verification of implied emission factors can, furthermore, be made when a measured or theoretical value of the CO_2 content in the respective fuel type (or other relevant parameter) is available. For the energy sector, all countries are, in principle, comparable and inter-country deviations arise from variations in fuel purities and fuel combustion efficiencies. A comparison of national emission density indicators, analogous to the implied emission factors, will give valuable information on the quality and efficiency of the national energy sectors.

Furthermore, the inter-country comparison of emission density indicators and comparison of theoretical values gives a methodological verification of the derivation of emission intensity values, and of the correlation between emission intensity values and activity values.

When emissions are compared with non-dependent parameters, similarities with regard to geography, climate, industry structure and level of economic development may be necessary for obtaining comparable emission density indicators.

Data Storage level 4	3.Completeness	DS.4.3.1	National and international validation including explanation of the discrepancies.

Refer to DS 4.2.1

Data Storage level 4	3.Completeness	DS.4.3.2	Check that the no sources where a methodology exists in the IPCC guidelines are reported as NE.

It is verified both by DCE experts and by EU consistency checks that no sources where methodologies and default parameters exist have been reported as NE. If methodologies do exist efforts are made to estimate and report emissions.

Data Storage level 4	4.Consistency	DS.4.4.1	The inventory reporting must follow the international guidelines suggested by UNFCCC and IPCC.

The inventory reporting is in accordance with the UNFCCC guidelines on reporting and review (UNFCCC, 2007). The present report includes detailed and complete information on the inventories for all years from the base year to the year of the current annual inventory submission, in order to ensure the transparency of the inventory. The annual emission inventory for Denmark is reported in the Common Reporting Format (CRF) as requested in the reporting guidelines. The CRF-spreadsheets contain data on emissions, activity data and implied emission factors for each year. Emission trends are given for each greenhouse gas and for total greenhouse gas emissions in CO_2 equivalents. The link to complete sets of CRF-files and more information on the Danish emission inventories are on the ENVS homepage (http://envs.au.dk/videnudveksling/luft/emissioner/emissioninventory).

Data Storage level 4	4.Consistency	DS.4.4.2	Check time series consistency of the reporting of Greenland and the Faroe Islands prior to aggregating the final submissions

The time series for all pollutants in the submissions from Greenland and the Faroe Islands are checked at the CRF 3 level for large variations in the time series. Any large variations are explained or corrected in cooperation with the authorities in Greenland and the Faroe Islands.

Data Storage level 4	5.Correctness	DS.4.5.1	Check that the aggregated submissions for Denmark under the Kyoto Protocol and the UNFCCC matches the sum of the individual submissions

To ensure that the submission for Denmark under the Kyoto Protocol matches the sum of the submissions of Denmark and Greenland a spreadsheet check has been implemented to ensure complete correctness of the submitted inventory. The same procedure is followed for the submission under the UNFCCC, where it is ensured that the submitted emissions equate to the sum of Denmark, Greenland and the Faroe Islands. Special attention is paid to the additional information provided in the CRF, e.g. for the agricultural sector. Certain parameters cannot simply be added, e.g. animal weights. In these cases a weighted average is reported in the CRF tables.

Data Storage level 4	6. Robustness	DS.4.6.1	The reporting to the UNFCCC must be anchored to two responsible persons who can replace each other in the technical issue of reporting to and communicating with the UNFCCC secretariat.

The reporting to the UNFCCC secretariat is currently anchored by two team members. All official correspondence between the secretariat and DCE involves both the responsible team members.

Data Storage level 4	7.Transparency	DS.4.7.1	Perform QA on the documentation report provided by the Government of Greenland

The documentation report is received by DCE from the Government of Greenland in the early spring every year. The documentation report is included in the NIR as Chapter 16. DCE experts read and provide comments on the report to the Government of Greenland, so that any questions are resolved prior to the UNFCCC reporting deadline of April 15.

1.7 General uncertainty evaluation, including data on the overall uncertainty for the inventory totals

1.7.1 Tier 1 uncertainties

The uncertainty estimates are based on the Approach 1 methodology in the 2006 IPCC Guidelines (IPCC, 2006). Uncertainty estimates for the following sectors are included in the current year: stationary combustion plants, mobile combustion, fugitive emissions from fuels, industry, solid waste and wastewater treatment, CO_2 from solvents, agriculture and LULUCF. The sources included in the uncertainty estimate cover 100 % of the total net Danish greenhouse gas emissions and removals.

The uncertainties for the activity rates and emission factors are shown in Table 1.3.

Table 1.3 Summary of base year and 2013 emissions in kt CO_2 eqv. and activity data and emission factor uncertainties. Calculated Approach 1 and Approach 2 uncertainties for each emission source are given as % of the total 2013 emission. The base year for F-gases is 1995 and for all other gases the base year is 1990. Approach 2 uncertainty is not calculated for LULUCF.

IPCC Source category	Gas	Base year emission kt CO_2 eqv.	2013 emission kt CO_2 eqv.	Activity data uncertainty %	Emission factor uncertainty %	Approach 1 Combined uncertainty % of total emissions	Approach 2 uncertainty % of total emissions
1A Stationary combustion, Coal, ETS data	CO_2	0.0	12294.4	0.5	0.3	0.583	0.126
1A Stationary combustion, Coal, no ETS data	CO_2	23833.9	386.7	1.0	1.0	1.422	0.010
1A Stationary combustion, BKB	CO_2	11.3	1.8	3.0	5.0	5.831	0.000
1A Stationary combustion, Coke oven coke	CO_2	136.5	69.9	1.7	5.0	5.283	0.007
1A Stationary combustion, Fossil waste, ETS data	CO_2	0.0	964.0	2.0	5.0	5.385	0.093
1A Stationary combustion, Fossil waste, no ETS data	CO_2	573.5	638.7	5.0	10.0	11.180	0.135
1A Stationary combustion, Petroleum coke, ETS data	CO_2	0.0	559.3	0.5	0.5	0.707	0.007
1A Stationary combustion, Petroleum coke, no ETS data	CO_2	414.7	4.8	2.0	5.0	5.385	0.000
1A Stationary combustion, Residual oil, ETS data	CO_2	0.0	338.9	0.5	0.5	0.707	0.004
1A Stationary combustion, Residual oil, no ETS data	CO_2	2496.0	107.7	1.4	2.0	2.441	0.005
1A Stationary combustion, Gas oil	CO_2	4542.5	786.7	2.4	1.5	2.798	0.040
1A Stationary combustion, Kerosene	CO_2	367.6	2.1	2.8	3.0	4.111	0.000
1A Stationary combustion, LPG	CO_2	186.7	79.3	2.5	4.0	4.695	0.007
1A1b Stationary combustion, Petroleum refining, Refinery gas	CO_2	816.1	897.1	1.0	2.0	2.236	0.035
1A Stationary combustion, Natural gas, onshore	CO_2	3790.5	6514.9	1.2	0.4	1.294	0.149
1A1c_ii Stationary combustion, Oil and gas extraction, Off shore gas turbines, Natural gas	CO_2	544.9	1333.7	0.5	0.5	0.707	0.016
1A1 Stationary Combustion, Solid fuels	CH_4	5.3	2.9	1	100	100.005	0.008
1A1 Stationary Combustion, Liquid fuels	CH_4	0.7	0.6	1	100	100.005	0.002
1A1 Stationary Combustion, not engines, gaseous fuels	CH_4	0.8	2.1	1	100	100.005	0.006
1A1 Stationary Combustion, Waste	CH_4	0.2	0.3	3	100	100.045	0.001
1A1 Stationary Combustion, not engines, Biomass	CH_4	3.6	9.8	3	100	100.045	0.025
1A2 Stationary Combustion,solid fuels	CH_4	3.8	1.0	2	100	100.020	0.003
1A2 Stationary Combustion,Liquid fuels	CH_4	0.9	0.6	2	100	100.020	0.002
1A2 Stationary Combustion, not engines, gaseous fuels	CH_4	0.6	0.8	2	100	100.020	0.002
1A2 Stationary Combustion, Waste	CH_4	0.0	1.3	3	100	100.045	0.004
1A2 Stationary Combustion, not engines, Biomass	CH_4	1.6	2.1	10	100	100.499	0.006
1A4 Stationary Combustion, Solid fuels	CH_4	6.2	0.5	3	100	100.045	0.001
1A4 Stationary Combustion, Liquid fuels	CH_4	2.9	0.3	3	100	100.045	0.001
1A4 Stationary Combustion, not engines, gaseous fuels	CH_4	0.6	1.0	3	100	100.045	0.003
1A4 Stationary Combustion, Waste	CH_4	0.7	0.3	3	100	100.045	0.001
1A4 Stationary Combustion, not engines, not residential wood and not residential/agricultural straw, Biomass	CH4	0.1	0.4	10	100	100.499	0.001
1A4b_i Stationary combustion, Residential wood combustion	CH_4	70.7	88.0	20	150	151.327	0.420
1A4b_i/1A4c_i Stationary Combustion, Residential and agricultural straw combustion	CH_4	63.6	36.2	15	150	150.748	0.185
1A Stationary combustion, Natural gas fuelled engines, gaseous fuels	CH_4	5.5	115.2	1	2	2.236	0.004
1A Stationary combustion, Biogas fuelled engines, Biomass	CH_4	1.8	38.8	3	10	10.440	0.007

IPCC Source category	Gas	Base year emission kt CO_2 eqv.	2013 emission kt CO_2 eqv.	Activity data uncertainty %	Emission factor uncertainty %	Approach 1 Combined uncertainty % of total emissions	Approach 2 uncertainty % of total emissions
1A1 Stationary Combustion, Solid fuels	N_2O	57.4	31.1	1	400	400.001	0.313
1A1 Stationary Combustion, Liquid fuels	N_2O	2.8	2.0	1	1000	1000.000	0.047
1A1 Stationary Combustion, Gaseous fuels	N_2O	12.2	19.0	1	750	750.001	0.355
1A1 Stationary Combustion, Waste	N_2O	5.2	13.1	3	400	400.011	0.134
1A1 Stationary Combustion, Biomass	N_2O	8.4	32.6	3	400	400.011	0.339
1A2 Stationary Combustion, Solid fuels	N_2O	6.7	9.6	2	400	400.005	0.101
1A2 Stationary Combustion, Liquid fuels	N_2O	28.6	7.8	2	1000	1000.002	0.189
1A2 Stationary Combustion, Gaseous fuels	N_2O	7.2	9.3	2	750	750.003	0.174
1A2 Stationary Combustion, Waste	N_2O	0.0	2.1	3	400	400.011	0.022
1A2 Stationary Combustion, Biomass	N_2O	6.9	9.2	10	400	400.125	0.098
1A4 Stationary Combustion, Solid fuels	N_2O	1.5	0.7	3	400	400.011	0.007
1A4 Stationary Combustion, Liquid fuels	N_2O	11.2	1.4	3	1000	1000.004	0.034
1A4 Stationary Combustion, Gaseous fuels	N_2O	7.7	11.6	3	750	750.006	0.217
1A4 Stationary Combustion, Waste	N_2O	1.1	0.4	3	400	400.011	0.004
1A4 Stationary Combustion, not residential wood and not residential/agricultural straw, Biomass	N_2O	0.4	1.9	10	400	400.125	0.020
1A4b_i Stationary Combustion, Residential wood combustion	N_2O	10.7	37.2	20	500	500.400	0.495
1A4b_i/1A4c_i Stationary Combustion, Residential and agricultural straw combustion	N_2O	10.1	5.8	15	500	500.225	0.075
1.A.2.g Industry (mobile)	CO_2	843.7	1024.6	41	5	41.304	0.901
1.A.3.a Civil aviation	CO_2	257.6	140.2	10	5	11.180	0.029
1.A.3.b Road Transport	CO_2	9283.5	11020.8	2	5	5.385	1.083
1.A.3.c Railways	CO_2	296.7	247.8	2	5	5.385	0.024
1.A.3.d Navigation (large vessels)	CO_2	747.7	393.2	11	5	12.083	0.093
1.A.4.a Commercial/Institutional (mobile)	CO_2	73.7	171.4	35	5	35.355	0.126
1.A.4.b Residential (mobile)	CO_2	39.1	62.3	35	5	35.355	0.046
1.A.4.c ii Agriculture (mobile)	CO_2	1272.3	1126.6	24	5	24.515	0.567
1.A.4.c ii Forestry (mobile)	CO_2	35.7	16.8	30	5	30.414	0.011
1.A.4.c iii Fisheries	CO_2	586.1	511.0	2	5	5.385	0.050
1.A.5.b Other (military)	CO_2	47.9	98.4	41	5	41.304	0.014
1.A.5.b Other (small boats)	CO_2	119.0	140.7	2	5	5.385	0.089
1.A.2.g Industry (mobile)	CH_4	1.6	0.8	41	100	108.079	0.002
1.A.3.a Civil aviation	CH_4	0.1	0.1	10	100	100.499	0.000
1.A.3.b Road Transport	CH_4	55.8	12.0	2	40	40.050	0.009
1.A.3.c Railways	CH_4	0.3	0.2	2	100	100.020	0.000
1.A.3.d Navigation (large vessels)	CH_4	0.4	0.2	11	100	100.603	0.000
1.A.4.a Commercial/Institutional (mobile)	CH_4	2.9	4.3	35	100	105.948	0.011
1.A.4.b Residential (mobile)	CH_4	1.3	1.1	35	100	105.948	0.003
1.A.4.c ii Agriculture (mobile)	CH_4	2.3	2.3	24	100	102.840	0.005
1.A.4.c ii Forestry (mobile)	CH_4	4.0	0.4	30	100	104.403	0.001
1.A.4.c iii Fisheries	CH_4	0.3	0.3	2	100	100.020	0.001
1.A.5.b Other (military)	CH_4	1.9	0.3	41	100	108.079	0.000
1.A.5.b Other (small boats)	CH_4	0.1	0.1	2	100	100.020	0.001
1.A.2.g Industry (mobile)	N_2O	10.2	13.0	41	1000	1000.840	0.348
1.A.3.a Civil aviation	N_2O	3.0	2.1	10	1000	1000.050	0.058
1.A.3.b Road Transport	N_2O	87.1	113.0	2	50	50.040	0.133
1.A.3.c Railways	N_2O	2.4	2.0	2	1000	1000.002	0.057
1.A.3.d Navigation (large vessels)	N_2O	14.0	7.4	11	1000	1000.060	0.124
1.A.4.a Commercial/Institutional (mobile)	N_2O	0.3	0.8	35	1000	1000.612	0.020
1.A.4.b Residential (mobile)	N_2O	0.2	0.3	35	1000	1000.612	0.009

IPCC Source category	Gas	Base year emission kt CO_2 eqv.	2013 emission kt CO_2 eqv.	Activity data uncertainty %	Emission factor uncertainty %	Approach 1 Combined uncertainty % of total emissions	Approach 2 uncertainty % of total emissions
1.A.4.c ii Agriculture (mobile)	N_2O	14.7	14.3	24	1000	1000.288	0.403
1.A.4.c ii Forestry (mobile)	N_2O	0.2	0.2	30	1000	1000.450	0.005
1.A.4.c iii Fisheries	N_2O	11.1	9.6	2	1000	1000.002	0.245
1.A.5.b Other (military)	N_2O	0.4	1.0	41	1000	1000.840	0.046
1.A.5.b Other (small boats)	N_2O	1.1	1.5	2	1000	1000.002	0.030
1.B.2.a.1 Exploration, oil	CO_2	4.7	3.0	2	10	10.198	0.001
1.B.2.a.2 Production, oil	CO_2	0.0	0.0	2	100	100.020	0.000
1.B.2.a.3 Transport, oil	CO_2	0.0	0.0	2	40	40.050	0.000
1.B.2.b.1 Exploration, gas	CO_2	8.3	0.0	2	10	10.198	0.000
1.B.2.b.2 Production, gas	CO_2	0.1	0.1	2	100	100.020	0.000
1.B.2.b.4 Transmission and storage, gas	CO_2	0.0	0.0	15	2	15.133	0.000
1.B.2.b.5 Distribution, gas	CO_2	0.0	0.0	25	10	26.926	0.000
1.B.2.c.1.ii Venting, gas	CO_2	0.0	0.0	15	2	15.133	0.000
1.B.2.c.2.i Flaring, oil	CO_2	22.9	14.7	11	2	11.180	0.003
1.B.2.c.2.ii Flaring, gas	CO_2	304.7	220.5	7.5	2	7.762	0.031
1.B.2.a.1 Exploration, oil	CH_4	0.0	0.0	2	125	125.016	0.000
1.B.2.a.2 Production, oil	CH_4	0.1	0.2	2	100	100.020	0.004
1.B.2.a.3 Transport, oil	CH_4	20.4	19.2	2	40	40.050	0.015
1.B.2.a.4 Refining/storage	CH_4	10.9	15.5	1	125	125.004	0.056
1.B.2.b.1 Exploration, gas	CH_4	0.8	0.0	2	125	125.016	0.000
1.B.2.b.2 Production, gas	CH_4	48.8	44.7	2	100	100.020	0.125
1.B.2.b.4 Transmission and storage, gas	CH_4	4.8	0.4	15	2	15.133	0.000
1.B.2.b.5 Distribution, gas	CH_4	6.4	3.1	25	10	26.926	0.002
1.B.2.c.1.ii Venting, gas	CH_4	1.5	1.3	15	2	15.133	0.000
1.B.2.c.2.i Flaring, oil	CH_4	0.2	0.1	11	15	18.601	0.000
1.B.2.c.2.ii Flaring, gas	CH_4	28.8	22.9	7.5	125	125.225	0.084
1.B.2.a.1 Exploration, oil	N_2O	0.0	0.0	2	1000	1000.002	0.000
1.B.2.b.1 Exploration, gas	N_2O	1.4	0.0	2	1000	1000.002	0.000
1.B.2.c.2.i Flaring, oil	N_2O	0.1	0.0	11	1000	1000.060	0.001
1.B.2.c.2.ii Flaring, gas	N_2O	51.2	41.1	7.5	1000	1000.028	0.540
2A1 Cement production	CO_2	882.4	867.1	1	2	2.236	0.035
2A2 Lime production	CO_2	105.1	54.2	5	4	6.403	0.006
2A3 Glass production	CO_2	20.2	7.0	1	2	2.236	0.000
2A4a Ceramics	CO_2	41.3	26.6	5	2	5.385	0.003
2A4b Other uses of soda ash	CO_2	11.8	9.1	5	2	5.385	0.001
2A4d Other process uses of carbonates	CO_2	17.5	31.5	30	2	30.067	0.019
2B10 Production of catalysts	CO_2	0.9	1.3	5	5	7.071	0.000
2C1a Steel	CO_2	30.3	0.0	5	10	11.180	0.000
2C5 Lead production	CO_2	0.2	0.2	10	50	50.990	0.000
2D1 Lubricant use	CO_2	49.7	31.7	10	20	22.361	0.014
2D2 Paraffin wax use	CO_2	21.7	84.7	15	60	61.847	0.122
2D3 Paint Application	CO_2	13.2	7.8	10	15	18.028	0.003
2D3 Degreasing, dry cleaning	CO_2	0.0	0.0	10	15	18.028	0.000
2D3 Chemical products	CO_2	19.4	11.6	10	15	18.028	0.004
2D3 Other use of solvents	CO_2	60.6	48.3	10	20	22.361	0.021
2D3 Road paving with asphalt	CO_2	0.1	0.1	20	75	77.621	0.000
2D3 Asphalt roofing	CO_2	0.0	0.0	20	75	77.621	0.000
2D3 Urea based catalysts	CO_2	0.0	6.0	5	10	11.180	0.001
2G4 Fireworks	CO_2	0.1	0.2	15	60	61.847	0.000
2D2 Paraffin wax use	CH_4	0.0	0.1	15	60	61.847	0.000
2D3 Road paving with asphalt	CH_4	0.3	0.4	20	75	77.621	0.000

IPCC Source category	Gas	Base year emission kt CO_2 eqv.	2013 emission kt CO_2 eqv.	Activity data uncertainty %	Emission factor uncertainty %	Approach 1 Combined uncertainty % of total emissions	Approach 2 uncertainty % of total emissions
2G4 Fireworks	CH_4	0.0	0.1	15	60	61.847	0.000
2G4 Tobacco	CH_4	1.0	0.7	15	60	61.847	0.000
2G4 Charcoal	CH_4	1.1	2.1	15	60	61.847	0.000
2B2 Nitric acid production	N_2O	1002.5	0.0	2	25	25.080	0.000
2D2 Paraffin wax use	N_2O	0.1	0.2	15	60	61.847	0.000
2G3a Medical application of N_2O	N_2O	11.9	11.0	25	20	32.016	0.004
2G3b N_2O as propellant	N_2O	5.6	4.8	100	150	180.278	0.034
2G4 Fireworks	N_2O	0.7	2.6	15	60	61.847	0.000
2G4 Tobacco	N_2O	0.2	0.2	15	60	61.847	0.000
2G4 Charcoal	N_2O	0.1	0.1	15	60	61.847	0.000
2F1 Refrigeration and air conditioning	HFCs	42.6	703.8	10	50	50.990	0.780
2F2 Foam blowing agents	HFCs	199.5	60.7	10	50	50.990	0.070
2F4 Aerosols	HFCs	0.0	17.7	10	50	50.990	0.020
2E Electronics industry	PFCs	0.0	3.7	10	50	50.990	0.004
2F1 Refrigeration and air conditioning	PFCs	0.6	7.1	10	50	50.990	0.008
2C4 Magnesium production	SF_6	34.2	0.0	10	30	31.623	0.000
2G1 Electrical equipment	SF_6	3.7	13.1	10	50	50.990	0.015
2G2 SF6 and PFCs from other product use	SF_6	64.5	117.4	10	50	50.990	0.132
3A Enteric Fermentation	CH_4	3798.9	3466.5	2	20	20.100	0.946
3B Manure Management	CH_4	1728.9	1917.6	5	20	20.616	0.380
3F Field Burning of Agricultural Residues	CH_4	2.2	3.2	25	50	55.902	0.003
3B Manure Management	N_2O	780.6	614.9	25	100	103.078	1.293
3B5 Atmospheric deposition	N_2O	197.2	140.4	16	100	101.272	0.373
3Da1 Inorganic N fertilizer	N_2O	1875.0	906.4	3	100	100.045	5.079
3Da2a Animal manure applied to soils	N_2O	1002.3	976.0	25	100	103.078	2.905
3Da2b Sewage sludge applied to soils	N_2O	14.6	11.5	15	100	101.119	0.041
3Da2c Other organic fertilizer applied to soils	N_2O	7.2	21.5	20	100	101.980	0.020
3Da3 Urine and dung deposited by grazing animals	N_2O	299.0	184.7	10	100	100.499	0.838
3Da4 Crop Residues	N_2O	569.3	640.5	25	100	103.078	1.639
3Da5 Mineralization	N_2O	189.9	168.8	50	100	111.803	0.610
3Da6 Cultivation of organic soils	N_2O	542.7	367.5	20	100	101.980	1.505
3Db1 Atmospheric deposition	N_2O	312.5	152.0	16	100	101.272	0.791
3Db2 Leaching	N_2O	549.3	329.1	20	100	101.980	1.606
3F Field Burning of Agricultural Residues	N_2O	0.7	1.0	25	50	55.902	0.001
3G Liming	CO_2	565.5	243.9	5	100	100.125	1.556
3H Urea applicaton	CO_2	14.7	0.7	3	100	100.045	0.039
3I Other carbon-containing fertilizers	CO_2	38.4	1.9	3	100	100.045	0.135
4.A.1 Forest land remaining forest land, Living biomass	CO2	0.0	-3169.1	5	2	5.385	
4.A.1 Forest land remaining forest land, Dead organic matter	CO_2	0.0	534.5	5	2	5.385	
4.A.1 Forest land remaining forest land, Mineral soils	CO_2	0.0	0.0	5	2	5.385	
4.A.1 Forest land remaining forest land, Organic soils	CO_2	252.9	250.2	10	50	50.990	
4.A.2 Land converted to forest land	CO_2	79.0	40.0	10	9	13.280	
4.B.1 Cropland remaining cropland, Living biomass	CO_2	-81.0	69.3	3	15	15.207	
4.B.1 Cropland remaining cropland, Mineral soils	CO_2	1415.3	1253.1	3	75	75.042	
4.B.1 Cropland remaining cropland, Organic soils	CO_2	4115.8	2750.0	3	50	50.109	
4.B .2 Forest land converted to cropland	CO_2	15.5	10.0	10	50	50.990	

IPCC Source category	Gas	Base year emission kt CO_2 eqv.	2013 emission kt CO_2 eqv.	Activity data uncertainty %	Emission factor uncertainty %	Approach 1 Combined uncertainty % of total emissions	Approach 2 uncertainty % of total emissions
4.B .2 Other land uses converted to cropland	CO_2	-5.2	-11.5	10	50	50.990	
4.C.1 Grassland remaining grassland, Living biomass	CO_2	83.2	45.4	3	7	7.433	
4.C.1 Grassland remaining grassland, Organic soils	CO_2	716.2	517.7	3	50	50.109	
4.C.2 Forest land converted to grassland	CO_2	8.9	2.3	9	50	50.758	
4.C.2 Other land uses converted to grassland	CO_2	12.4	13.5	9	50	50.758	
4.D.1.1 Peat extraction remaining peat extraction	CO_2	99.5	20.3	10	75	75.664	
4.D.1.2 Flooded land remaining flooded land	CO_2	0.0	0.0	10	75	75.664	
4.E.2 Forest land converted to settlements	CO_2	3.1	13.5	10	75	75.664	
4.E.2 Other land uses converted to settlements	CO_2	9.8	60.4	10	75	75.664	
4.G Harvested wood products	CO_2	-2.1	-88.9	25	75	79.057	
4.D.2 Land converted to wetland	CO_2	2.4	0.0	25	50	55.902	
4(V) Biomass Burning	CH_4	0.7	0.0	10	30	31.623	
4(II) Grassland on organic soils	CH_4	9.3	6.7	10	90	90.554	
4(II) Land converted to wetlands	CH_4	0.0	0.1	10	90	90.554	
4(II) Peat extraction remaining peat extraction	CH_4	0.2	0.1	10	90	90.554	
4(III) Mineralization/immobilization	N_2O	0.3	38.1	10	90	90.554	
4(V) Biomass burning	N_2O	0.4	0.0	10	30	31.623	
4(II) Drainage and rewetting, Forest soils	N_2O	34.8	34.4	10	50	50.990	
4(II) Peat extraction remaining peat extraction	N_2O	0.2	0.1	10	50	50.990	
5.E Accidental fires	CO_2	17.5	16.0	10	300	300.167	0.147
5.A Solid waste disposal	CH_4	1774.1	844.0	10	118	118.323	4.389
5.B.1 Composting	CH_4	34.7	125.7	40	100	107.703	0.339
5.C.1 Incineration of corpses	CH_4	0.0	0.0	1	150	150.003	0.000
5.C.2 Incineration of carcasses	CH_4	0.0	0.0	40	150	155.242	0.000
5.D Wastewater treatment and discharge	CH_4	99.5	112.7	24	32	39.678	0.012
5.E Accidental fires	CH_4	1.9	1.8	10	500	500.100	0.028
5.B.1 Composting	N_2O	12.4	123.3	40	100	107.703	0.251
5.C.1 Incineration of corpses	N_2O	0.2	0.2	1	150	150.003	0.001
5.C.2 Incineration of carcasses	N_2O	0.0	0.1	40	150	155.242	0.000
5.D Wastewater treatment and discharge	N_2O	100.9	73.9	22	50	54.145	0.028

1.7.2 Results of the Approach 1 uncertainty estimation

The estimated uncertainties for total GHG and for CO_2, CH_4, N_2O and F-gases are shown in Table 1.4. The base year for F-gases is 1995 and for all other sources the base year is 1990. The total Danish net GHG emission is estimated with an uncertainty of ±5.2 % and the trend in net GHG emission since the base year has been estimated to be -25.4 % ± 1.9 %-age points. The GHG uncertainty estimates do not take into account the uncertainty of the GWP factors.

The uncertainty on CH_4 emission from solid waste disposal, N_2O emission from leaching and run-off and N_2O emission from animal waste applied to soil, crop residues and synthetic fertiliser are the largest sources of uncertainty for the Danish GHG inventory (excluding LULUCF). For LULUCF the largest sources of uncertainty are soil emissions from cropland.

The uncertainty of the GHG emission from combustion (sector 1A) is 2.2 % and the trend uncertainty is -21.7 % ±1.7 %-age points.

Table 1.4 Uncertainties 1990-2013.

	Uncertainty [%]	Trend [%]	Uncertainty in trend [%-age points]
GHG	5.2	-25.4	± 1.9
CO_2	4.3	-27.1	± 1.6
CH_4	18.8	-11.6	± 11.4
N_2O	35.5	-34.1	± 10.4
F-gases	44.7	187.2	± 143.2
CO_2 excl. LULUCF	2.0	-22.3	± 1.6
GHG excl. LULUCF	4.5	-21.5	± 2.1

1.7.3 Tier 2 uncertainties

On the recommendation of the UNFCCC expert review team (ERT) in 2009 Denmark has undertaken a tier 2 uncertainty analysis. Please see the sectoral chapters for the sectoral results of the tier 2 uncertainty analysis. Below is a description on the theoretical basis for the tier 2 uncertainty calculations. For the overall result please refer to Chapter 1.7.4.

When to use Tier 2

When the activity data and emission factors cannot fulfil the criteria for using the error propagation equations in Tier 1 an alternative stochastic simulation, i.e. Monte Carlo method, can be employed. The Monte Carlo method constitutes Tier 2 and Approach 2 in IPCC (2000 and 2006) and is suitable for estimating uncertainty in emission rates, from uncertainties in activity data and emission factors, when:

- Uncertainties are large.
- Their distribution is non-normal.
- The algorithms are complex function and not only simple multiplication of activity data with emission factors.
- Correlations occur between some of the activity data sets, emission factors, or both.

Uncertainties found in inventory source categories can vary widely from a few per cent to orders of magnitude. When using a normal distribution for a parameter with large uncertainty there is a risk of having a certain probability for negative values, which is not possible in reality. Furthermore large uncertainty gives a certain probability of having extremely large values, i.e. values orders of magnitude larger than the mean value. Extreme values are an often occurring quality for the distribution of realistic activity data and emission factors. However, in some cases the extreme values are unrealistic and here the method allows for upper and lower truncation of input parameters. This implies applying a lower and/or upper boundary for the distribution function of input parameters. A logarithmic plot of data with large uncertainties will transform a skewed distribution probability function (a) into a bell-shaped log-normal distribution function (b), cf. Figure 1.5. The latter can be defined by a mean value, α, and standard deviation, σ, respectively. The log-normal distribution is selected as standard in the first version of the Tier 2 and Approach 2 uncertainty assessment for year 2009. A further feature of applying truncation boundaries is that a probability distribution will converge towards a box distribution when narrowing the truncation interval.

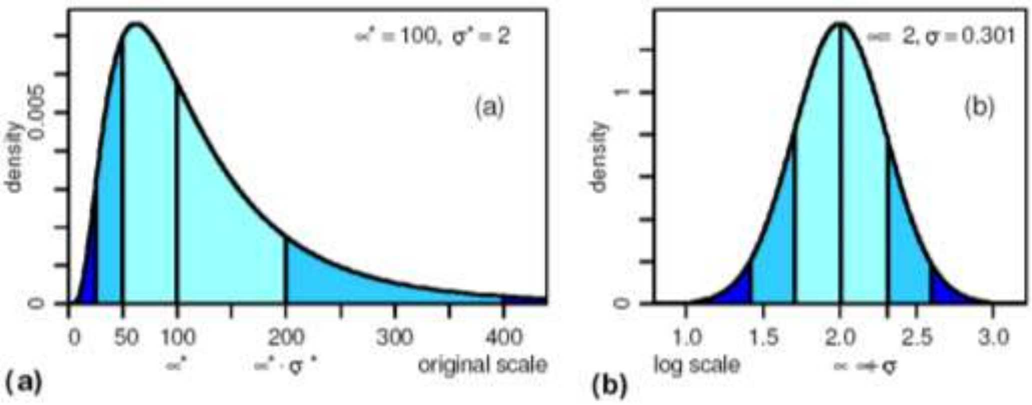


Figure 1.5 Log-normal distribution ($\log_{10}$), both on original (a) and log scale (b). The median (α^*) is 100 and the multiple standard deviation (σ^*) is 2. The resulting median (equal mean) and the standard deviation in the $\log_{10}$ distribution is respectively $\alpha = \log_{10}(100) = 2$ and $\sigma = \log_{10}(2) = 0.301$ (Limbert et al., 2001).

In case the uncertainty is much smaller than the mean value, then the normal and log-normal distributions will not differ much, cf. Figure 1.6, where the relationship between normal and log-normal distributions are illustrated (Limbert et al., 2001).

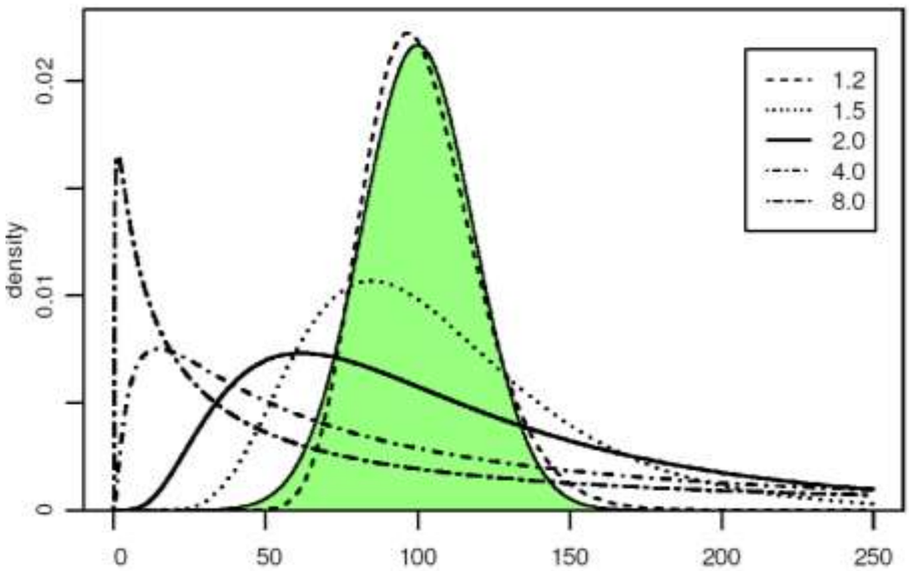


Figure 1.6 Comparison between the normal distribution (green area, median 100, standard deviation 20) the different degrees of variability (described by σ^*) for log-normal distributions that all have the same median value, i.e. α^* on original scale, of 100 (Limbert et al., 2001).

The difference in shape between a normal and log-normal distribution is seen in Figure 1.6 for different values of σ^*. The standard deviation for the normal distribution is 20 and thus equal to 20 % of the mean value and the log-normal distribution having a σ^* value of 1.2 reflects the same level of "deviation" as in the normal distribution. So, the discrepancy between the green area and the curve for $\sigma^*=1.2$ illustrates the difference in interpretation of a 20 % deviation as measured by respectively the normal and log-normal distribution. This discrepancy is so limited that it is overruled by the vagueness related to empirical quantification of the uncertainty level based on expert knowledge and data and the fact that any assumed distribution function is an approximation. Therefore, by using log-normal distributions as standard description of all uncertainty input it will in reality include normal distributions when the magnitude of uncertainty is limited to a minor fraction of the mean value.

A way of calculating the intervals of confidence, expressed by the median (α^*) and standard deviation (σ^*), for a log-normal distribution on original scale, cf. Figure 1a, is presented in Limbert et al. (2001). For normally distributed data, the interval [median ± standard deviation] covers a probability of 68.3 %, while [median ± 2*standard deviation] covers 95.5 %. Correspondingly for log normal data on original scale, cf. Figure 1a, the interval [α^* / σ^*, α^* * σ^*] covers 68.3 % and the interval [α^* / $(\sigma^*)^2$, α^* * $(\sigma^*)^2$] covers 95.5 %.

Often the default uncertainty values in IPCC (2000) e.g. for emission factors, are expressed as a percentage, e.g. 30 %. When this represents a standard deviation (68.3 %) on original scale we will proceed using σ^* = 1.3 in the uncertainty analysis. When it represents a 95 % interval of confidence, we will use σ^* = (1.3)^0.5 = 1.14 in the uncertainty analysis. When the 95 % interval of confidence on original scale is below approximately 300 % the standard deviation for a log-normal distribution on original scale, can be approximated by dividing with a factor of 2, i.e. 0.3/2 = 0.15, and thus σ^* = 1.15.

Procedure of Tier 2 (Monte Carlo method)

The procedure of the Tier 2 (MC) analysis consists of four steps where only Step 1 requires effort from the user:

- Step 1: Estimation of activity data and emission factors, their associated mean values, uncertainties such as standard deviation, probability density functions and any correlations.
- Step 2: Selection of random values of activity data and emission factors.
- Step 3: Calculate emissions from selected random values.
- Step 4: The calculated result in step 3 is stored and the process is repeated from step 2.

Repetition of steps 2 and 3 are continued until the calculated mean value and error intervals are sufficiently determined (typically 10,000 times). Each single repetition is denoted a “single sample” in the following and one execution of steps 2 and 3 is denoted a “MC sample”.

The software is developed in excel VBA programming by a scientist associated with the sector experts, which enables a transparent and accurate transfer and interpretation of emission factors and activity data (input) and calculated emissions with uncertainties (output).

Different criteria and guidelines for estimation of value uncertainty for activity data and emission factors are outlined in the next section. Whether they are based on information from models, empirical data or expert judgement, they form lines of evidence towards the most appropriate estimate. The basic paradigm for a MC analysis is outlined in Figure 1.7.

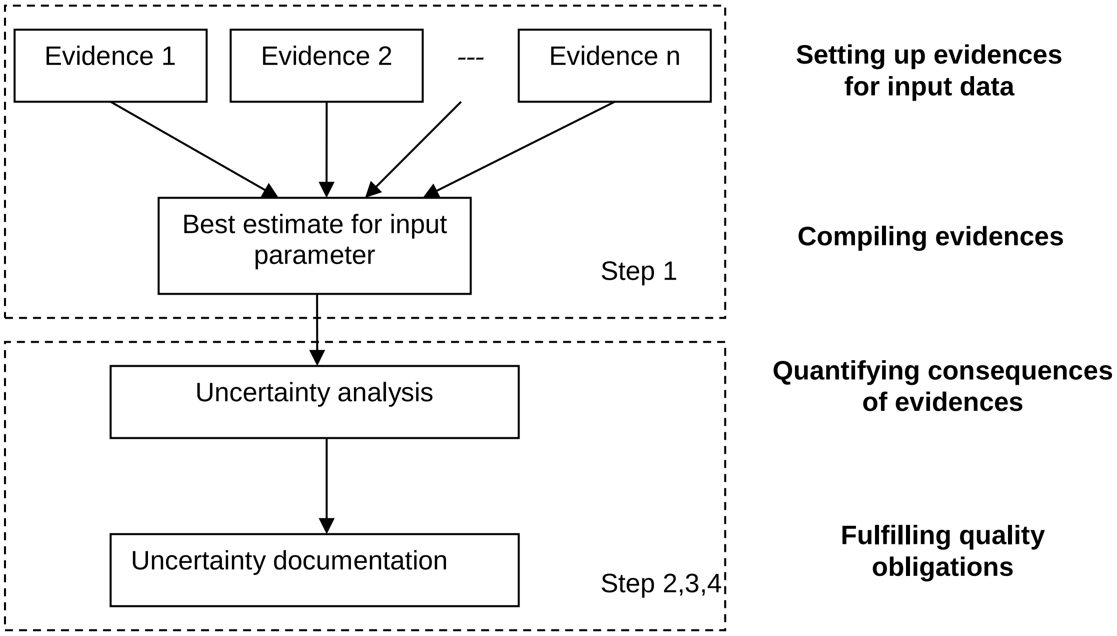


Figure 1.7 Methodological principle in compiling and quantifying input data for input parameters, e.g. emission factors, which are to be used in Tier 2 (MC) uncertainty analysis. Each evidence is formed from assessment of information from models, empirical data or expert judgement. The upper dotted box represents step 1 in the MC analysis, which is performed for each input parameter. The lower dotted box represents steps 2 to 4, and is performed in the emission modelling with all input parameters.

The principle of the MC method is to generate many "possible" calculations and thus map the resulting "possible" results. The possible calculations are made based on the "realistic" variability (uncertainty) related to the input parameter values. This variability needs to be described as a distribution function. The MC method is considered in two parts: (1) A distribution estimation part, where the variabilities of the input parameters are parameterised; (2) A technical part that makes the simulation based on the estimated distributions. The first part is highly critical and requires high attention. The second part is a question of programming and therefore mostly a technical issue. The MC method is a model for how uncertainty of input parameters influences the calculation results, so the MC also involves uncertainty in the prediction of uncertainty. It is therefore important to predict the variability of the input parameters as correctly as possible. The MC method does not include the validity of the calculations as estimators of reality but only the uncertainty of the input parameter values. Consequently, there are many fundamental types of uncertainty that are not included in the MC method.

The method is based on single samples, where the mean is unity and where the variability is determined by the uncertainty of the parameter as discussed above, see Figure 1.8. This sampled value is subsequently multiplied with the best estimate of the parameter value to yield a sampled value for this parameter. The reason for this two stage sampling is that it makes it possible directly to include correlation in uncertainty between years as explained below.

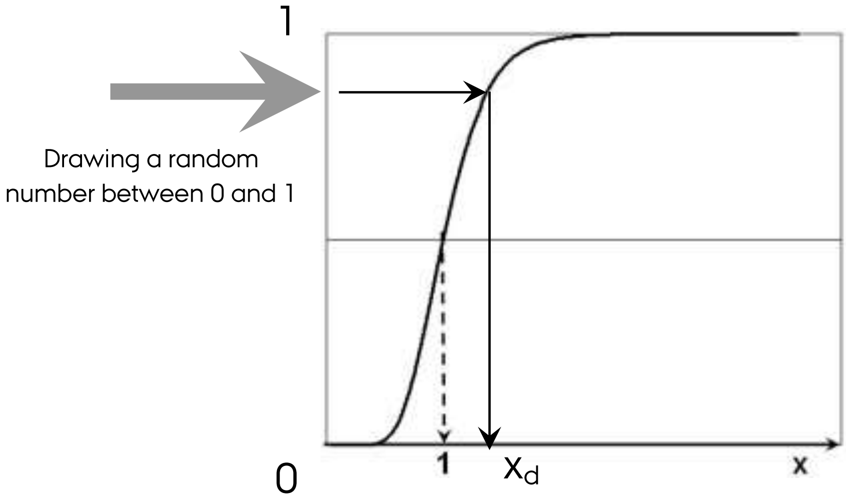


Figure 1.8 The principle in a single MC draw of the value x_d, where the median (α^*) is unity and where the standard deviation (σ^*) determines the variation around 1.

Correlation in the uncertainty may occur between years, e.g. when the same sources are responsible for uncertainties in several years. This takes place because many sources of uncertainty are dependent between years, so if a parameter is over-estimated for one year then this parameter may also tend to be overestimated other years. This implies that when the uncertainty is high one year the uncertainty will also be high the other year(s). The principle of performing a MC analysis with an emission factor and activity data that have uncertainties that are correlated between one or more years is illustrated in Figure 1.9.

The principle in Figure 1.9 is to sample a value (x) as shown in Figure 4, where the median value is unity and subsequently multiply the sampled value with the estimated median value (e.g. $AD_{s1}=AD_1 \cdot x$). This two-step approach makes is possible to include correlating uncertainty between different years. If two years are correlated then a deviation from the estimated mean value is assumed to be the same in relative terms for the two years. By sampling, using the median of unity once, and subsequently use this value to estimate the value for the two years, using the two medians for each year, this will yield the correlation between the two years as a simple consequence and thereby be directly simulated in the MC sampling.

The MC sampling is illustrated in Figure 1.9 for a single source, where s is the sampling number index, counting up to e.g. 10,000. In Figure 5 there will be a strong correlation between year 2 and 3, because both the uncertainty of *EF* and *AD* is correlated, for year 1 there will be a partial correlation with respectively year 2 and 3 because the uncertainty of the *EF* value is correlated, but the uncertainty is independent for *AD*. Year 4 is completely independent of the other years. The figure is only illustrating a single source and typically the emission estimates includes several sources each having some more or less correlated uncertainty. The final emission estimates are thus more or less correlated between years in a highly complex way.

Performing MC analysis for correlated parameters corresponds to the calculation scheme for MC analysis of emissions and the trend of a category as shown in Appendix A (IPCC, 2006) (Figure 3.7 pp. 3.36). The scheme shows calculations for correlated and non-correlated parameters.

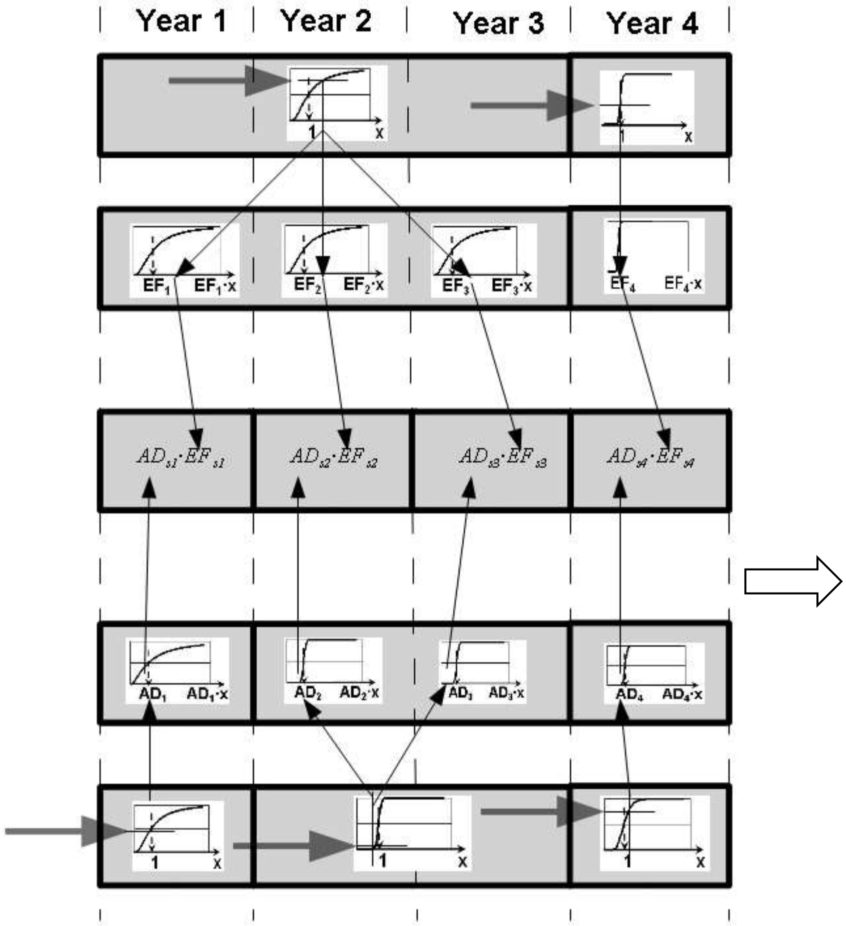


Figure 1.9 The principle of a MC sample for draws of random numbers and generation of any emission factor and activity data for a four year period. The upper half illustrates the sampling of any emission factor for year 1 to year 4. The uncertainty associated to the emission factor is correlated for year 1, 2 and 3 and therefore the same random number is used for generating EF1, EF2 and EF3. The lower half illustrates the sampling of activity data. The uncertainty associated to the activity data is correlated for year 2 and 3 and therefore the same random number is used for generating AD2 and AD3. In the middle row the emission factor and activity data are multiplied for each year.

In some cases there exists additional a priori information about categories of activity data, where the total sum is known with high certainty, but where the sub categories are more uncertain. In this case the single samples within one year are adjusted so all sub sources together adds up to the correct total number and the single sampling in this case will describe the uncertainty between the single categories.

MC analyses for emissions

When a 95% confidence interval has been entered as percentages of median values of the input parameters, i.e. emission factors and activity data, for source categories and sub-categories, the above MC procedure is executed 10,000 times. The output of the MC analysis is reported as in Table 1.5 where the median emissions are shown together with the 95% confidence interval (2.5% - 97.5%).

Two basic questions are important to answer: (1) What is the uncertainty for a time trend estimate; (2) What is the uncertainty within the same year of the single sub-categories, source categories and the total estimate. The first question takes correlation of uncertainty between years into account and the second question considers one year at a time and correlation between years is not relevant.

In the ideal case it will be possible to answer the two questions based on the same MC samples, where every single sample is stored for every source and for every year. However, this is not possible in the VBA programming due to limitations in variable table on a normal pc. Thus two MC samplings take place: (1) The total emission is calculated for every year and every MC sample, so for 10,000 MC samples and 20 years, this needs storage of 200,000 numbers; (2) Every year is analysed separately where only results for one year is stored at a time, so for 10,000 MC samples and 50 sources this yields 500,000 numbers to be stored. Using this two-stage approach it is easily possible to run the MC analysis in Excel. Consequently, the exact value for the median analysed for a specific year (question 2 above) is not similar with the medians in the time trend analysis (question 1 above) due to a finite number of MC samples, but this is not a real problem. If this discrepancy is considered as critical then it simply tells that the number of MC samples should be increased and that the analysis thus has to be redone.

Table 1.5 Example of output scheme for tier 2 MC uncertainty analysis. Median emissions and 95 % confidence intervals are calculated for total emission, emissions for source categories and emissions for sub-categories. Calculated 95% confidence intervals are furthermore calculated for activity data and emission factors.

Source category	Sub-categories	Activity			EF			Emissions			
		< 2.5%	>97.5%	Interval	< 2.5%	> 97.5%	Interval	Median	< 2.5%	> 97.5%	Interval
all	all	-	-	-	-	-	-				
A	all	-	-	-	-	-	-				
B	all	-	-	-	-	-	-				
C	all	-	-	-	-	-	-				
A	1										
A	2										
A	3										
B	1										
B	2										
C	1										
C	2										
C	3										
C	4										

Results for each row can also be reported as:

Median emission [- (median - <2.5%)/median/100%, + (>97.5% - median)/median/100%]

MC trend analysis

The trend analysis is performed by comparing emissions from two individual years at a time. The probability for Year 1 (base year) to be above Year 2 (latest year) is calculated using the equation:

$$P_{Year1>Year2} = \frac{N_{year1>year2}}{N_{total}},$$

where $N_{year1>year2}$ is the number of MC samples where year 1 is estimated to have higher emission compared to year 2 and N_{total} is the total number of MC runs. In case of $P_{year1>year2} \approx 1$ it is strongly significant to conclude that year 1 has higher emission than year 2, and reverse for $P_{year1>year2} \approx 0$. This is a comparison between years in pairs that can be filled in to a matrix, where all years are compared with all other years.

Table 1.6 Comparison of emissions between years in trend analysis.

	Year 1	Year 2	Year 3	Year 4
Year 1	0			
Year 2		0		
Year 3			0	
Year 4				0

Results for trend analysis of emissions between two years, year 1 and year 2, can be reported as median difference, <2.5% and >97.5%, or as:

Median difference [- (median difference - <2.5%)/median difference/100%, + (>97.5% - median difference)/median difference/100%]

Quantifying uncertainties in Tier 2

In order to perform the four steps of a Tier 2 (MC) uncertainty analysis as described in the previous paragraph the user has to gather the information stated in step 1. It is essential to establish the best possible estimate, and the following guide sets up a procedure for assessing, quantifying and compiling uncertainties for the parameters that are entered in the emission models. The guide is based on IPCC guidelines (IPCC, 2000 & 2006) and NUSAP and expert elicitation in van der Sluijs et al. (2004).

The uncertainty of a parameter, e.g. activity data and emission factor, is considered to be proportional to the associated parameter. This means that the uncertainty is expressed as a percentage of the parameter value. The median value is used and the uncertainties represent the parameter standard deviation, σ^*. We assume log-normal distributions, which equals normal distributions at low uncertainty values. Although van der Sluijs et al. (2004) suggest different probability distribution functions depending on the level of knowledge on input parameters we will use log-normal distributions for all parameters, as argued in the previous section.

The methodology offers a possibility for correlating the uncertainties of two or more parameters. When uncertainties of two or more parameters are assumed to be correlated they will be attributed the same random number in any MC sample, as explained in the previous paragraph.

Uncertainties will be reported according to the IPCC General Reporting Table for Uncertainty. Uncertainties will be reported for:

- Total uncertainty of the entire sector
- Key source categories
- Aggregated CRF levels
- Most differentiated CRF category levels that are entered by the user

IPCC guideline - Sources of data

Quantifying uncertainties is dependent on the source of data, and in general there are three broad sources of data and information (IPCC, 2000 & 2006):

Information contained in models

A model is a representation of the real world and does therefore not exactly mimic real-world systems. The structure of a model is often thought of in terms of the equations used. The key considerations in model uncertainty are; has the correct, most relevant real-world system been identified and are the model equations accurate representations of the chosen system. Typically the model equations are the product of activity data and emission factors, cf. Eq 1, but there may also be more complex model equations for emissions and also for derivation of activity data and emission factors.

In some cases, model uncertainty can be significant. It is typically poorly characterised and may not be characterised at all. The inventory expert must consider the parameters that are used and assess if there are model assumptions that are imprecise or inaccurate. For the most critical models an effort can be made to evaluate and quantify the size of the potential error that occurs from using the model. There are at least three approaches for estimating the model uncertainty: 1) comparison of a model result with independent data, 2) comparison of a model result with the result of alternative models, and 3) expert judgement regarding the magnitude of the model uncertainty. These approaches can be used in combination.

Empirical data for sources and sinks and activity

This implies empirical data associated with measurements of emissions, emission factors and activity data from surveys and censuses. When estimating uncertainty from measured emissions data, considerations include; representativeness of the data and potential for bias, precision and accuracy of the measurements, sample size and inter-individual variability in measurements and their implications for uncertainty in mean annual emissions, inter-annual variability in emissions and whether estimates are based on an average of several years or on the basis of a particular year.

Quantification of uncertainties and defining the probability distribution function (PDF) for empirical data can be summarised as follows: 1) Compilation of activity data, emission factors and other parameters. These data typically represent variability, 2) Visualisation of data by plotting empirical distribution functions for each parameter; horizontally according to numerical value or interval and vertically by frequency, 3) Fitting, evaluation and selection of PDFs for representing variability of data, 4) Characterisation of mean value and of uncertainty in the mean of the distributions for variability. If the standard error of the mean is small, a normality assumption can be made regardless of the sample size or skewness of data. If the standard error of the mean is large, then typically a log-normality assumption can be made, 5) Once mean values, uncertainties and standard errors have been specified, these can be used as input to Tier 2 MC analysis for estimating uncertainties in total emissions, 6) Sensitivity analysis can be used to determine which parameters induce highest uncertainties in the total uncertainty, and prioritise efforts to develop good estimates of these key uncertainties.

Expert judgement as a source of information

In many situations, relevant empirical data are not available for activity data, emission factors etc. to an inventory. In such situations, a practical solution is to obtain well informed judgements from domain experts regarding best estimates and uncertainties of input data.

Commonly used methods for converting an expert's judgement regarding uncertainty into a quantitative PDF are: 1) Fixed value; Estimate the probability of being higher (or lower) than an arbitrary value and repeat, three or five times. For example, what is the probability that an emission factor would be less than 100? 2) Fixed probability; Estimate the value associated with a specified probability of being higher (or lower). For example, what is the emission factor such that there is only a 2.5% probability that the emission factor could be lower (or higher) than that value, 3) Interval methods; For example, choose a value of the emission factor such that it is equally likely that the true emission factor would be higher or lower than that value. This yields the median. Then divide the lower range into two bins such that there is assumed to be equally likely (25% probability) that the emission factor could be in either bin. Repeat this for the other end of the distribution. Finally, either fixed probability or fixed value methods could be used to get judgements for extreme values, 4) Graphing; the expert draws a distribution. This should be used cautiously because some experts are overconfident about their knowledge of PDFs.

Sometimes the only available expert judgement consists of a range, maybe quoted together with a most likely value. Under these circumstances the following rules are considered good practice: Where experts only provide an upper and a lower value, assume that the PDF is uniform and that the range corresponds to the 95 per cent confidence interval. Where experts also provide a most likely value (point estimate), assume a triangular PDF using the most likely values as the mode and assume that the upper and lower values each exclude 2.5% of the population. The distribution needs not to be symmetrical. Normal or log-normal distributions can be used given appropriate justifications.

Concluding remarks and planned improvements

Tier 2 uncertainties are typically found to be greater than Tier 1 uncertainties. When large input uncertainties, e.g. > 10%, are used, the deviation becomes pronounced. For smaller input uncertainties, e.g. < 1%, Tier 1 approximates Tier 2 calculations.

The Log-normal distribution was selected due the likely conditions for the distribution as being close to a normal distribution for smaller uncertainties on one hand and close to the understanding of larger uncertainties on the other hand. However, in case of larger uncertainty the outcome of the MC analysis includes rather extreme values that in some cases are unrealistic. The method therefore allows for truncation of input uncertainties, either a lower boundary, upper boundary or both, depending of which truncation are most realistic.

1.7.4 Results of the tier 2 uncertainty estimation

Tier 2 uncertainty results for sectors and categories are shown in Table 1.3. The input uncertainties for activity data and emission factors stated in Table 1.3 are used both in Tier 1 and Tier 2 uncertainty calculations. The total Danish net GHG emission for 2013 is estimated with an uncertainty of +6.5 % and -4.3 % and the trend in net GHG emission since 1990 is estimated with an uncertainty of +6.9 and -6.3 %-age points.

Tier 2 uncertainties are typically larger than Tier 1 uncertainties when input uncertainties are larger than approximately 25%, which corresponds to the model domain of Tier 1 method. This implies that the Tier 2 method is more reliable for large input uncertainties.

1.8 General assessment of the completeness

The present Danish greenhouse gas emission inventory includes all sources identified by the 2006 IPPC Guidelines. Please see Annex 5 for detailed discussion on minor sources that are not included.

1.9 ETS emissions

The table below includes data for the share of national total emissions covered by the EU ETS in 2013.

Table 1.7 Share of ETS emissions.

	2013
National total emission without LULUCF, kt CO_2e	54 583.81
ETS emission, kt CO_2e	21 627.11
Share of ETS emission, %	39.6

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2 Trends in greenhouse gas emissions

The trends presented in this Chapter cover the emissions from Denmark. Due to the small emissions originating from Greenland the trends are very similar in fact close to identical. A trend discussion of the aggregated greenhouse gas emissions from Denmark and Greenland is included in Chapter 17.1.

2.1 Description and interpretation of emission trends for aggregated greenhouse gas emissions

2.1.1 Greenhouse Gas Emissions

The greenhouse gas emissions are estimated according to the IPCC guidelines and are aggregated into six main sectors. The greenhouse gases include CO_2, CH_4, N_2O, HFCs, PFCs, SF_6 and NF_3. Figure 2.1 shows the estimated total greenhouse gas emissions in CO_2 equivalents from 1990 to 2013. The emissions are not corrected for electricity trade or temperature variations. CO_2 is the most important greenhouse gas contributing in 2013 to the national total in CO_2 equivalents excluding LULUCF (Land Use and Land Use Change and Forestry) with 76.3 % followed by N_2O with 12.7 %, CH_4 9.4 % and F-gases (HFCs, PFCs and SF_6) with 1.7 %. Seen over the time-series from 1990 to 2013 these percentages have been increasing for CH_4 and F-gases, and decreasing for N_2O. The percentages for CO_2 show larger fluctuations during the time series. Stationary combustion plants, Transport and Agriculture represent the largest contributing categories to emissions of greenhouse gases, followed by Industrial processes and product use, Waste, and fugitive emissions, see Figure 2.1. The net CO_2 emission by LULUCF in 2013 is 4.4 % of the total emission in CO_2 equivalents excl. LULUCF. The national total greenhouse gas emission in CO_2 equivalents excluding LULUCF has decreased by 21.2 % from 1990 to 2013 and decreased 25.1 % including LULUCF. From 2012 to 2013 the total greenhouse gas emission excluding LULUCF decreased by 4.9 %. The decrease is mainly caused by decreasing emissions from the energy sector due to increasing import of electricity and increasing production of wind power. Comments on the overall trends etc. seen in Figure 2.1 are given in the sections below on the individual greenhouse gases.

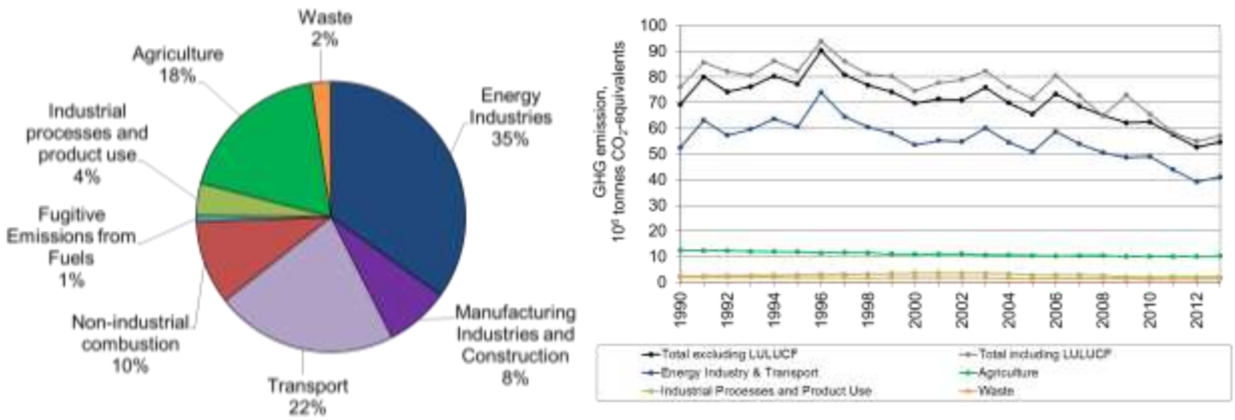


Figure 2.1 Greenhouse gas emissions in CO_2 equivalents distributed on main sectors for 2013 (excluding LULUCF) and time series for 1990 to 2013 (including LULUCF).

2.2 Description and interpretation of emission trends by gas

2.2.1 Carbon dioxide

The largest source of the emission of CO_2 is the energy sector, which includes the combustion of fossil fuels such as oil, coal and natural gas (Figure 2.2). Energy Industries contribute with 45.1 % of the emissions (excl. LULUCF). About 28 % come from the transport sector. The CO_2 emission (excl. LULUCF) increased by 4.8 % from 2012 to 2013. The main reason for this increase owe to decreasing fuel consumption, mainly for coal and natural gas. The decrease partly owe to increasing import of electricity and increasing production of wind power. In 2013, the actual CO_2 emission (incl. LULUCF) was 25.1 % less than the emission in 1990.

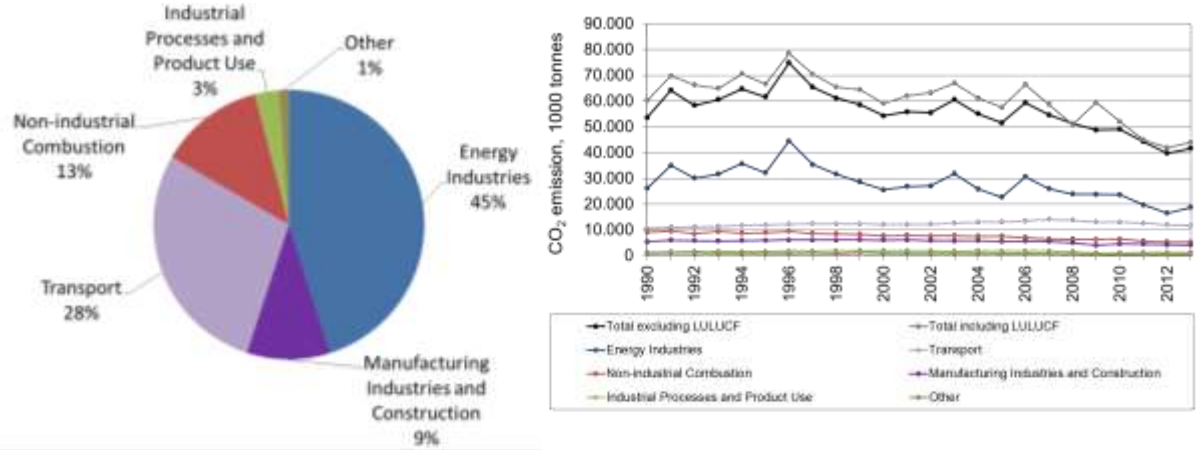


Figure 2.2 CO_2 emissions. Distribution according to the main sectors (2013) and time series for 1990 to 2013.

2.2.2 Nitrous oxide

Agriculture is the most important N_2O emission source in 2013 contributing 87.9 % (Figure 2.3) of which N_2O from agricultural soils accounts for 83.3 %. N_2O is emitted as a result of microbial processes in the soil. Substantial emissions also come from drainage water and coastal waters where nitrogen is converted to N_2O through bacterial processes. However, the nitrogen converted in these processes originates mainly from the agricultural use of manure and nitrogen fertilisers. The main reason for the decrease in the emissions of N_2O in the agricultural sector of 28.8 % from 1990 to 2013 is legislation to improve the utilisation of nitrogen in manure. The legislation has resulted in less nitrogen excreted per unit of livestock produced and a considerable reduction in the use of nitrogen fertilisers. The basis for the N_2O emission is then reduced. Combustion of fossil fuels in the energy sector, both stationary and mobile sources, contributes 7.8 %. The N_2O emission from transport contributed with 2.2 % in 2013. This emission has increased during the nineties because of the increase in the use of catalyst cars. Production of nitric acid stopped in 2004 and the emissions from industrial processes is therefore not occurring from 2005 onwards. The sector Solvent and Other Product Use covers N_2O from e.g. anaesthesia.

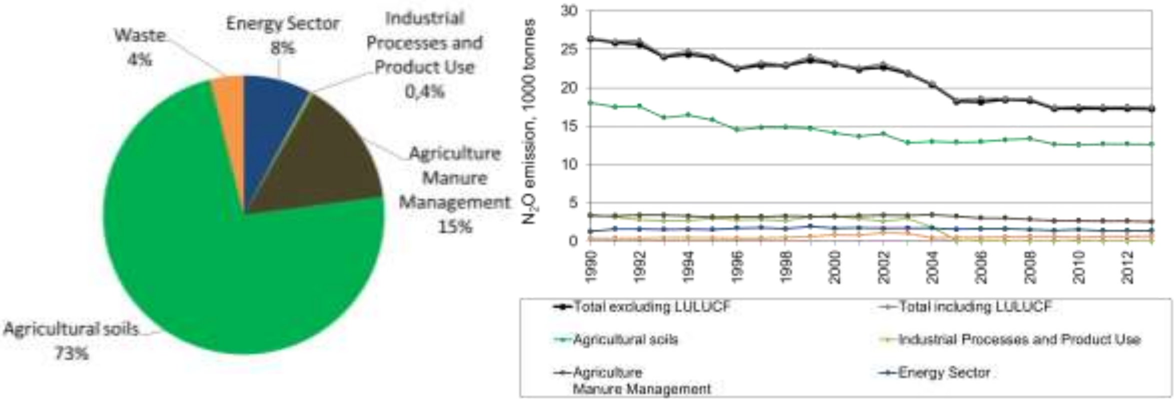


Figure 2.3 N_2O emissions. Distribution according to the main sectors (2013) and time series for 1990 to 2013.

2.2.3 Methane

The largest sources of anthropogenic CH_4 emissions are agricultural activities contributing in 2013 with 78.0 %, waste (15.7 %), public power and energy industries (2.0 %), see Figure 2.4. The emission from agriculture derives from enteric fermentation and management of animal manure contributing with 50.2 % and 27.8 % of the national CH_4 emission excl. LULUCF in 2013. The CH_4 emission from public power and district heating plants increased in the nineties, mainly 1992-1996, due to the increasing use of gas engines in the decentralised cogeneration plant sector. Up to 3 % of the natural gas in the gas engines is not combusted. The deregulation of the electricity market has made production of electricity in gas engines less favourable, therefore the fuel consumption has decreased and hence the CH_4 emission has decreased. Over the time series from 1990 to 2013, the emission of CH_4 from enteric fermentation has decreased 8.7 % due to the decrease in the number of cattle. However, the emission from manure management has in the same period increased 10.9 % due to a change in traditional stable systems towards an increase in slurry-based stable systems. Altogether, the emission of CH_4 from the agriculture sector has decreased by 2.6 % from 1990 to 2013. The emission of CH_4 from solid waste disposal has decreased 52.4 % since 1990 due to an increase in the incineration of waste and hence a decrease in the waste being deposited at landfills and a ban on depositing waste fit for incineration.

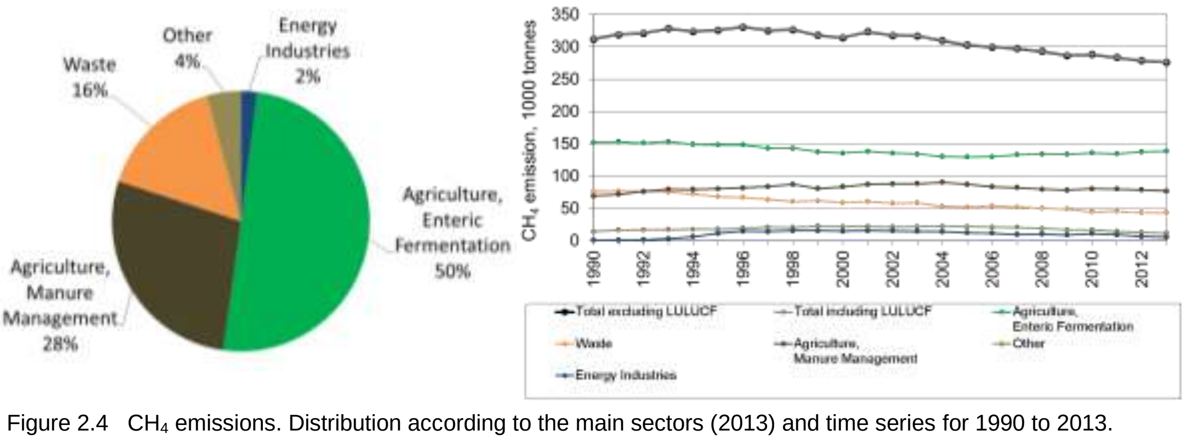


Figure 2.4 CH_4 emissions. Distribution according to the main sectors (2013) and time series for 1990 to 2013.

2.2.4 HFCs, PFCs, SF_6 and NF_3

This part of the Danish inventory only comprises a full data set for all substances from 1995. From 1995 to 2000, there has been a continuous and substantial increase in the contribution from the range of F-gases as a whole, calculated as the sum of emissions in CO_2 equivalents, see Figure 2.5. This increase is simultaneous with the increase in the emission of HFCs. For the time series 2000-2013, the increase is lower than for the years 1995 to 2000. The increase from 1995 to 2013 for the total F-gas emission is 154.9 %, while emissions decreased from 2011 to 2013 by 2.2 % mainly due to decreasing emissions of HFCs. SF_6 contributed considerably to the F-gas sum in earlier years, with 30 % in 1995. Environmental awareness and regulation of this gas under Danish law has reduced its use in industry, see Figure 2.5. A further result is that the contribution of SF_6 to F-gases in 2013 was only 14.1 %. The use of HFCs has increased several folds. HFCs have, therefore, become even more dominant, comprising 70.1 % in 1995, but 84.7 % in 2013. HFCs are mainly used as a refrigerant. Danish legislation regulates the use of F-gases, e.g. since January 1, 2007, new HFC-based refrigerant stationary systems are forbidden. Refill of old systems is still allowed. The use of air conditioning in mobile systems and the amount of HFC for this purpose increases.

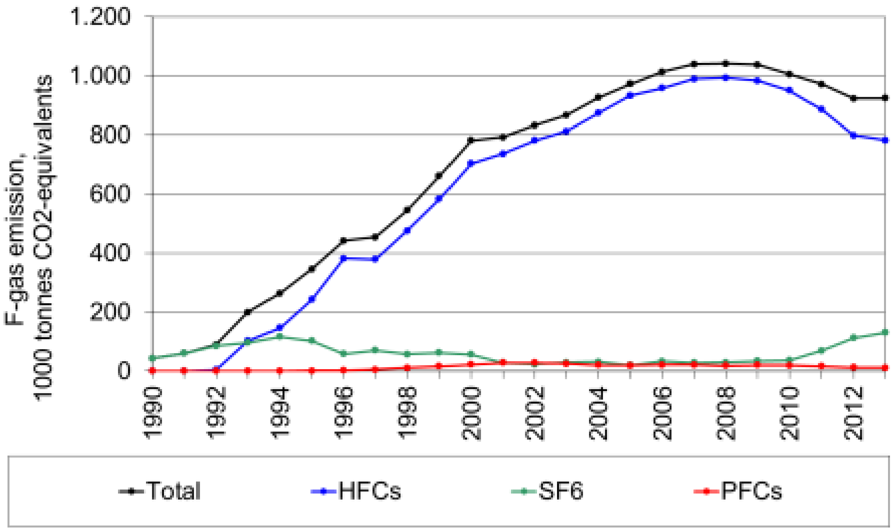


Figure 2.5 F-gas emissions. Time series for 1990 to 2013.

2.3 Description and interpretation of emission trends by source

2.3.1 Energy

The emission of CO_2 from Energy Industries has decreased by 28.2 % from 1990 to 2013. The relatively large fluctuation in the emission is due to inter-country electricity trade. Thus, the high emissions in 1991, 1994, 1996, 2003 and 2006 reflect a large electricity export and the low emissions in 1990, 1992 and 2005, 2008 and 2011-2013 are due to a large import of electricity. The main reason for this decrease owe to decreasing fuel consumption, mainly for coal and natural gas. This decrease is partly due to increasing import of electricity and partly to increasing production of wind power and other renewable energy sources.

The increasing emission of CH_4 during the nineties is due to the increasing use of gas engines in decentralised cogeneration plants. The CH_4 emissions from this sector have been decreasing from 2001 to 2013 due to the liberalisation of the electricity market. The CO_2 emission from the transport sector increased by 11.5 % from 1990 to 2013, mainly due to increasing road traffic.

2.3.2 Industrial processes and product use

The GHG emissions from industrial processes and product use, i.e. emissions from processes other than fuel combustion, amount in 2013 to 3.9 % of the total emission in CO_2 equivalents (excl. LULUCF). The main sources are cement production, refrigeration, foam blowing and calcination of limestone. The CO_2 emission from cement production – which is the largest source contributing in 2013 with 1.6 % of the national total – decreased by 1.7 % from 1990 to 2013. The second largest source has previously been N_2O from the production of nitric acid. However, the production of nitric acid/fertiliser ceased in 2004 and therefore the emission of N_2O also ceased.

The emission of HFCs, PFCs and SF_6 has increased by 140.7 % from 1995 until 2012, largely due to the increasing emission of HFCs. The use of HFCs, and especially HFC-134a, has increased several fold and thus HFCs have become the dominant F-gases, contributing 67 % to the F-gas total in 1995, rising to 83.9 % in 2012. HFC-134a is mainly used as a refrigerant. However, the use of HFC-134a is now stabilising. This is due to Danish legislation, which in 2007 banned new HFC-based refrigerant stationary systems. However, in contrast to this trend is the increasing use of air conditioning systems in mobile systems.

2.3.3 Agriculture

The agricultural sector contributes in 2013 with 18.6 % of the total greenhouse gas emission in CO_2 equivalents (excl. LULUCF) and is the most important sector regarding the emissions of N_2O and CH_4. In 2013, the contribution of N_2O and CH_4 to the total emission of these gases was 86.7 % and 77.9 %, respectively. The N_2O emission from agriculture decreased by 28.8 % from 1990 to 2013. The main reason for the decrease is a legislative demand for an improved utilisation of nitrogen in manure. This result in less nitrogen excreted per livestock unit produced and a considerable reduction in the use of fertilisers. From 1990 to 2013, the emission of CH_4 from enteric fermentation has decreased due to decreasing numbers of cattle. However, the emission from manure management has increased due to changes in stable management systems towards an increase in slurry-based systems. Altogether, the emission of CH_4 for the agricultural sector has decreased by 2.6 % from 1990 to 2013.

2.3.4 Land use, Land-use change and forestry

The trend in CO_2 uptake from forests varies greatly due to several factors both relating to weather and other effects. In 2013 the LULUCF sector is a net source of 2 390 kt CO_2 equivalents. LULUCF was also a GHG source in 2012, contributing 2 271 kt CO_2 equivalents.

The most important activities are forest land and cropland. In 2013 forest land is a sink of 2 310 kt equivalents and cropland is a source of 4 104 kt equivalents. Emissions and removals from LULUCF show large fluctuations over the time series. The largest fluctuations are found for forest land, partly due to the dependency of climatic parameters like temperature and wind. E.g. emission peaks occur in years with destruction of forest trees through storms or hurricanes. Also changes in changes in forest management practice can affect the emissions and removals from forests.

2.3.5 Waste

The waste sector contributes in 2013 with 2.4 % to the national total of greenhouse gas emissions (excl. LULUCF), 15.7 % of the total CH_4 emission and 3.8 % of the total N_2O emission. The sector comprises solid waste disposal on land, wastewater handling, waste incineration without energy recovery (e.g. incineration of animal carcasses) and other waste (e.g. composting and accidental fires).

The GHG emission from the sector has decreased by 36.4 % from 1990 to 2013. This decrease is a result of (1) a decrease in the CH_4 emission from solid waste disposal sites (SWDS) by 52.4 % due to the increasing use of waste for power and heat production, and (2) a decrease in emission of N_2O from wastewater (WW) handling systems of 26.7 % due to upgrading of WW treatment plants. These decreases are counteracted by an increase in CH_4 from WW of 13.3 % due to increasing industrial load to WW systems. In 2013 the contribution of CH_4 from SWDS was 12.2 % of the total CH_4 emission. The CH_4 emission from WW amounts in 2013 to 1.6 % of the total CH_4 emissions. The emission of N_2O from WW in 2013 is 1.4 % of national total of N_2O. Since all incinerated waste is used for power and heat production, the emissions are included in the 1A CRF category.

2.4 Description and interpretation of emission trends for KP-LULUCF inventory in aggregate, by activity and by gas

Coverage relating to reporting of activities under Article 3.3 and selected activities under Article 3.4 are listed in Table 2.1 for reporting concerning change in carbon pool and for greenhouse gas sources. All pools are reported. Carbon stock change in below-ground biomass for Cropland Management and Grazing Land Management under Article 3.4 are included under Above-ground biomass for the same area categories. Fertilisation of forests and other land is negligible and all fertiliser consumption is therefore reported in the agricultural sector. All liming is reported under the agriculture sector. Field burning of wooden biomass is prohibited in Denmark and therefore reported as not occurring. Wildfires are very seldom and if occurring very small in Denmark.

Table 2.1 Coverage of reporting of change of carbon pools relating to activities under Article 3.3 and elected activities under Article 3.4.

Activity	CHANGE IN CARBON POOL REPORTED						
	Above-ground biomass	Below-ground biomass	Litter	Dead wood	Soil		HWP
					Mineral	Organic	
Article 3.3 activities							
Afforestation and reforestation	R	R	R	R	R	R	R
Deforestation	R	R	R	R	R	R	R
Article 3.4 activities							
Forest management	R	R	R	R	R	R	R
Cropland management	R	IE	NO	NO	R	R	
Grazing land management	R	IE	NO	NO	R	R	
Revegetation	NA	NA	NA	NA	NA	NA	
Wetland drainage and rewetting	NA	NA	NA	NA		NA	

Activity	GREENHOUSE GAS SOURCES REPORTED							
	Fertilization	Drained, rewetted and other soils		Nitrogen mineralization in mineral soils	Indirect N_2O emissions from managed soil	Biomass burning		
	N_2O	CH_4	N_2O	N_2O	N_2O	CO_2	CH_4	N_2O
Article 3.3 activities								
Afforestation and reforestation	IE	NE	R	NO	R	IE	IE	IE
Deforestation	IE	R	R	R	IE	IE	IE	IE
Article 3.4 activities								
Forest management	IE	NE	R	NO	IE	R	R	R
Cropland management		R		IE		NO	NO	NO
Grazing land management		R		IE		IE	R	R
Revegetation	NA	NA	NA	NA	NA	NA	NA	NA
Wetland drainage and rewetting	NA	NA	NA		NA	NA	NA	NA

R: reported, NR: not reported, IE: included elsewhere, NO: not occurring, NA: not applicable. Biomass burning does not occur in all years and therefore sometimes reported as NO in the CRF.

CO_2 is by far the most important greenhouse gas relating to activities under Article 3.3 and Article 3.4. There is however a minor contribution of CH_4 and N_2O. Large fluctuations of emissions and removals occur for the LULUCF sector, partly due to annual climatic variations, e.g. temperature and wind, but also regulations and changes in the forestry are important parameters.

2.4.1 Forest

The trends in emissions and removals from forests are dependent on both the current structure of the forests and the management actions in the coming years. If similar management is applied as in the previous 15 years a decline in the total carbon stock in the forest is expected. However, for some years a sink in forest is reported. For the afforested areas a steady increase in carbon stocks is expected also in the future years. The rate of increase of area will depend on both availability of land and on possible subsidies for afforestation. Deforestation occurs mainly in relation to other specific projects e.g. for nature restoration or test areas for wind turbines.

2.4.2 Cropland, Grassland and Wetlands

The trend for the Cropland Management and Grazing Land Management under KP-LULUCF indicates that there has been a stabilisation of the loss of carbon from agricultural soils compared to previous due to an increased input of organic matter in the soil. However, the loss depends much of the climatic conditions. As a consequence of the global warming, where most years since 1990 have been above the average for 1961-1990, it is difficult to avoid substantial losses of carbon from the agricultural soils in the future. The changes in Cropland Management since 1990 have undoubtedly prevented further losses of soil carbon. A further increase in the actual temperature will affect the ability to prevent further losses of soil carbon.

The reestablishment of wetlands on agricultural land is especially targeted towards organic soils, which leads to a decreased emission from these soils. Further reestablishments are expected to take place in the future.

3 Energy

3.1 Overview of the sector

The data presented in Chapter 3 relates to Denmark only, whereas information for Greenland is included in Chapter 16 and for the Faroe Islands in Annex 8.

The energy sector has been reported in four main chapters:

3.2 Stationary combustion plants (CRF sector 1A1, 1A2 and 1A4)
3.3 Transport (CRF sector 1A2, 1A3, 1A4 and 1A5)
3.4 Additional information on fuel combustion (Reference approach)
3.5 Fugitive emissions (CRF sector 1B)

Summary tables for the energy sector are shown below.

Table 3.1.1 CO_2 emissions from the energy sector.

Greenhouse gas source categories	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	(Gg)									
1. Energy	51,658	62,183	56,354	58,645	62,602	59,396	72,639	63,112	59,044	56,472
A. Fuel Combustion (Sectoral Approach)	51,317	61,533	55,677	58,063	62,024	58,943	72,141	62,414	58,522	55,366
1. Energy Industries	26,146	35,015	30,086	31,662	35,696	32,168	44,462	35,334	31,677	28,588
2. Manufacturing Industries and Construction	5,449	5,978	5,841	5,705	5,801	5,911	6,061	6,111	6,130	6,220
3. Transport	10,586	10,998	11,203	11,309	11,788	11,925	12,171	12,345	12,297	12,316
4. Other Sectors	8,969	9,204	8,351	9,091	8,425	8,620	9,202	8,379	8,135	7,978
5. Other	167	338	195	295	314	318	246	245	282	265
B. Fugitive Emissions from Fuels	341	649	677	582	578	453	498	697	523	1,106
1. Solid Fuels	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
2. Oil and Natural Gas	341	649	677	582	578	453	498	697	523	1,106

Continued	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
	(Gg)									
1. Energy	52,123	53,775	53,397	58,628	53,054	49,470	57,384	52,611	49,412	47,516
A. Fuel Combustion (Sectoral Approach)	51,400	53,005	52,724	57,959	52,302	48,922	56,853	52,068	49,025	47,255
1. Energy Industries	25,565	26,852	27,071	31,815	25,933	22,731	30,648	26,010	23,891	23,834
2. Manufacturing Industries and Construction	6,014	6,108	5,817	5,779	5,834	5,537	5,672	5,503	5,002	4,071
3. Transport	12,115	12,114	12,210	12,663	12,984	13,099	13,466	14,079	13,771	13,047
4. Other Sectors	7,509	7,744	7,442	7,511	7,209	7,181	6,839	6,200	6,153	6,042
5. Other	197	188	184	191	343	374	228	276	208	260
B. Fugitive Emissions from Fuels	723	770	674	669	752	548	531	543	387	261
1. Solid Fuels	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
2. Oil and Natural Gas	723	770	674	669	752	548	531	543	387	261

Continued	2010	2011	2012	2013
	(Gg)			
1. Energy	47,905	42,827	38,327	40,172
A. Fuel Combustion (Sectoral Approach)	47,552	42,575	38,110	39,934
1. Energy Industries	23,628	19,738	16,526	18,768
2. Manufacturing Industries and Construction	4,516	4,486	4,223	4,135
3. Transport	12,985	12,650	12,032	11,802
4. Other Sectors	6,216	5,410	5,114	4,990
5. Other	206	292	214	239
B. Fugitive Emissions from Fuels	353	252	217	238
1. Solid Fuels	NO	NO	NO	NO
2. Oil and Natural Gas	353	252	217	238

Table 3.1.2 CH$_4$ emissions from the energy sector.

Greenhouse gas source categories	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
					(Gg)					
1. Energy	14.54	17.33	18.01	20.00	23.35	29.15	33.73	34.83	35.64	37.99
A. Fuel Combustion (Sectoral Approach)	9.63	10.64	11.19	13.27	16.43	22.23	26.39	25.99	27.28	26.97
1. Energy Industries	0.63	0.97	1.37	2.99	6.08	11.42	14.59	13.91	15.30	15.40
2. Manufacturing Industries and Construction	0.34	0.36	0.34	0.34	0.34	0.41	0.78	0.78	0.88	0.87
3. Transport	2.27	2.36	2.38	2.36	2.34	2.26	2.19	2.12	2.05	1.94
4. Other Sectors	6.31	6.85	7.01	7.48	7.56	8.04	8.74	9.07	8.95	8.67
5. Other	0.08	0.10	0.09	0.09	0.10	0.10	0.10	0.10	0.10	0.10
B. Fugitive Emissions from Fuels	4.91	6.69	6.82	6.73	6.92	6.92	7.34	8.85	8.36	11.02
1. Solid Fuels	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
2. Oil and Natural Gas	4.91	6.69	6.82	6.73	6.92	6.92	7.34	8.85	8.36	11.02

Continued	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
					(Gg)					
1. Energy	36.26	37.38	36.33	35.72	36.33	34.03	32.32	30.21	28.99	25.54
A. Fuel Combustion (Sectoral Approach)	26.39	27.20	26.66	26.26	26.06	24.42	23.04	21.47	21.11	19.08
1. Energy Industries	14.69	15.57	15.14	14.40	14.08	12.44	11.53	9.60	10.12	8.84
2. Manufacturing Industries and Construction	1.08	1.14	1.04	1.01	1.02	0.88	0.74	0.52	0.56	0.51
3. Transport	1.81	1.70	1.60	1.52	1.41	1.30	1.19	1.09	0.93	0.80
4. Other Sectors	8.72	8.70	8.79	9.25	9.46	9.73	9.52	10.21	9.46	8.90
5. Other	0.09	0.09	0.09	0.08	0.08	0.07	0.06	0.05	0.04	0.03
B. Fugitive Emissions from Fuels	9.87	10.18	9.68	9.46	10.27	9.61	9.29	8.74	7.88	6.47
1. Solid Fuels	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
2. Oil and Natural Gas	9.87	10.18	9.68	9.46	10.27	9.61	9.29	8.74	7.88	6.47

Continued	2010	2011	2012	2013
		(Gg)		
1. Energy	27.64	23.44	19.04	17.26
A. Fuel Combustion (Sectoral Approach)	21.33	18.17	14.40	12.97
1. Energy Industries	11.01	9.22	6.38	5.60
2. Manufacturing Industries and Construction	0.57	0.53	0.39	0.37
3. Transport	0.71	0.63	0.56	0.50
4. Other Sectors	9.01	7.76	7.05	6.48
5. Other	0.03	0.02	0.02	0.01
B. Fugitive Emissions from Fuels	6.31	5.27	4.64	4.30
1. Solid Fuels	NO	NO	NO	NO
2. Oil and Natural Gas	6.31	5.27	4.64	4.30

Table 3.1.3 N_2O emissions from the energy sector.

Greenhouse gas source categories	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
					(Gg)					
1. Energy	1.26	1.57	1.55	1.52	1.56	1.54	1.71	1.75	1.61	1.92
A. Fuel Combustion (Sectoral Approach)	1.08	1.22	1.18	1.21	1.24	1.30	1.44	1.37	1.33	1.31
1. Energy Industries	0.29	0.37	0.34	0.36	0.39	0.38	0.51	0.44	0.42	0.41
2. Manufacturing Industries and Construction	0.20	0.22	0.22	0.20	0.20	0.25	0.25	0.25	0.26	0.25
3. Transport	0.36	0.37	0.39	0.39	0.41	0.42	0.43	0.44	0.42	0.42
4. Other Sectors	0.23	0.24	0.23	0.24	0.23	0.24	0.24	0.23	0.22	0.23
5. Other	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
B. Fugitive Emissions from Fuels	0.18	0.35	0.37	0.32	0.31	0.24	0.27	0.39	0.28	0.61
1. Solid Fuels	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
2. Oil and Natural Gas	0.18	0.35	0.37	0.32	0.31	0.24	0.27	0.39	0.28	0.61

Continued	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
					(Gg)					
1. Energy	1.68	1.72	1.66	1.70	1.70	1.55	1.62	1.60	1.50	1.37
A. Fuel Combustion (Sectoral Approach)	1.28	1.30	1.29	1.33	1.28	1.25	1.34	1.31	1.29	1.24
1. Energy Industries	0.38	0.40	0.40	0.44	0.39	0.36	0.42	0.36	0.35	0.36
2. Manufacturing Industries and Construction	0.25	0.24	0.23	0.22	0.23	0.22	0.24	0.24	0.23	0.18
3. Transport	0.41	0.40	0.39	0.39	0.39	0.38	0.38	0.39	0.40	0.39
4. Other Sectors	0.24	0.25	0.25	0.27	0.26	0.29	0.30	0.31	0.31	0.31
5. Other	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
B. Fugitive Emissions from Fuels	0.40	0.43	0.37	0.37	0.42	0.29	0.29	0.29	0.21	0.14
1. Solid Fuels	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
2. Oil and Natural Gas	0.40	0.43	0.37	0.37	0.42	0.29	0.29	0.29	0.21	0.14

Continued	2010	2011	2012	2013
		(Gg)		
1. Energy	1.48	1.36	1.30	1.35
A. Fuel Combustion (Sectoral Approach)	1.29	1.24	1.19	1.21
1. Energy Industries	0.37	0.33	0.31	0.33
2. Manufacturing Industries and Construction	0.20	0.19	0.18	0.17
3. Transport	0.40	0.42	0.41	0.42
4. Other Sectors	0.32	0.29	0.28	0.28
5. Other	0.01	0.01	0.01	0.01
B. Fugitive Emissions from Fuels	0.19	0.12	0.11	0.14
1. Solid Fuels	NO	NO	NO	NO
2. Oil and Natural Gas	0.19	0.12	0.11	0.14

3.2 Stationary combustion

Stationary combustion is the largest source of CO_2 emission in Denmark accounting for 60 % of the national total CO_2 emissions (excl. LULUCF) in 2013. The CO_2 emission from stationary combustion has increased by 9 % since 2012 and decreased by 34 % since 1990. The decreased emission since 1990 is a result of a change of fuels; the consumption of coal has decreased whereas the consumption of natural gas and biomass has increased since 1990. The relatively large fluctuations in the CO_2 emission time series from 1990 to 2013 are due to inter-country electricity trade fluctuations caused mainly by variation in hydropower generation in Norway and Sweden. The CO_2 emission in 2013 was higher than in 2012 due to a lower electricity import in 2013 than in 2012.

The methane (CH_4) emission from stationary combustion plants accounted for 4 % of the national CH_4 emission in 2013. The CH_4 emission from stationary combustion has increased by 78 % since 1990. This results from the considerable number of lean-burn gas engines installed in CHP plants in Denmark during the 1990s. The deregulation of the electricity market has made production of electricity in gas engines less favourable, therefore the fuel consumption and CH_4 emission has decreased since 2004. The CH_4 emission in 2013 was 10 % lower than in 2012 due to lower fuel consumption in gas engines.

The nitrous oxide (N_2O) emission from stationary combustion plants accounted for 4 % of the national N_2O emission in 2013. The N_2O emission from stationary combustion has increased by 9 % since 1990, but as for CO_2, fluctuations in emission level due to electricity import/export are considerable. The emission in 2013 was 2 % higher than in 2012 due to a lower electricity import in 2013 than in 2012.

3.2.1 Source category description

Source category definition

Stationary combustion plants are included in the emission source subcategories:

- 1A1 Energy, Fuel consumption, Energy Industries
  - 1A1a Public electricity and heat production
  - 1A1b Petroleum refining
  - 1A1c Oil and gas extraction
- 1A2 Energy, Fuel consumption, Manufacturing Industries and Construction
  - 1A2a Iron and steel
  - 1A2b Non-ferrous metals
  - 1A2c Chemicals
  - 1A2d Pulp, Paper and Print
  - 1A2e Food processing, beverages and tobacco
  - 1A2f Non-metallic minerals
  - 1A2 g viii Other manufacturing industry
- 1A4 Energy, Fuel consumption, Other Sectors
  - 1A4a i Commercial/Institutional plants.
  - 1A4b i Residential plants.
  - 1A1c i Agriculture/Forestry.

The emission and fuel consumption data included in tables and figures in Chapter 3.2 only include emissions originating from stationary combustion plants of a given CRF sector.

In the Danish emission database all activity rates and emissions are defined in SNAP sector categories (Selected Nomenclature for Air Pollution) according the CORINAIR system. The emission inventories are prepared from a complete emission database based on the SNAP source categories. Danish Centre for Environment and Energy, Aarhus University (DCE) has modified the SNAP categorisation to enable direct reporting of the disaggregated data for manufacturing industries and construction. Aggregation to the IPCC source category codes is based on a correspondence list enclosed in Annex 3A-1. Stationary combustion is defined as combustion activities in the SNAP sectors 01 – 03, not including SNAP 0303.

The CO_2 emission from calcinations is not part of the source category *Energy*. This emission is included in the source category *Industrial Processes*.

Methodology overview, tier

The type of emission factor and the applied tier level for each emission source are shown in Table 3.2.1 below. The tier level has been determined based on the IPCC Guidelines (IPCC, 2006).

The fuel consumption data for transformation are technology specific. For end-use of fuels, the disaggregation to specific technologies is less detailed.

However, for residential wood combustion the technology disaggregation is technology specific.

The distinction between tier 2 and 3 has been based on the emission factor. The tier definitions have been interpreted as follows:

The tier level definitions have been interpreted as follows:

- Tier 1: The emission factor is an IPCC default tier 1 value.
- Tier 2: The emission factors are country-specific and based on a limited number of emission measurements or a technology specific IPCC tier 2 emission factor.
- Tier 3: Emission data are based on:
  - Plant specific emission measurements or
  - Technology specific fuel consumption data and country-specific emission factors based on a considerable number of emission measurements from Danish plants.

Table 3.2.1 gives an overview of the calculation methods and type of emission factor. The table also shows which of the source categories are key in any of the key category analysis[1] (including LULUCF, approach 1/approach 2, level/trend).

[1] Key category according to the KCA approach 1 or approach 2 for Denmark (excluding Greenland and Faroe Islands), including LULUCF, level 1990/level 2013/trend.

Table 3.2.1 Methodology and type of emission factor.

		Tier	EMF[1)]	Key category[2)]
1A Stationary combustion, Coal, ETS data	CO_2	Tier 3	PS	Yes
1A Stationary combustion, Coal, no ETS data	CO_2	Tier 3 / Tier 1 [3)]	CS (1A1) or D (1A2, 1A4)	Yes
1A Stationary combustion, BKB	CO_2	Tier 1	D	No
1A Stationary combustion, Coke oven coke	CO_2	Tier 1	D	No
1A Stationary combustion, Fossil waste, ETS data	CO_2	Tier 3	PS	Yes
1A Stationary combustion, Fossil waste, no ETS data	CO_2	Tier 2	CS	Yes
1A Stationary combustion, Petroleum coke, ETS data	CO_2	Tier 3	PS	Yes
1A Stationary combustion, Petroleum coke, no ETS data	CO_2	Tier 2	CS	Yes
1A Stationary combustion, Residual oil, ETS data	CO_2	Tier 3	PS	Yes
1A Stationary combustion, Residual oil, no ETS data	CO_2	Tier 2 / Tier 1 [4)]	CS (1A1a) / D (1A2, 1A4)	Yes
1A Stationary combustion, Gas oil	CO_2	Tier 2 / Tier 3 [5)]	CS / PS	Yes
1A Stationary combustion, Kerosene	CO_2	Tier 1	D	Yes
1A Stationary combustion, LPG	CO_2	Tier 1	D	No
1A1b Stationary combustion, Petroleum refining, Refinery gas	CO_2	Tier 3	CS	Yes
1A Stationary combustion, Natural gas, onshore	CO_2	Tier 3	CS	Yes
1A1c_ii Stationary combustion, Oil and gas extraction, Off shore gas turbines, Natural gas	CO_2	Tier 3	CS	Yes
1A1 Stationary Combustion, Solid fuels	CH_4	Tier 2	D(2)	No
1A1 Stationary Combustion, Liquid fuels	CH_4	Tier 1 / Tier 2	D / D(2) / CS	No
1A1 Stationary Combustion, not engines, gaseous fuels	CH_4	Tier 2	CS / D(2)	No
1A1 Stationary Combustion, Waste	CH_4	Tier 2	CS	No
1A1 Stationary Combustion, not engines, Biomass	CH_4	Tier 3 / Tier 2 / Tier 1	CS / D(2) / D	No
1A2 Stationary Combustion, solid fuels	CH_4	Tier 1	D	No
1A2 Stationary Combustion, Liquid fuels	CH_4	Tier 1 / Tier 2	D / D(2) / CS	No
1A2 Stationary Combustion, not engines, gaseous fuels	CH_4	Tier 2	CS / D(2)	No
1A2 Stationary Combustion, Waste	CH_4	Tier 1	D	No
1A2 Stationary Combustion, not engines, Biomass	CH_4	Tier 2 / Tier 1	D(2) / D	No
1A4 Stationary Combustion, Solid fuels	CH_4	Tier 1	D	No
1A4 Stationary Combustion, Liquid fuels	CH_4	Tier 1 / Tier 2	D / D(2)	No
1A4 Stationary Combustion, not engines, gaseous fuels	CH_4	Tier 2	D(2)	No
1A4 Stationary Combustion, Waste	CH_4	Tier 1	D	No
1A4 Stationary Combustion, not engines, not residential wood and not residential/agricultural straw, Biomass	CH_4	Tier 1 / Tier 2	D / D(2) / CS	No
1A4b_i Stationary combustion, Residential wood combustion	CH_4	Tier 2	CS	Yes
1A4b_i/1A4c_i Stationary Combustion, Residential and agricultural straw combustion	CH_4	Tier 1	D	Yes
1A Stationary combustion, Natural gas fuelled engines, gaseous fuels	CH_4	Tier 3	CS	No
1A Stationary combustion, Biogas fuelled engines, Biomass	CH_4	Tier 3	CS	No
1A1 Stationary Combustion, Solid fuels	N_2O	Tier 2	CS / D(2)	Yes
1A1 Stationary Combustion, Liquid fuels	N_2O	Tier 2 / Tier 1	D(2) / CS / D	No
1A1 Stationary Combustion, Gaseous fuels	N_2O	Tier 3 / Tier 2	CS / D(2)	Yes
1A1 Stationary Combustion, Waste	N_2O	Tier 2	CS	Yes
1A1 Stationary Combustion, Biomass	N_2O	Tier 2 / Tier 1	CS / D(2) / D	Yes
1A2 Stationary Combustion, Solid fuels	N_2O	Tier 1	D	No
1A2 Stationary Combustion, Liquid fuels	N_2O	Tier 2 / Tier 1	D(2) / CS / D	Yes
1A2 Stationary Combustion, Gaseous fuels	N_2O	Tier 3 / Tier 2	CS / D(2)	Yes
1A2 Stationary Combustion, Waste	N_2O	Tier 1	D	No
1A2 Stationary Combustion, Biomass	N_2O	Tier 1 / Tier 2	D / CS	No
1A4 Stationary Combustion, Solid fuels	N_2O	Tier 1	D	No
1A4 Stationary Combustion, Liquid fuels	N_2O	Tier 2 / Tier 1	D(2) / CS / D	Yes
1A4 Stationary Combustion, Gaseous fuels	N_2O	Tier 3 / Tier 2	CS / D(2)	Yes
1A4 Stationary Combustion, Waste	N_2O	Tier 1	D	No
1A4 Stationary Combustion, not residential wood and not residential/agricultural straw, Biomass	N_2O	Tier 1 / Tier 2	D / CS	No
1A4b_i Stationary Combustion, Residential wood combustion	N_2O	Tier 1	D	Yes
1A4b_i/1A4c_i Stationary Combustion, Residential and agricultural straw combustion	N_2O	Tier 1	D	No

1) D: IPCC (2006) default, tier 1. D(2): IPCC (2006) default, tier 2. CS: Country specific. PS: Plant specific.

2) KCA approach 1 or approach 2 for Denmark (excluding Greenland and Faroe Islands), including LULUCF, level 1990 or level 2013 or trend 1990-2013.

3) Tier 1 for 64 % of the emission in this emission source category in 2013, but less than 2 % of the total coal consumption.

4) Tier 1 for 80 % of the emission source category in 2013, but less than 20 % of the total residual oil consumption.

5) Tier 3 for 8 % of the gas oil consumption in 2013.

Key Categories

Key Category Analysis (KCA) approach 1 and approach 2 for the years 1990 and 2013 and for the trend 1990-2013 for Denmark has been carried out in accordance with the IPCC Guidelines (IPCC, 2006). Table 3.2.2 shows the 24 stationary combustion key categories. The table is based on the analysis including LULUCF. Detailed key category analysis is shown in NIR Chapter 1.5 and Annex 1.

The CO_2 emissions from stationary combustion are key categories for all the major fuels. In addition, CH_4 from residential wood combustion and from straw combustion in agriculture/residential plants are key categories in the approach 2 analysis. Finally, due to the relatively high uncertainty for N_2O, emission factors the N_2O emission from a number of emission sources are also key categories in the approach 2 analysis.

Table 3.2.2 Key categories[2], stationary combustion.

			Approach 1			Approach 2		
			1990	2013	1990-2013	1990	2013	1990-2013
Energy	1A Stationary combustion, Coal, ETS data	CO_2		Level	Trend		Level	Trend
Energy	1A Stationary combustion, Coal, no ETS data	CO_2	Level	Level	Trend	Level		Trend
Energy	1A Stationary combustion, Fossil waste, ETS data	CO_2		Level	Trend			Trend
Energy	1A Stationary combustion, Fossil waste, no ETS data	CO_2	Level	Level	Trend		Level	
Energy	1A Stationary combustion, Petroleum coke, ETS data	CO_2		Level	Trend			
Energy	1A Stationary combustion, Petroleum coke, no ETS data	CO_2	Level		Trend			
Energy	1A Stationary combustion, Residual oil, ETS data	CO_2		Level	Trend			
Energy	1A Stationary combustion, Residual oil, no ETS data	CO_2	Level		Trend			Trend
Energy	1A Stationary combustion, Gas oil	CO_2	Level	Level	Trend	Level		Trend
Energy	1A Stationary combustion, Kerosene	CO_2	Level		Trend			
Energy	1A1b Stationary combustion, Petroleum refining, Refinery gas	CO_2	Level	Level	Trend			
Energy	1A Stationary combustion, Natural gas, onshore	CO_2	Level	Level	Trend		Level	Trend
Energy	1A1c_ii Stationary combustion, Oil and gas extraction, Off shore gas turbines, Natural gas	CO_2	Level	Level	Trend			
Energy	1A4b_i Stationary combustion, Residential wood combustion	CH_4				Level	Level	Trend
Energy	1A4b_i/1A4c_i Stationary Combustion, Residential and agricultural straw combustion	CH_4				Level		
Energy	1A1 Stationary Combustion, Solid fuels	N_2O				Level	Level	Trend
Energy	1A1 Stationary Combustion, Gaseous fuels	N_2O					Level	Trend
Energy	1A1 Stationary Combustion, Waste	N_2O						Trend
Energy	1A1 Stationary Combustion, Biomass	N_2O					Level	Trend
Energy	1A2 Stationary Combustion, Liquid fuels	N_2O				Level	Level	Trend
Energy	1A2 Stationary Combustion, Gaseous fuels	N_2O					Level	Trend
Energy	1A4 Stationary Combustion, Liquid fuels	N_2O				Level		Trend
Energy	1A4 Stationary Combustion, Gaseous fuels	N_2O					Level	Trend
Energy	1A4b_i Stationary Combustion, Residential wood combustion	N_2O					Level	Trend

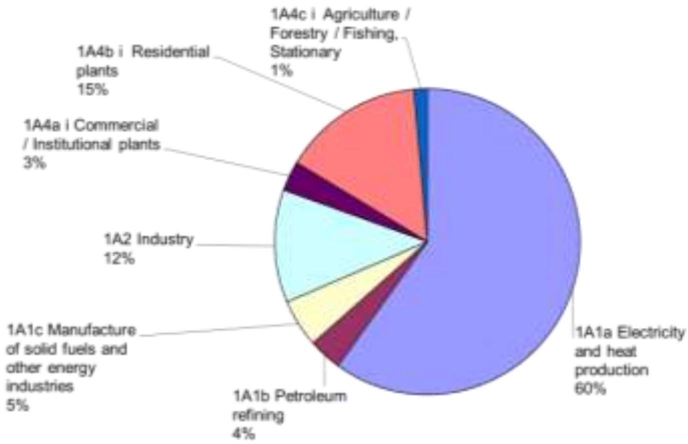
[2] For Denmark, not including Greenland and Faroe Island. Based on the KCA including LULUCF.

3.2.2 Fuel consumption data

In 2013, the total fuel consumption for stationary combustion plants was 461 PJ of which 331 PJ was fossil fuels and 130 PJ was biomass.

Fuel consumption distributed according to the stationary combustion subcategories is shown in Figure 3.2.1 and Figure 3.2.2. The majority - 60 % - of all fuels is combusted in the source category, *Public electricity and heat production*. Other source categories with high fuel consumption are *Residential* and *Industry*.

Fuel consumption including biomass



Fuel consumption, fossil fuels

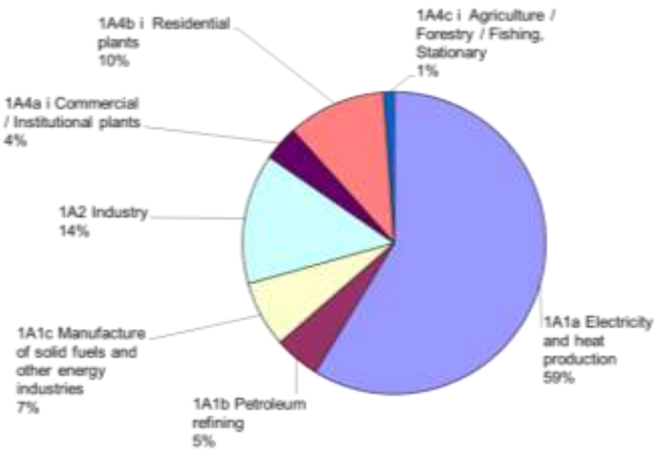
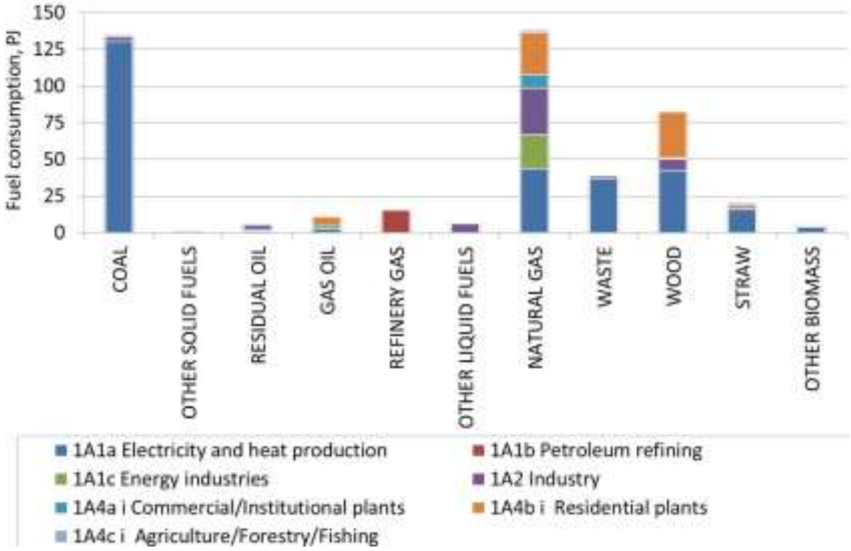


Figure 3.2.1 Fuel consumption of stationary combustion source categories, 2013. Based on DEA (2014a).

Coal, natural gas and wood are the most utilised fuels for stationary combustion plants. Coal is mainly used in power plants and natural gas is used in power plants and decentralised combined heating and power (CHP) plants, as well as in industry, residential plants and off-shore gas turbines (see Figure 3.2.2). Wood is mainly applied for public electricity and heat production and in residential plants.

Detailed fuel consumption rates are shown in Annex 3A-2.



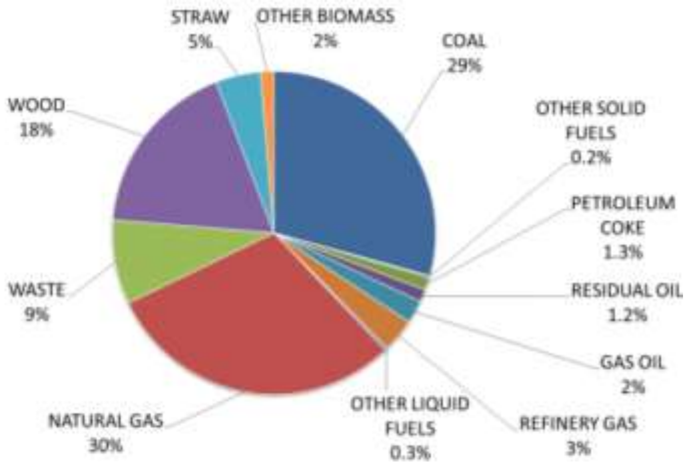
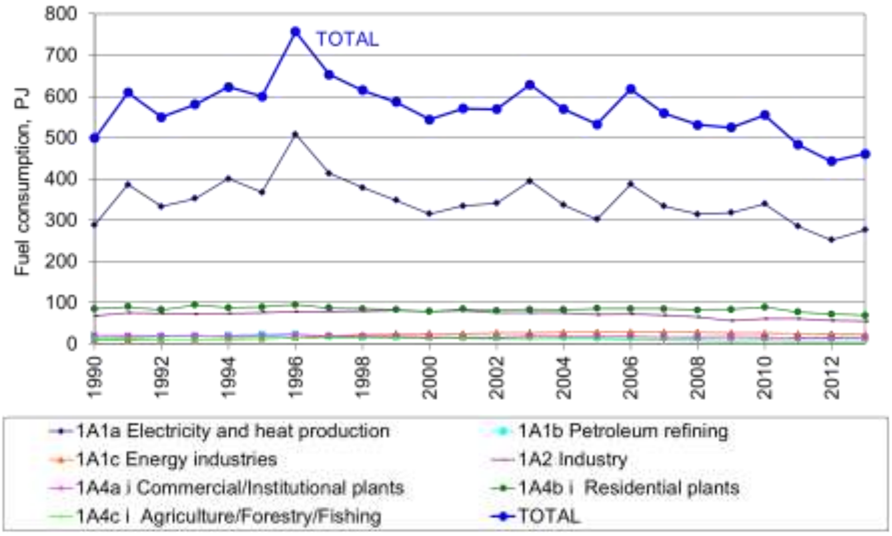


Figure 3.2.2 Fuel consumption of stationary combustion 2013, disaggregated to fuel type. Based on DEA (2014a).

Fuel consumption time series for stationary combustion plants are presented in Figure 3.2.3. The fuel consumption for stationary combustion was 8 % lower in 2013 than in 1990, while the fossil fuel consumption was 28 % lower and the biomass fuel consumption 3.2 times the level in 1990.

The consumption of natural gas, waste and biomass has increased since 1990 whereas the consumption of coal and oil has decreased.



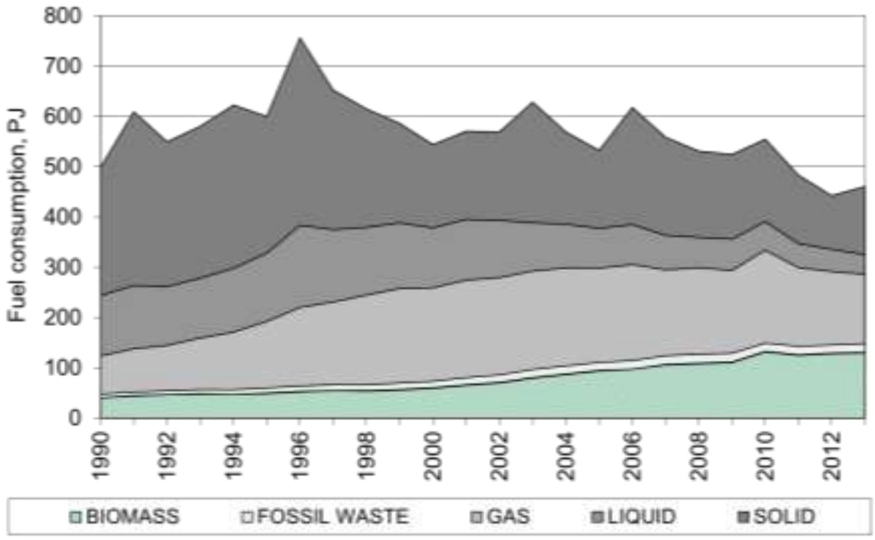


Figure 3.2.3 Fuel consumption time series, stationary combustion. Based on DEA (2014a).

The fluctuations in the time series for fuel consumption are mainly a result of electricity import/export, but also of outdoor temperature variations from year to year. This, in turn, leads to fluctuations in emission levels. The fluctuations in electricity trade, fuel consumption, CO_2 and NO_x emission are illustrated and compared in Figure 3.2.4. In 1990, the Danish electricity import was large causing relatively low fuel consumption, whereas the fuel consumption was high in 1996 due to a large electricity export. In 2013, the net electricity import was 4 PJ, whereas there was a 19 PJ electricity import in 2012. The large electricity export that occurs some years is a result of low rainfall in Norway and Sweden causing insufficient hydropower production in both countries.

The Danish electricity production is highly dependent on the electricity trade with especially Sweden and Norway. Denmark has a number of central coal-fuelled power plants that consists of a number of blocks. These do not under normal conditions operate at max load, i.e. there is free capacity for peak situations. In addition, there are blocks, which are mothballed but can be reopened in situations where there is a significant increase in the electricity demand.

To be able to follow the national energy consumption as well as for statistical and reporting purposes, the Danish Energy Agency (DEA) produces a correction of the actual fuel consumption and CO_2 emission without random variations in electricity import/export and in ambient temperature. This fuel consumption trend is also illustrated in Figure 3.2.4. The corrections are included here to explain the fluctuations in the time series for fuel rate and emission.

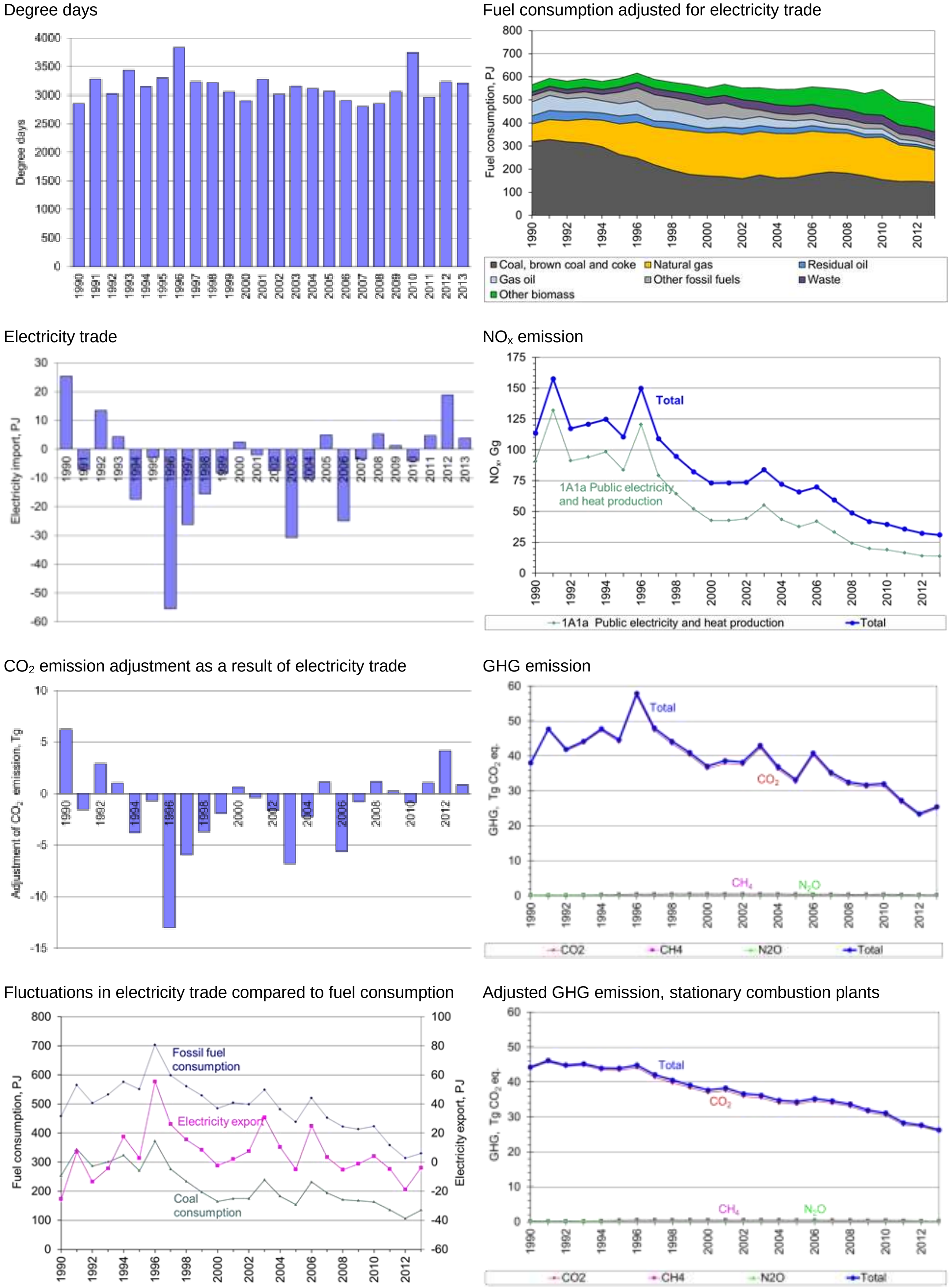


Figure 3.2.4 Comparison of time series fluctuations for electricity trade, fuel consumption, CO_2 emission and NO_x emission. Based on DEA (2014a).

Fuel consumption time series for the subcategories to stationary combustion are shown in Figure 3.2.5, 3.2.6 and 3.2.7.

Fuel consumption for *Energy Industries* fluctuates due to electricity trade as discussed above. The fuel consumption in 2013 was 1 % higher than in 1990. However, the fossil fuel consumption was 21 % lower. The fluctuation in electricity production is based on fossil fuel consumption in the subcategory *Public electricity and Heat Production*. The energy consumption in *Oil and gas extraction* is mainly natural gas used in gas turbines in the off-shore industry. The biomass fuel consumption in *Energy Industries* in 2013 added up to 82 PJ, which is 5.1 times the level in 1990 and a 4 % increase since 2012.

The fuel consumption in *Industry* was 19 % lower in 2013 than in 1990 (Figure 3.2.6). The fuel consumption in industrial plants decreased considerably as a result of the financial crisis. The fuel consumption in 2013 was almost equal to the consumption in 2009. The biomass fuel consumption in *Industry* in 2013 added up to 9 PJ which is a 16 % increase since 1990.

The fuel consumption in *Other Sectors* decreased 23 % since 1990 (Figure 3.2.7) and decreased 3 % since 2012. The biomass fuel consumption in *Other sectors* in 2013 added up to 39 PJ which is 2.1 times the consumption in 1990 but a 2 % decrease since 2012. Wood consumption in residential plants in 2013 was 2.1 times the consumption in year 2000.

Time series for subcategories are shown in Chapter 3.2.4.

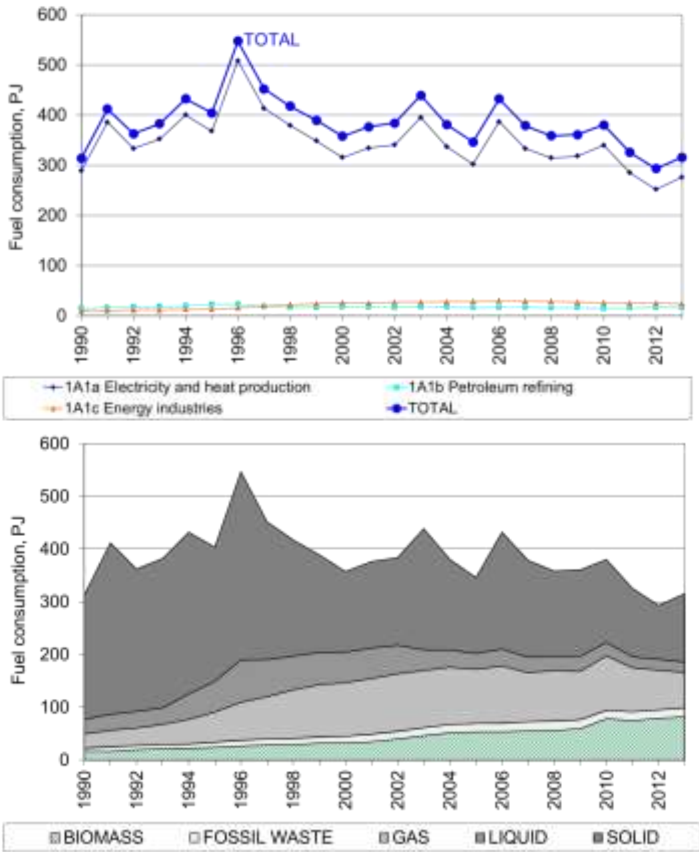


Figure 3.2.5 Fuel consumption time series for subcategories - 1A1 Energy Industries.

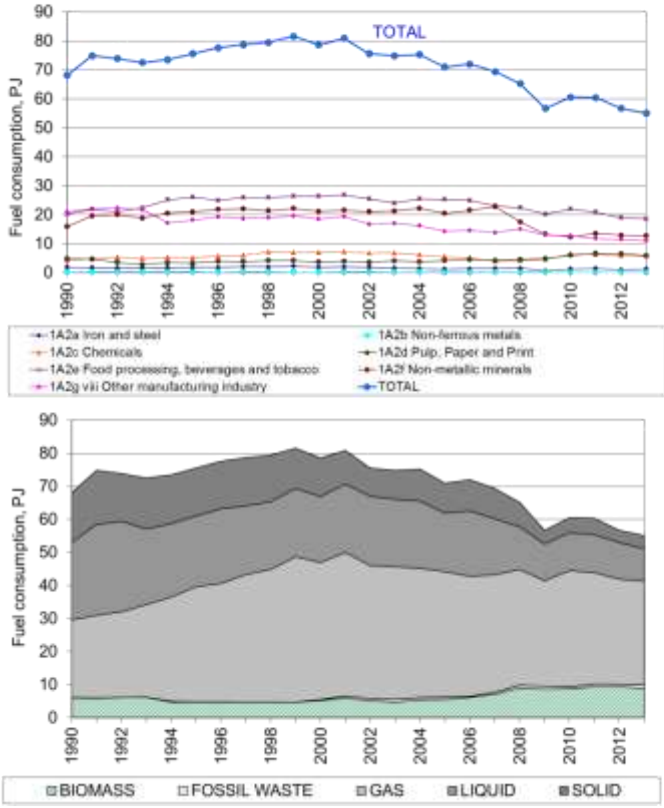


Figure 3.2.6 Fuel consumption time series for subcategories - 1A2 Industry.

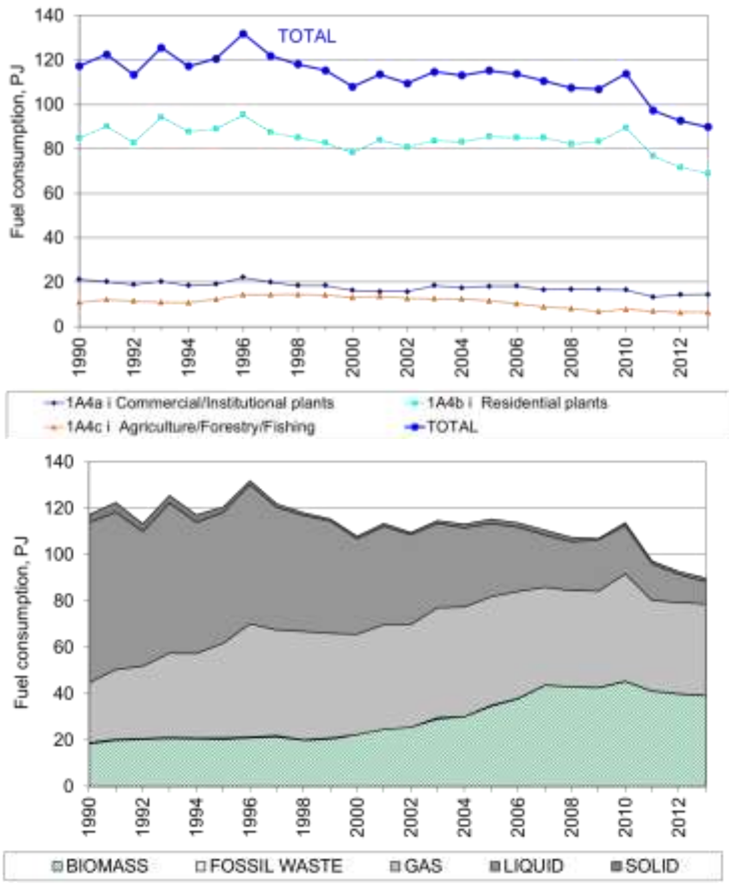


Figure 3.2.7 Fuel consumption time series for subcategories - 1A4 Other Sectors.

3.2.3 Emissions

Greenhouse gas emission

The greenhouse gas emissions from stationary combustion are listed in Table 3.2.3. The emission from stationary combustion accounted for 47 % of the national greenhouse gas emission (excluding LULUCF) in 2013.

The CO_2 emission from stationary combustion plants accounts for 60 % of the national CO_2 emission (excluding LULUCF). The CH_4 emission accounts for 4 % of the national CH_4 emission and the N_2O emission for 4 % of the national N_2O emission.

Table 3.2.3 Greenhouse gas emission, 2013 [1)].

	CO_2	CH_4	N_2O
	Gg CO_2 equivalent		
1A1 Fuel Combustion, Energy industries	18768	140	98
1A2 Fuel Combustion, Manufacturing Industries and Construction[1)]	3110	8	38
1A4 Fuel Combustion, Other sectors [1)]	3102	154	59
Emission from stationary combustion plants	24980	302	195
Emission share for stationary combustion	60%	4.4%	3.8%

[1)] Only stationary combustion sources of the category is included.

CO_2 is the most important greenhouse gas accounting for 98.0 % of the greenhouse gas emission (CO_2 eq.) from stationary combustion. CH_4 accounts for 1.2 % and N_2O for 0.8 % of the greenhouse gas emission (CO_2 eq.) from stationary combustion (Figure 3.2.8).

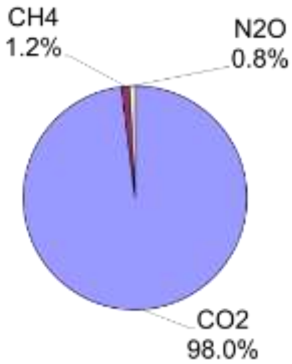


Figure 3.2.8 Stationary combustion - Greenhouse gas emission (CO_2 equivalent), contribution from each pollutant.

Figure 3.2.9 shows the time series of greenhouse gas emissions (CO_2 eq.) from stationary combustion. The greenhouse gas emission development follows the CO_2 emission development very closely. Both the CO_2 and the total greenhouse gas emission are lower in 2013 than in 1990, CO_2 by 34 % and greenhouse gas by 33 %. However, fluctuations in the GHG emission level are large.

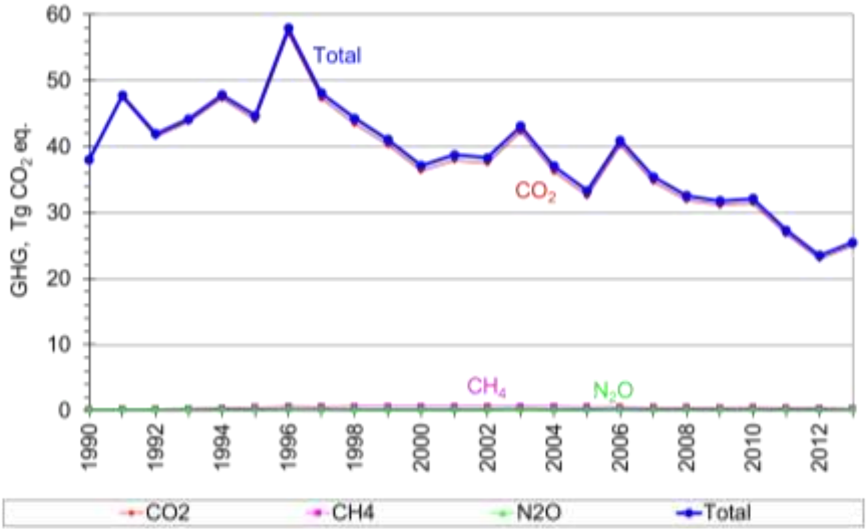


Figure 3.2.9 GHG emission time series for stationary combustion.

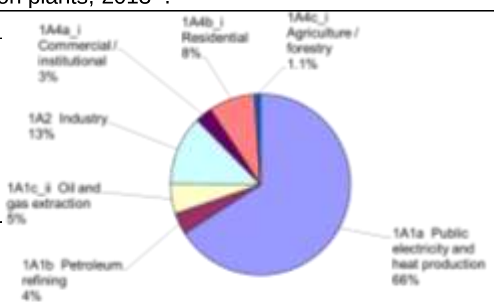
The fluctuations in the time series are largely a result of electricity import/export, but also of outdoor temperature variations from year to year. The fluctuations follow the fluctuations in fuel consumption discussed in Chapter 3.2.2. As mentioned in Chapter 3.2.2, the Danish Energy Agency estimates a correction of the actual CO_2 emission without random variations in electricity imports/exports and in ambient temperature. The greenhouse gas emission corrected for electricity import/export and ambient temperature has decreased by 40.5 % since 1990, and the CO_2 emission by 41.2 %. These data are included here to explain the fluctuations in the emission time series.

CO_2

The carbon dioxide (CO_2) emission from stationary combustion plants is one of the most important sources of greenhouse gas emissions. Thus, the CO_2 emission from stationary combustion plants accounts for 60 % of the national CO_2 emission. Table 3.2.4 lists the CO_2 emission inventory for stationary combustion plants for 2013. *Public electricity and heat production* accounts for 66 % of the CO_2 emission from stationary combustion. This share is somewhat higher than the fossil fuel consumption share for this category, which is 59 % (Figure 3.2.1). This is due to a large share of coal in this category. Other large CO_2 emission sources are *Industry* and *Residential* plants. These are the source categories, which also account for a considerable share of fuel consumption.

Table 3.2.4 CO_2 emission from stationary combustion plants, 2013[1)].

	CO_2 Gg
1A1a Public electricity and heat production	16477
1A1b Petroleum refining	950
1A1c Oil and gas extraction	1342
1A2 Industry	3110
1A4a Commercial/Institutional	748
1A4b Residential	2089
1A4c Agriculture/Forestry	265
Total	24980

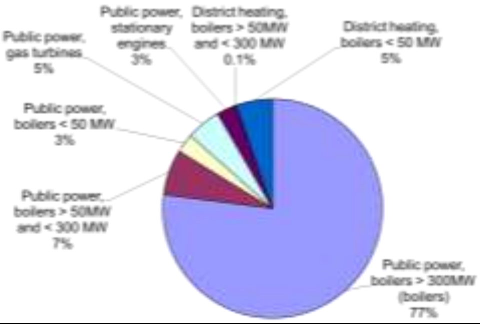


1) Only emission from stationary combustion plants in the categories is included.

In the Danish inventory, the source category *Public electricity and heat production* is further disaggregated. The CO_2 emission from each of the subcategories is shown in Table 3.2.5. The largest subcategory is power plant boilers >300MW.

Table 3.2.5 CO_2 emission from subcategories to 1A1a Public electricity and heat production.

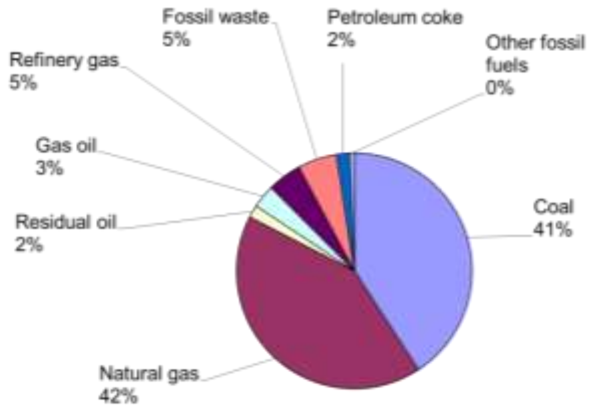
SNAP	SNAP name	CO_2, Gg
0101	Public power	
010101	Combustion plants ≥ 300MW (boilers)	12693
010102	Combustion plants ≥ 50MW and < 300 MW (boilers)	1111
010103	Combustion plants <50 MW (boilers)	460
010104	Gas turbines	836
010105	Stationary engines	469
0102	District heating plants	
010202	Combustion plants ≥ 50MW and < 300 MW (boilers)	16
010203	Combustion plants <50 MW (boilers)	892



CO_2 emission from combustion of biomass fuels is not included in the total CO_2 emission data, because biomass fuels are considered CO_2 neutral. The CO_2 emission from biomass combustion is reported as a memo item in the Climate Convention reporting. In 2013, the CO_2 emission from biomass combustion was 12 135 Gg.

In Figure 3.2.10, the fuel consumption share (fossil fuels) is compared to the CO_2 emission share disaggregated to fuel origin. Due to the higher CO_2 emission factor for coal than oil and gas, the CO_2 emission share from coal combustion is higher than the fuel consumption share. Coal accounts for 41 % of the fossil fuel consumption and for 51 % of the CO_2 emission. Natural gas accounts for 42 % of the fossil fuel consumption but only 31 % of the CO_2 emission.

Fossil fuel consumption share



CO_2 emission, fuel origin

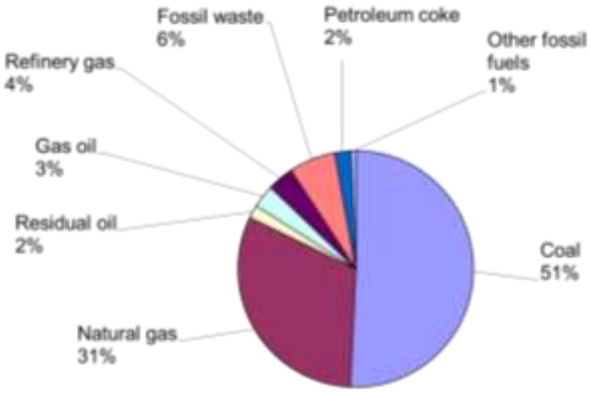


Figure 3.2.10 CO_2 emission, fuel origin.

The time series for CO_2 emission is provided in Figure 3.2.11. Despite a decrease in fuel consumption of 8 %[3] since 1990, the CO_2 emission from stationary combustion has decreased by 34 % because of the change of fuel type used.

The fluctuations in total CO_2 emission follow the fluctuations in CO_2 emission from *Public electricity and heat production* (Figure 3.2.11) and in coal consumption (Figure 3.2.4). The fluctuations are a result of electricity import/export as discussed in Chapter 3.2.2.

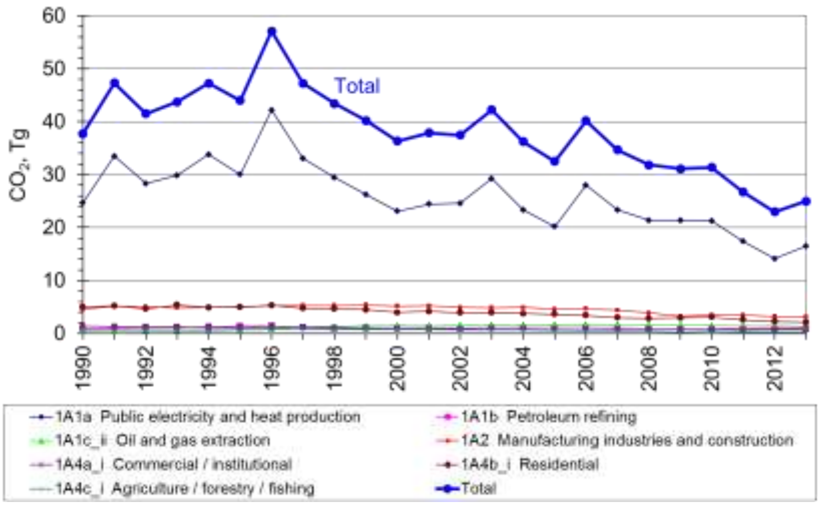


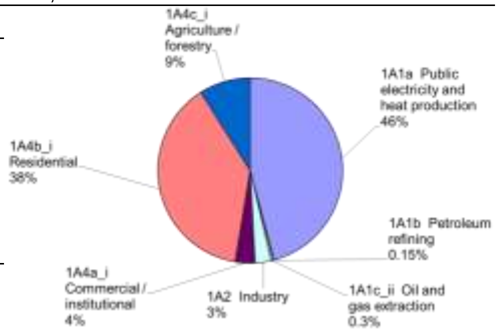
Figure 3.2.11 CO_2 emission time series for stationary combustion plants.

CH_4

The methane (CH_4) emission from stationary combustion plants accounts for 4 % of the national CH_4 emission. Table 3.2.6 lists the CH_4 emission inventory for stationary combustion plants in 2013. *Public electricity and heat production* accounts for 46 % of the CH_4 emission from stationary combustion. The emission from residential plants adds up to 38 % of the emission.

Table 3.2.6 CH_4 emission from stationary combustion plants, 2013[1)].

		CH_4, Mg
1A1a	Public electricity and heat production	5544
1A1b	Petroleum refining	19
1A1c	Oil and gas extraction	40
1A2	Industry	338
1A4a	Commercial/Institutional	417
1A4b	Residential	4641
1A4c	Agriculture/Forestry	1085
Total		12083



[1)] Only emission from stationary combustion plants in the source categories is included.

The CH_4 emission factor for reciprocating gas engines is much higher than for other combustion plants due to the continuous ignition/burn-out of the gas. Lean-burn gas engines have an especially high emission factor. A considerable number of lean-burn gas engines are in operation in Denmark and

[3] The consumption of fossil fuels has decreased 28 %.

in 2013, these plants accounted for 51 % of the CH_4 emission from stationary combustion plants (Figure 3.2.12). Most engines are installed in CHP plants and the fuel used is either natural gas or biogas. Residential wood combustion is also a large emission source accounting for 29 % of the emission in 2013.

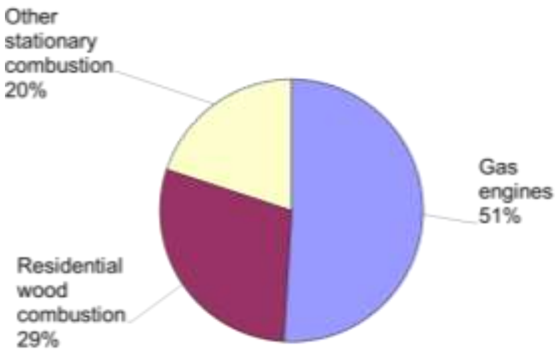


Figure 3.2.12 CH_4 emission share for gas engines and residential wood combustion, 2013.

Figure 3.2.13 shows the time series for CH_4 emission. The CH_4 emission from stationary combustion has increased 78 % since 1990. This results from the considerable number of lean-burn gas engines installed in CHP plants in Denmark during the 1990s. Figure 3.2.14 provides time series for the fuel consumption rate in gas engines and the corresponding increase of CH_4 emission. The decline in later years is due to structural changes in the Danish electricity market, which means that the fuel consumption in gas engines has been decreasing.

The CH_4 emission from residential plants has increased since 1990 due to increased combustion of biomass in residential plants. Combustion of wood accounted for 76 % of the CH_4 emission from residential plants in 2013.

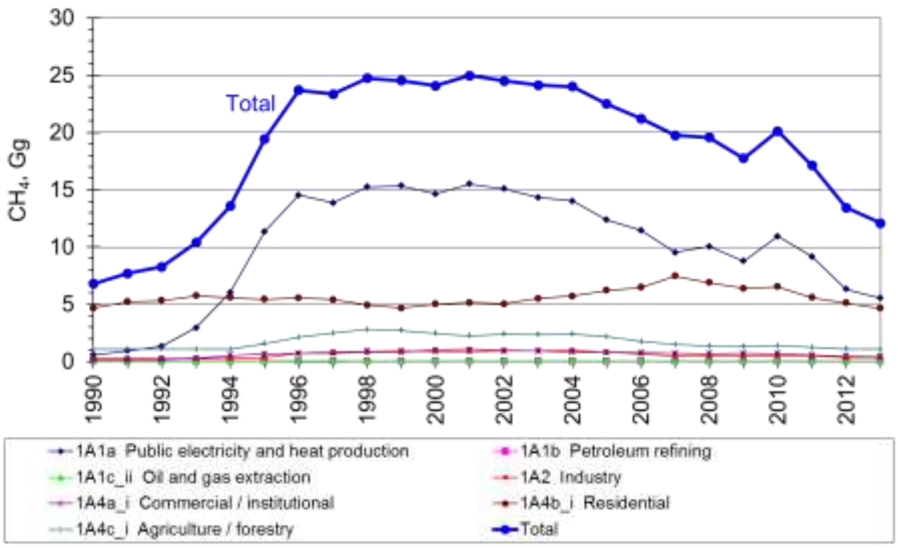


Figure 3.2.13 CH_4 emission time series for stationary combustion plants.

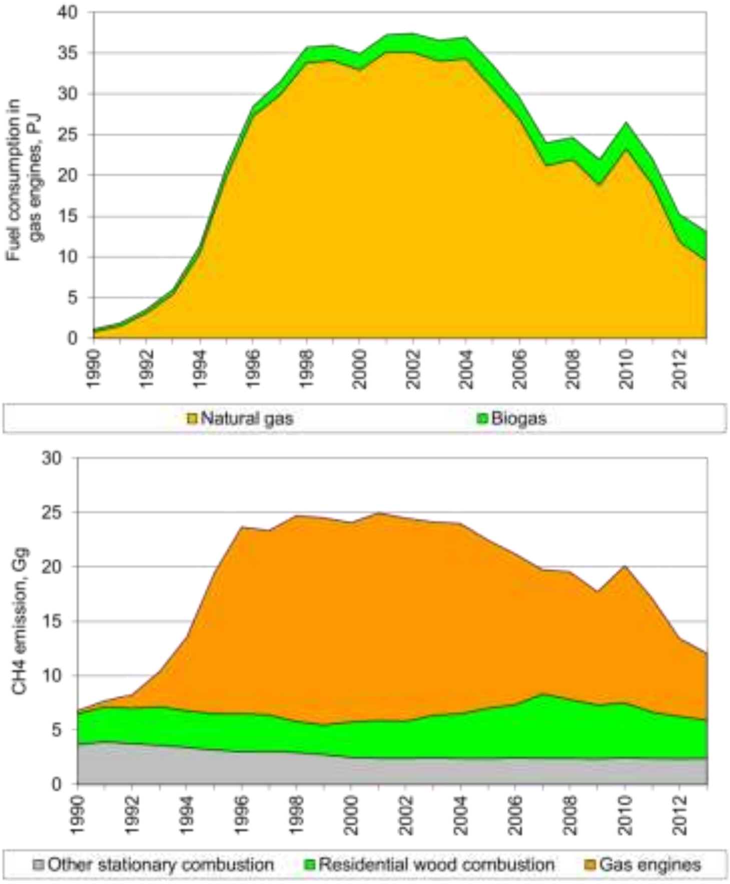


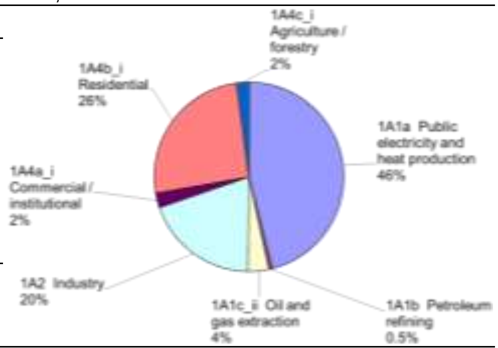
Figure 3.2.14 Time series for a) fuel consumption in gas engines and b) CH_4 emission from gas engines, residential wood combustion and other plants.

N_2O

The nitrous oxide (N_2O) emission from stationary combustion plants accounts for 4 % of the national N_2O emission. Table 3.2.7 lists the N_2O emission inventory for stationary combustion plants in the year 2013. *Public electricity and heat production* accounts for 46 % of the N_2O emission from stationary combustion.

Table 3.2.7 N_2O emission from stationary combustion plants, 2013[1)].

	N_2O, Mg
1A1a Public electricity and heat production	301
1A1b Petroleum refining	4
1A1c Oil and gas extraction	23
1A2 Industry	128
1A4a Commercial/Institutional	16
1A4b Residential	168
1A4c Agriculture/Forestry	14
Total	654



1) Only emission from stationary combustion plants in the source categories is included.

Figure 3.2.15 shows the time series for N_2O emission. The N_2O emission from stationary combustion has increased by 9 % from 1990 to 2013, but again fluctuations in emission level due to electricity import/export are considerable.

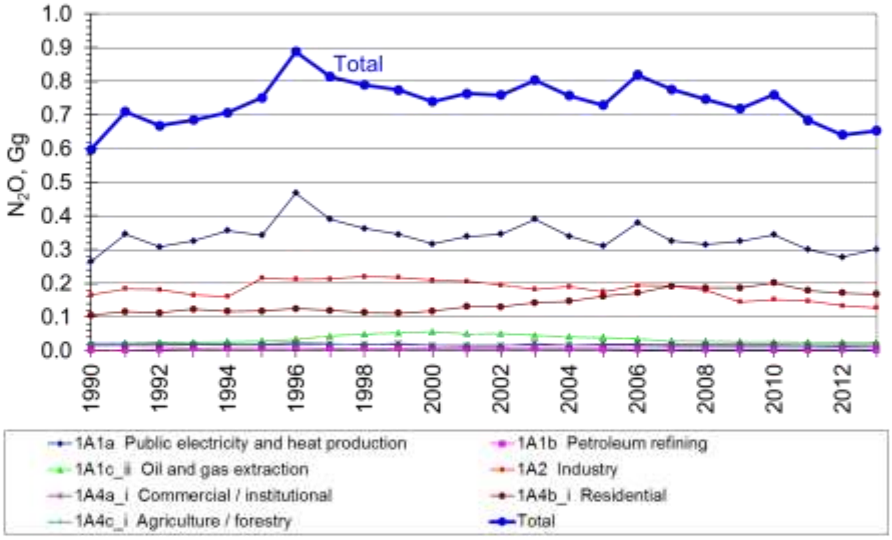


Figure 3.2.15 N2O emission time series for stationary combustion plants.

SO_2, NO_x, NMVOC and CO

The emissions of sulphur dioxide (SO_2), nitrogen oxides (NO_x), non-volatile organic compounds (NMVOC) and carbon monoxide (CO) from Danish stationary combustion plants are included in the Danish IIR (Nielsen et al., 2015). Please refer to the Danish IIR for data presentation and references for SO_2, NO_x, NMVOC and CO.

3.2.4 Trend for subsectors

In addition to the data for stationary combustion, this chapter presents and discusses data for each of the subcategories in which stationary combustion is included. Time series are presented for fuel consumption and emissions.

1A1 Energy industries

The emission source category *1A1 Energy Industries* consists of the subcategories:

- 1A1a Public electricity and heat production
- 1A1b Petroleum refining
- 1A1c Oil and gas extraction

Figure 3.2.16 – 3.2.17 present time series for the *Energy Industries*. *Public electricity and heat production* is the largest subcategory accounting for the main part of all emissions. Time series are discussed below for each subcategory.

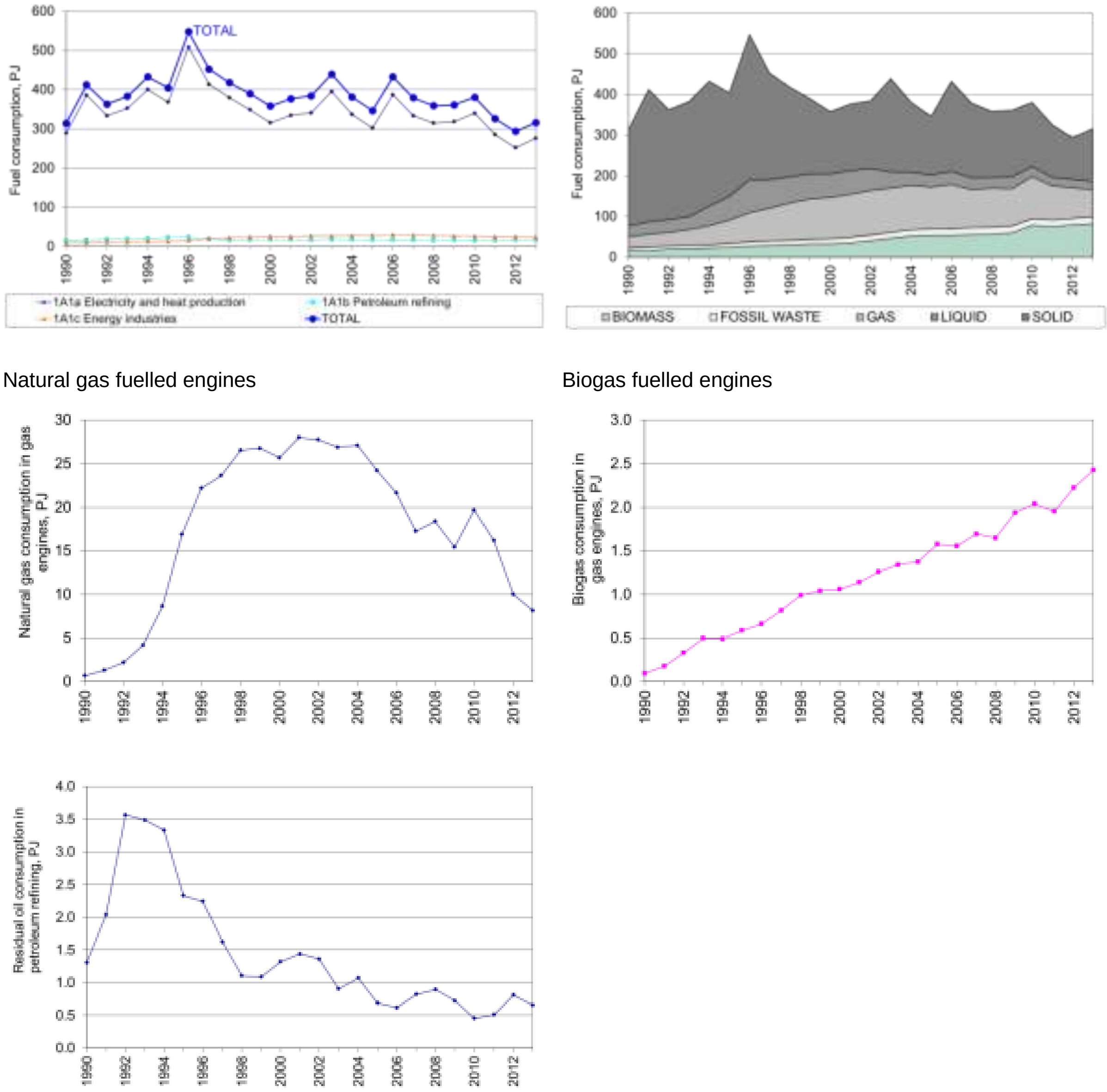


Figure 3.2.16 Time series for fuel consumption, 1A1 Energy industries.

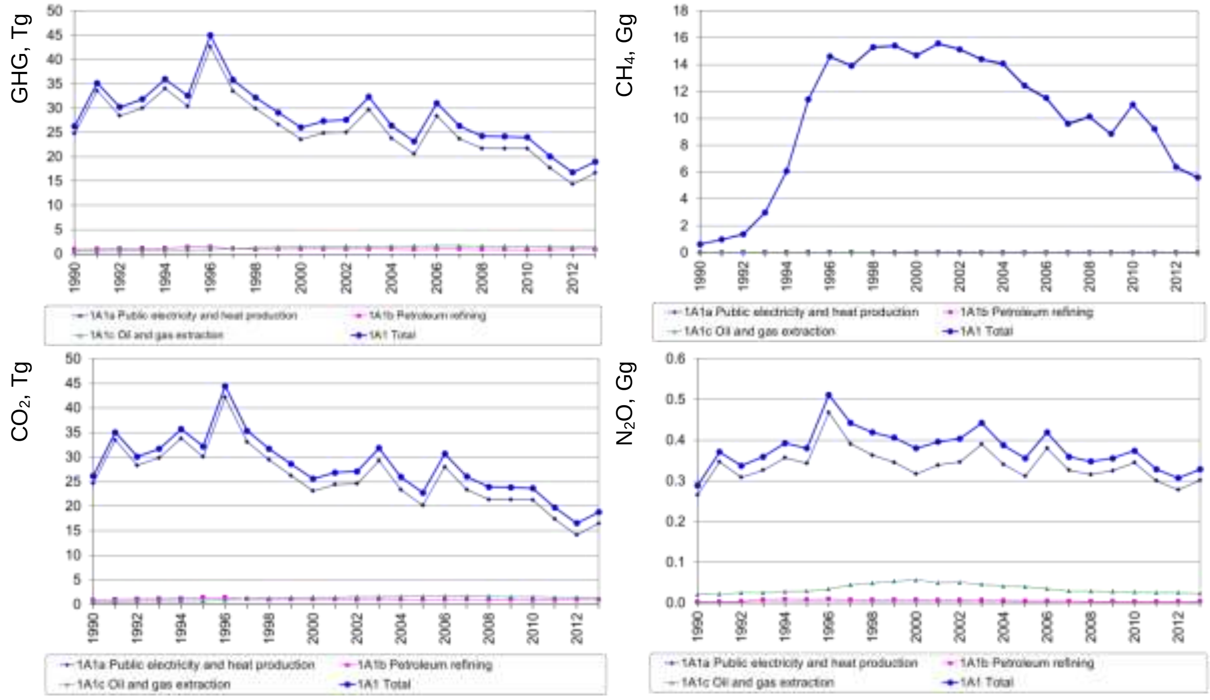


Figure 3.2.17 Time series for greenhouse gas emissions, 1A1 Energy industries.

1A1a Public electricity and heat production

Public electricity and heat production is the largest source category regarding both fuel consumption and greenhouse gas emissions for stationary combustion. Figure 3.2.18 shows the time series for fuel consumption and emissions.

The fuel consumption in public electricity and heat production was 4 % lower in 2013 than in 1990. As discussed in Chapter 3.2.2 the fuel consumption fluctuates mainly as a consequence of electricity trade. Coal is the fuel that is affected the most by the fluctuating electricity trade. Coal is the main fuel in the source category even in years with electricity import. The coal consumption in 2013 was 45 % lower than in 1990. Natural gas is also an important fuel and the consumption of natural gas has increased since 1990, but decreased since 2003. A considerable part of the natural gas is combusted in gas engines (Figure 3.2.16). The consumption of waste and biomass has increased.

The CO_2 emission was 33 % lower in 2013 than in 1990. This decrease – in spite of only a 4 % decrease in fuel consumption - is a result of the change of fuels used as discussed above.

The CH_4 emission has increase until the mid-nineties as a result of the considerable number of lean-burn gas engines installed in CHP plants in Denmark in this period. The decline in later years is due to structural changes in the Danish electricity market, which means that the fuel consumption in gas engines has been decreasing (Figure 3.2.16). The emission in 2013 was 9.3 times the 1990 emission level.

The N_2O emission in 2013 was 13 % higher than the 1990 emission level. The emission fluctuates similar to the fuel consumption.

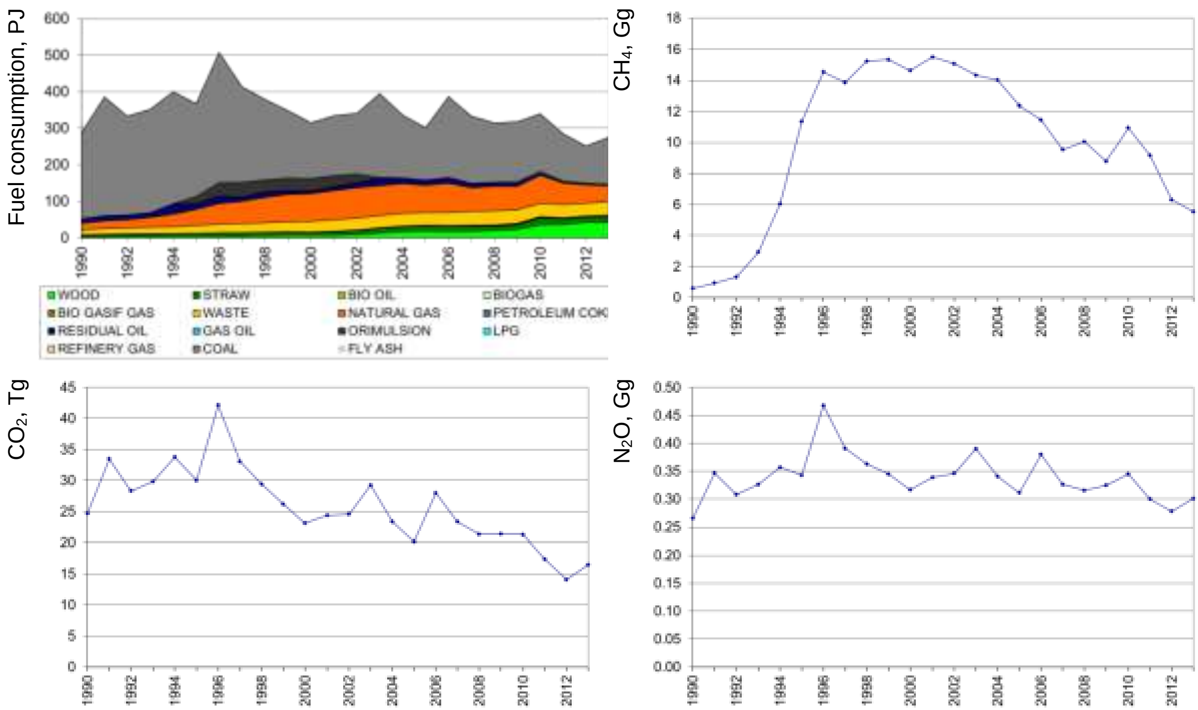


Figure 3.2.18 Time series for 1A1a Public electricity and heat production.

1A1b Petroleum refining

Petroleum refining is a small source category regarding both fuel consumption and greenhouse gas emissions for stationary combustion. There are presently only two refineries operating in Denmark. Figure 3.2.19 shows the time series for fuel consumption and emissions.

The significant decrease in both fuel consumption and emissions in 1996 is a result of the closure of a third refinery.

The fuel consumption has increased 5 % since 1990 and the CO_2 emission also increased 5 %.

The CH_4 emission has increased 4 % since 1990 and decreased 3 % since 2012. The reduction in CH_4 emission from 1995 to 1996 is caused by the closure of a refinery.

The N_2O emission was 62 % higher in 2013 than in 1990. The emission increased in 1990 – 1993 as a result of the installation of a gas turbine in one of the refineries. The gas turbine was installed in 1993 (DEA, 2014b).

The N_2O emission factor for the refinery gas fuelled gas turbine has been assumed equal to the emission factor for natural gas fuelled turbines and thus the emission factor have been decreasing since 1994. The time series for the emission factor cause the decreasing N_2O emission since 1994.

Emissions from refineries are further discussed in Chapter 3.5.

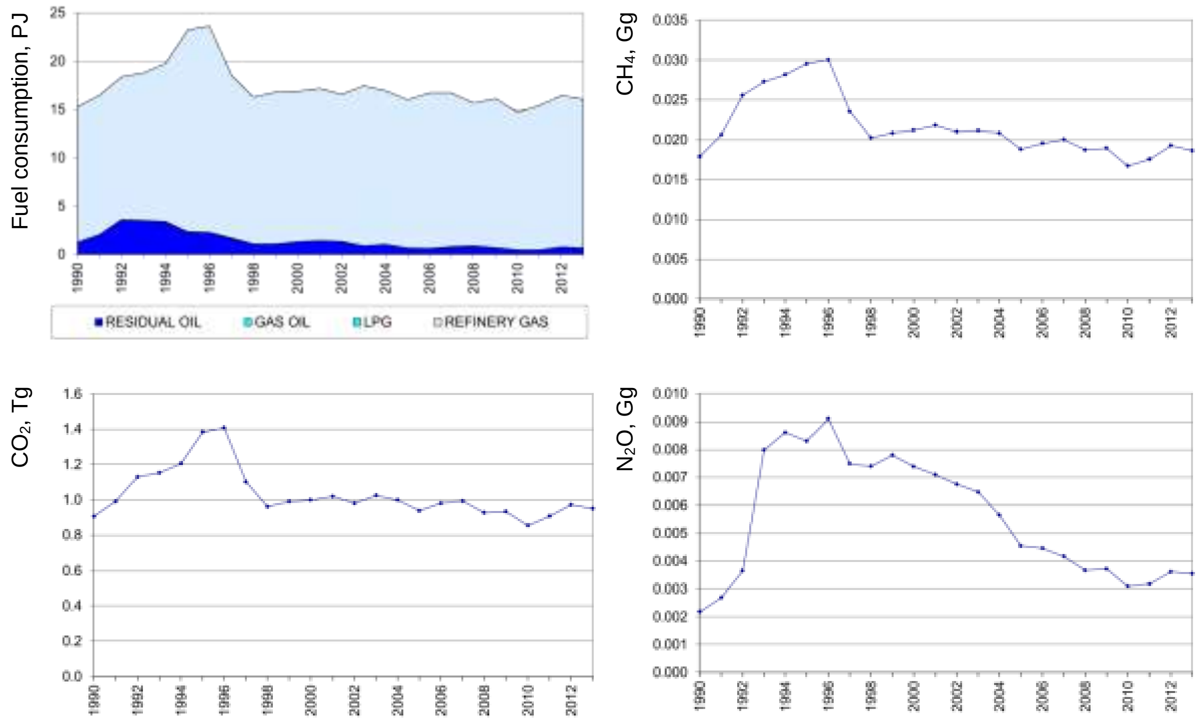


Figure 3.2.19 Time series for 1A1b Petroleum refining.

1A1c Oil and gas extraction

The source category *Oil and gas extraction* comprises natural gas consumption in the off-shore industry and in addition a small consumption in the Danish gas treatment plant[4]. Gas turbines are the main plant type. Figure 3.2.20 shows the time series for fuel consumption and emissions.

The fuel consumption in 2013 was 2.5 times the consumption in 1990. The CO_2 emission follows the fuel consumption and the emission in 2013 was also 2.5 times the emission in 1990.

The emission factor time series for N_2O follow the decreasing emission factor time series for gas turbines applied in CHP plants.

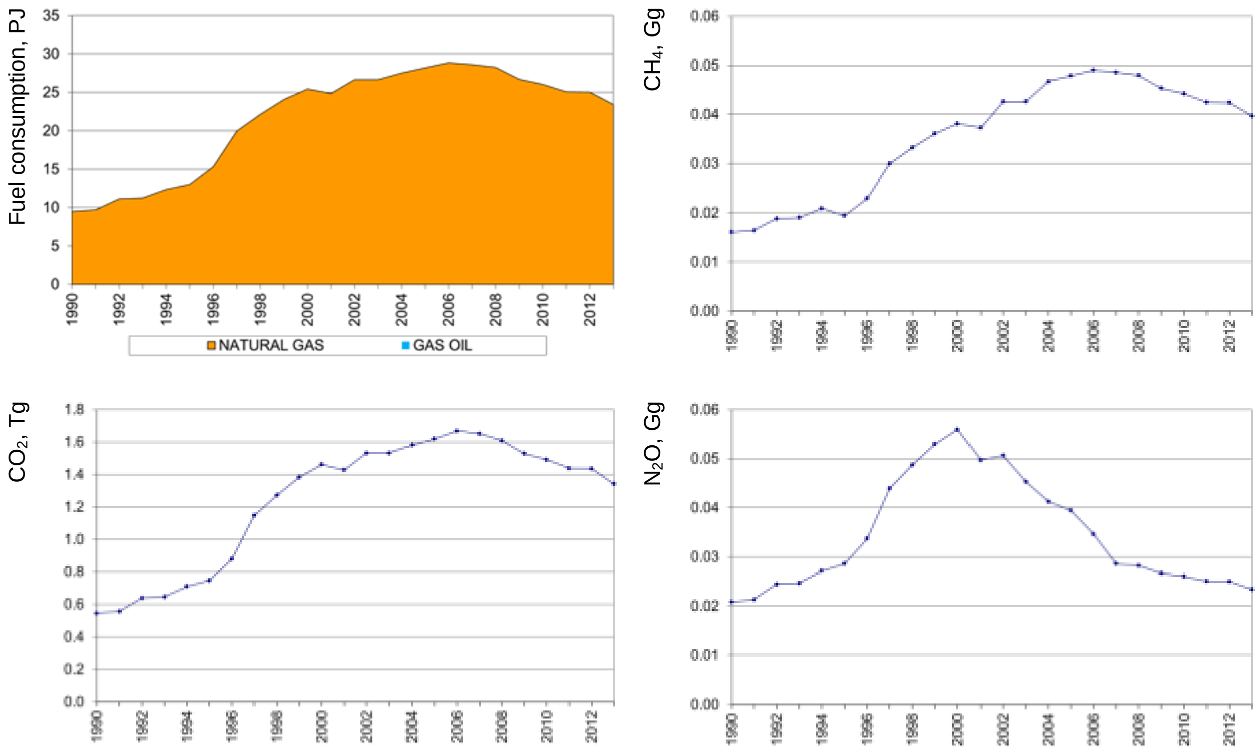


Figure 3.2.20 Time series for 1A1c Oil and gas extraction.

[4] Nybro.

1A2 Industry

Manufacturing industries and construction (Industry) consists of both stationary and mobile sources. In this chapter, only stationary sources are included.

The emission source category *1A2 Industry* consists of the subcategories:

- 1A2a Iron and steel
- 1A2b Non-ferrous metals
- 1A2c Chemicals
- 1A2d Pulp, Paper and Print
- 1A2e Food processing, beverages and tobacco
- 1A2f Non-metallic minerals
- 1A2 g viii Other manufacturing industry

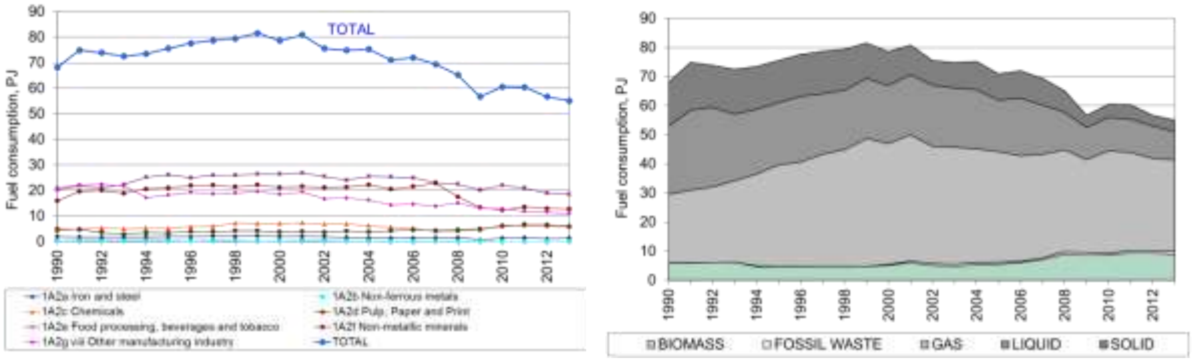
The figures 3.2.21-3.2.22 show the time series for fuel consumption and emissions. The subsectors *Non-metallic minerals*, *Other manufacturing industry* and *Food processing, beverages and tobacco* are the main subsectors for fuel consumption and emissions.

The total fuel consumption in industrial combustion was 19 % lower in 2013 than in 1990. The consumption of natural gas has increased since 1990 whereas the consumption of coal has decreased. The consumption of residual oil has decreased, but the consumption of petroleum coke increased. The biomass consumption has increased 46 % since 1990.

The greenhouse gas emission and the CO_2 emission are both rather stable until 2006 following the small fluctuations in fuel consumption. After 2006, the fuel consumption has decreased. Due to change of applied fuels, the greenhouse gas and CO_2 emissions have decreased more than the fuel consumption since 1990; both emissions have decreased 32 %.

The CH_4 emission has increased from 1994-2001 and decreased again from 2001 - 2007. In 2013, the emission was 24 % higher than in 1990. The CH_4 emission follows the consumption of natural gas in gas engines (Figure 3.2.21). Most industrial CHP plants based on gas engines came in operation in the years 1995 to 1999. The decrease in later years is a result of the liberalisation of the electricity market.

The N_2O emission has decreased since 1990, mainly due to the decreased residual oil consumption. The emission from other manufacturing industries increases from 1994 to 1995. This increase is related to combustion of coke oven coke in mineral wool production. Plant specific fuel consumption data are only available from 1995 onwards for the mineral wool production plants. If relevant data are available the time series will be improved for 1990-1994 for this sector in the next inventory.



Fuel consumption in natural gas fuelled engines

Fuel consumption, residual oil and wood

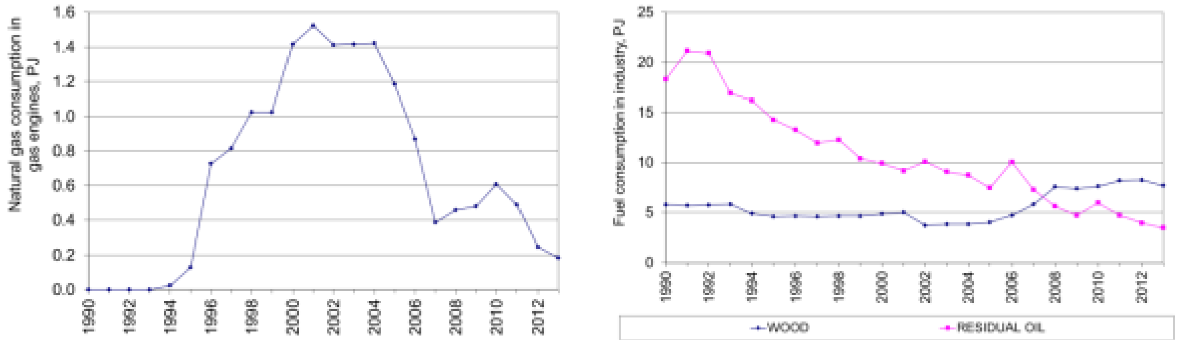


Figure 3.2.21 Time series for fuel consumption, 1A2 Industry.

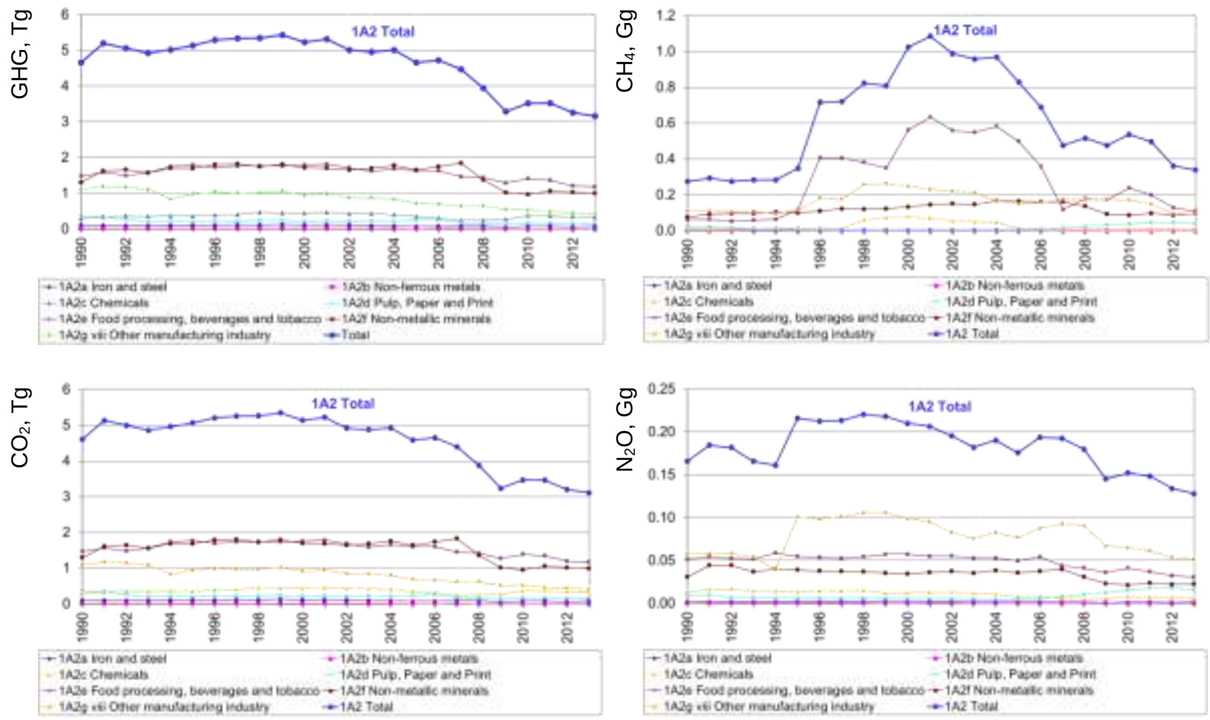


Figure 3.2.22 Time series for greenhouse gas emission, 1A2 Industry.

1A2a Iron and steel

Iron and steel is a very small emission source category. Figure 3.2.23 shows the time series for fuel consumption and emissions.

Natural gas is the main fuel in the subsector.

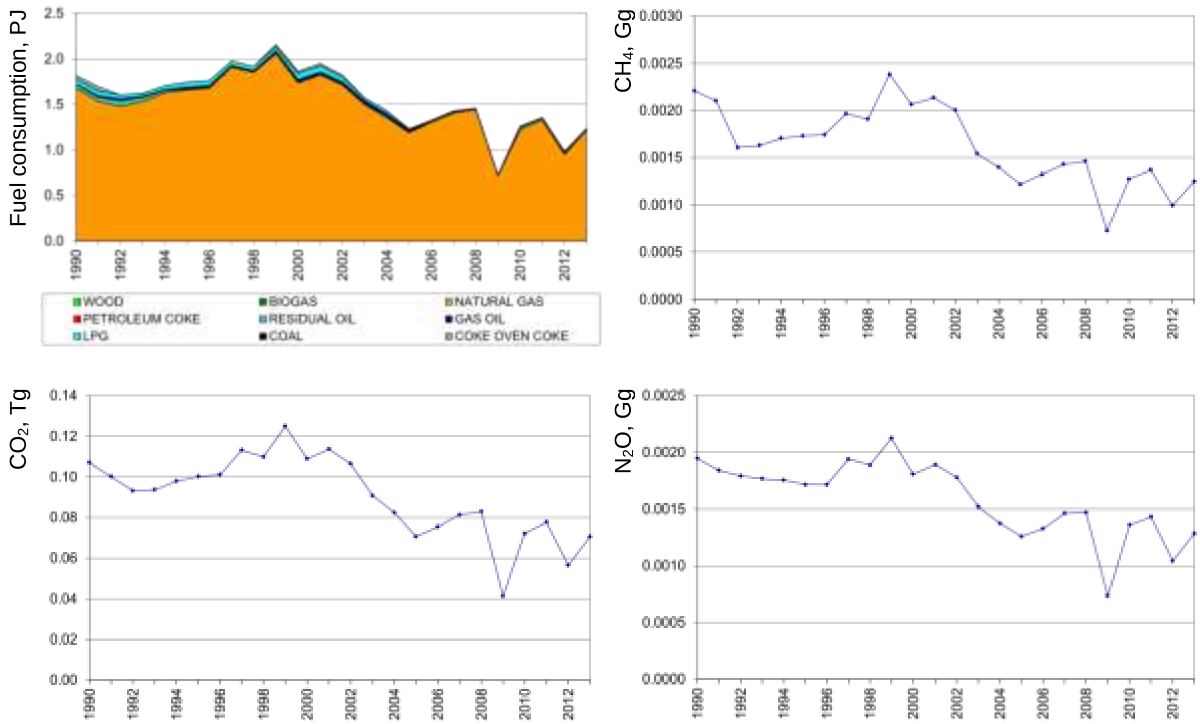


Figure 3.2.23 Time series for 1A2a Iron and steel.

1A2b Non-ferrous metals

Non-ferrous metals is a very small emission source category. Figure 3.2.24 shows the time series for fuel consumption and emissions.

Natural gas is the main fuel in the subsector. The fuel consumption is very low after 2009. This is in agreement with the data reported by DEA to Eurostat (DEA, 2014c)

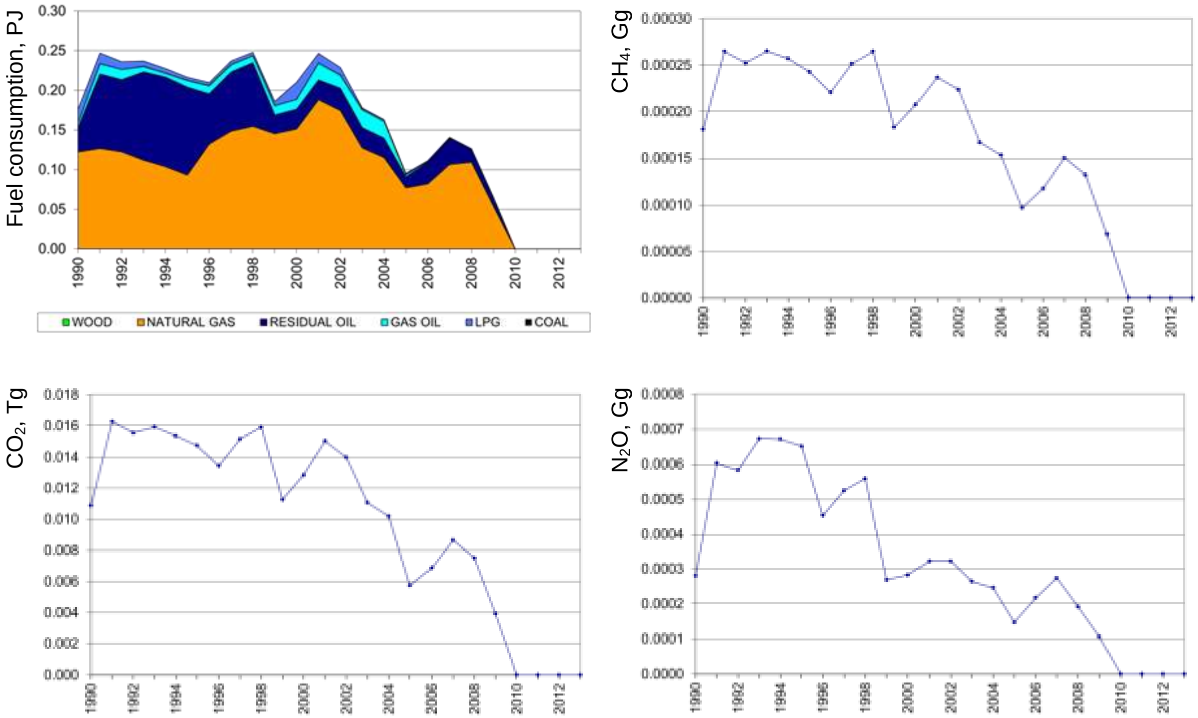


Figure 3.2.24 Time series for 1A2b Non-ferrous metals.

1A2c Chemicals

Chemicals is a minor emission source category. Figure 3.2.25 shows the time series for fuel consumption and emissions.

Natural gas is the main fuel in this subsector. The CO_2 emission time series follow the time series for fuel consumption. The time series for CH_4 emission is related to consumption of natural gas in gas engines. The decreasing time series for N_2O emission is related to the decreasing consumption of residual oil.

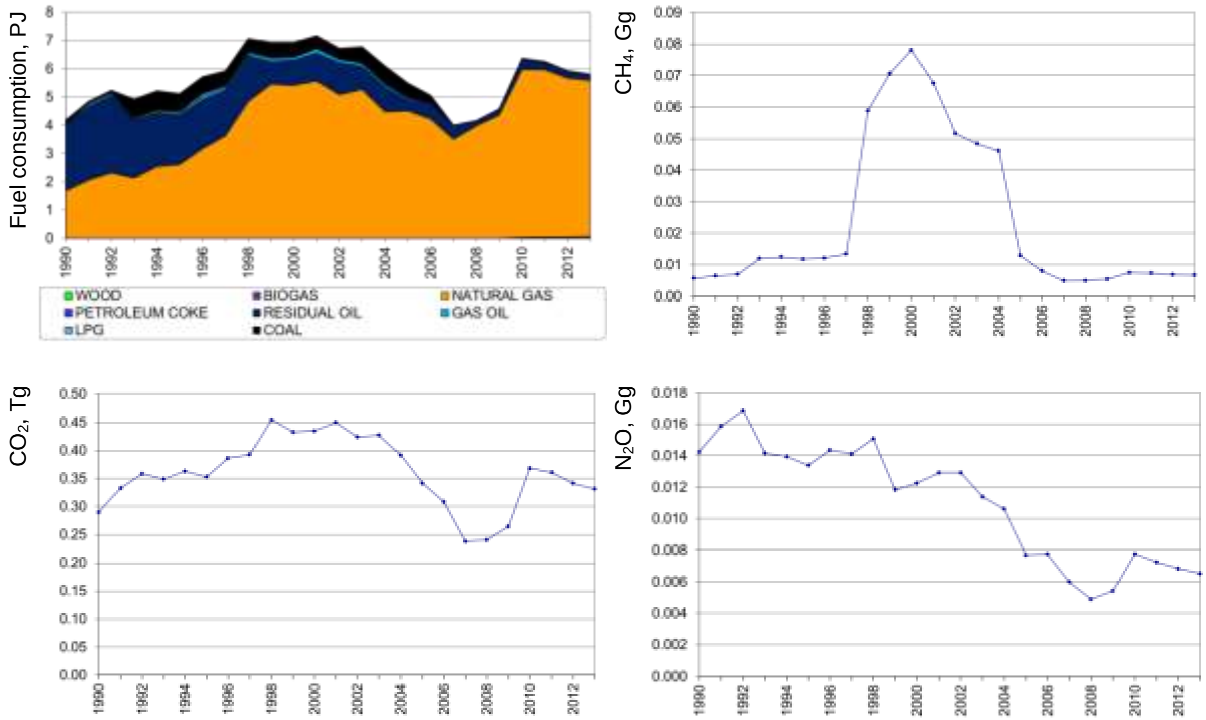


Figure 3.2.25 Time series for 1A2c Chemicals.

1A2d Pulp, paper and print

Pulp, paper and print is a minor emission source category. Figure 3.2.26 shows the time series for fuel consumption and emissions.

Natural gas and - since 2007 - also wood are the main fuels in the subsector. The increased use of wood is reflected in the CO_2 emission time series.

The increased consumption of wood in 2007 onwards is reflected in the CH_4 and N_2O emission time series.

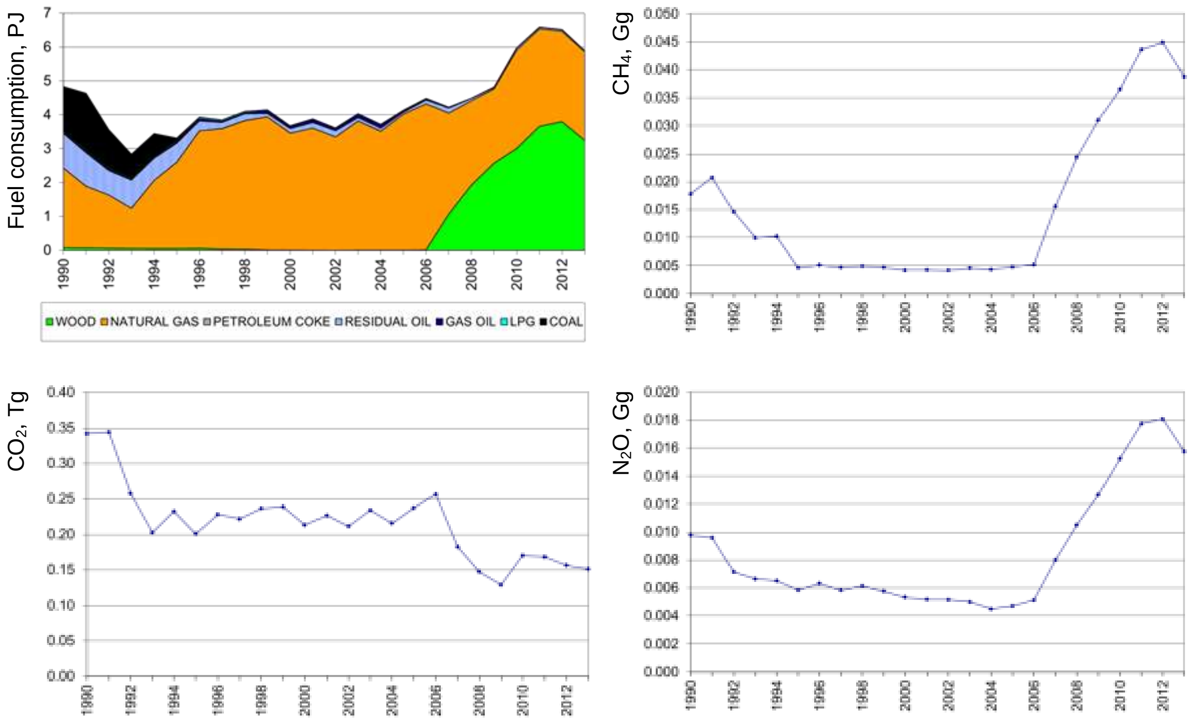


Figure 3.2.26 Time series for 1A2d Pulp, paper and print.

1A2e Food processing, beverages and tobacco

Food processing, beverages and tobacco is a considerable industrial subsector. Figure 3.2.27 shows the time series for fuel consumption and emissions.

Natural gas, residual oil and coal are the main fuels in the subsector. The consumption of coal and residual oil has decreased whereas the consumption of natural gas has increased.

The time series for CH_4 emission follows the consumption of natural gas in gas engines.

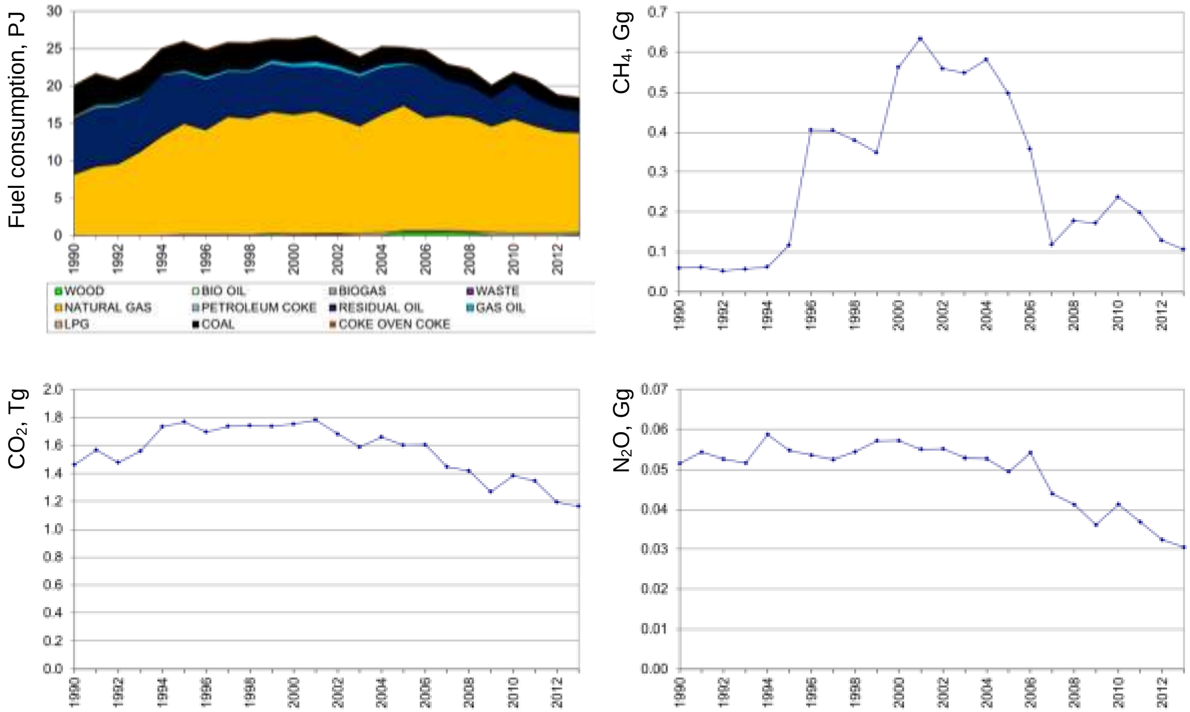


Figure 3.2.27 Time series for 1A2e Food processing, beverages and tobacco.

1A2f Non-metallic minerals

Non-metallic minerals is a considerable industrial subsector. The subsector includes cement production that is a major industrial emission source in Denmark. Figure 3.2.28 shows the time series for fuel consumption and emissions.

Petroleum coke, natural gas, industrial waste and coal are the main fuels in the subsector in recent years. The consumption of coal and residual oil has decreased.

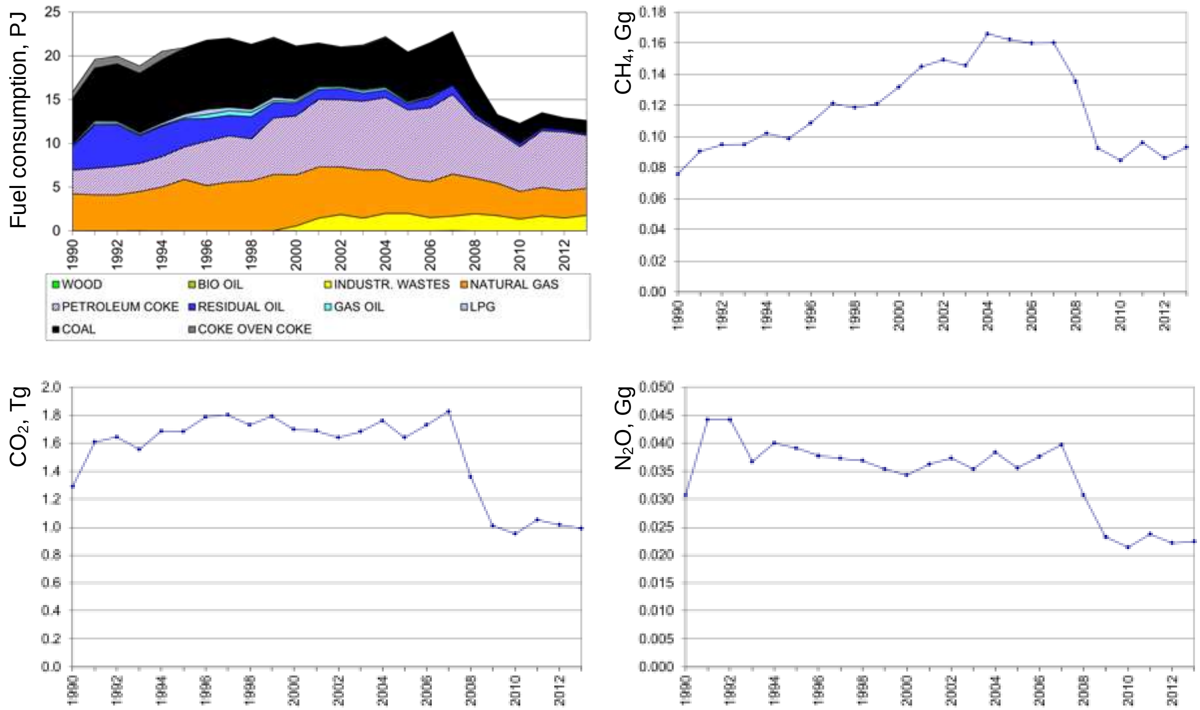


Figure 3.2.28 Time series for 1A2f Non-metallic minerals.

1A2g Other manufacturing industry

Other manufacturing industry is a considerable industrial subsector. Figure 3.2.29 shows the time series for fuel consumption and emissions.

Natural gas and wood are the main fuels in the subsector in recent years. The consumption of coal and residual oil has decreased.

The time series for CH_4 is related to the consumption of natural gas in gas engines.

Combustion of coke oven coke in mineral wood production is a large emission source for N_2O. Plant specific fuel consumption rates for the mineral wood production plants are available from 1995. This causes the increase in N_2O emission between 1994 and 1995 and if possible the data will be improved in the next inventory.

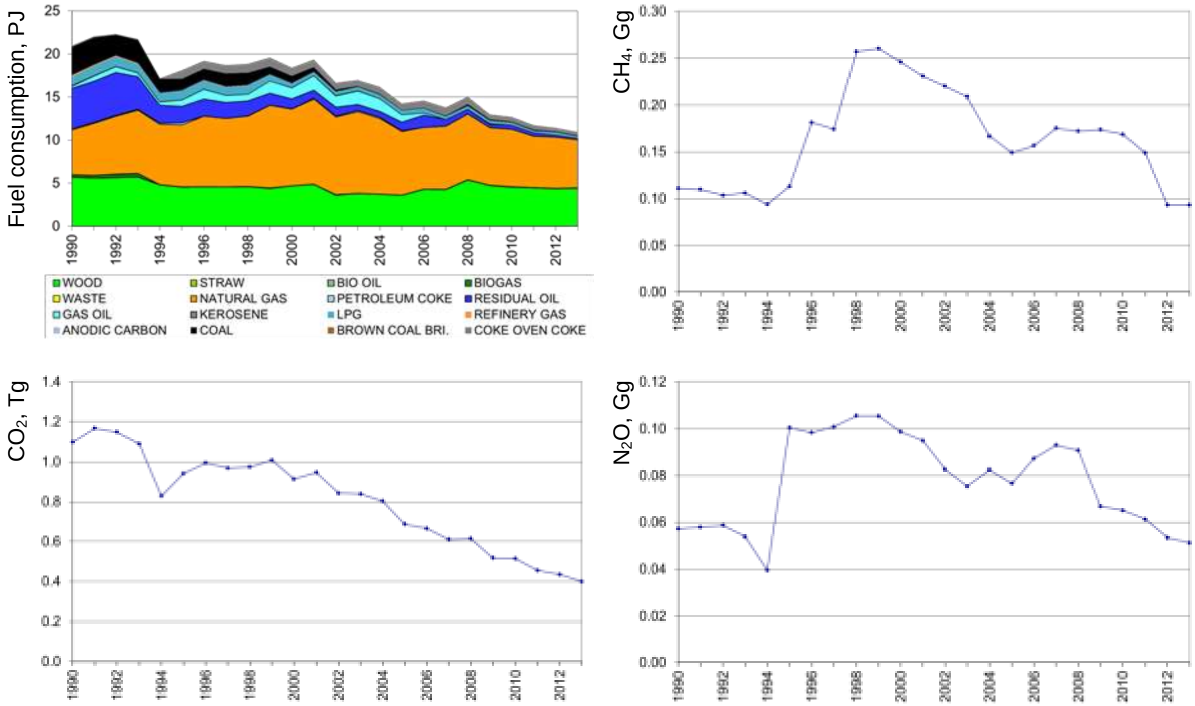


Figure 3.2.29 Time series for 1A2g Industry - other.

1A4 Other Sectors

The emission source category *1A4 Other Sectors* consists of the subcategories:

- 1A4a Commercial/Institutional plants.
- 1A4b Residential plants.
- 1A1c Agriculture/Forestry.

Figure 3.2.30-31 present time series for this emission source category. Residential plants is the dominant subcategory accounting for the largest part of all emissions. Time series are discussed below for each subcategory.

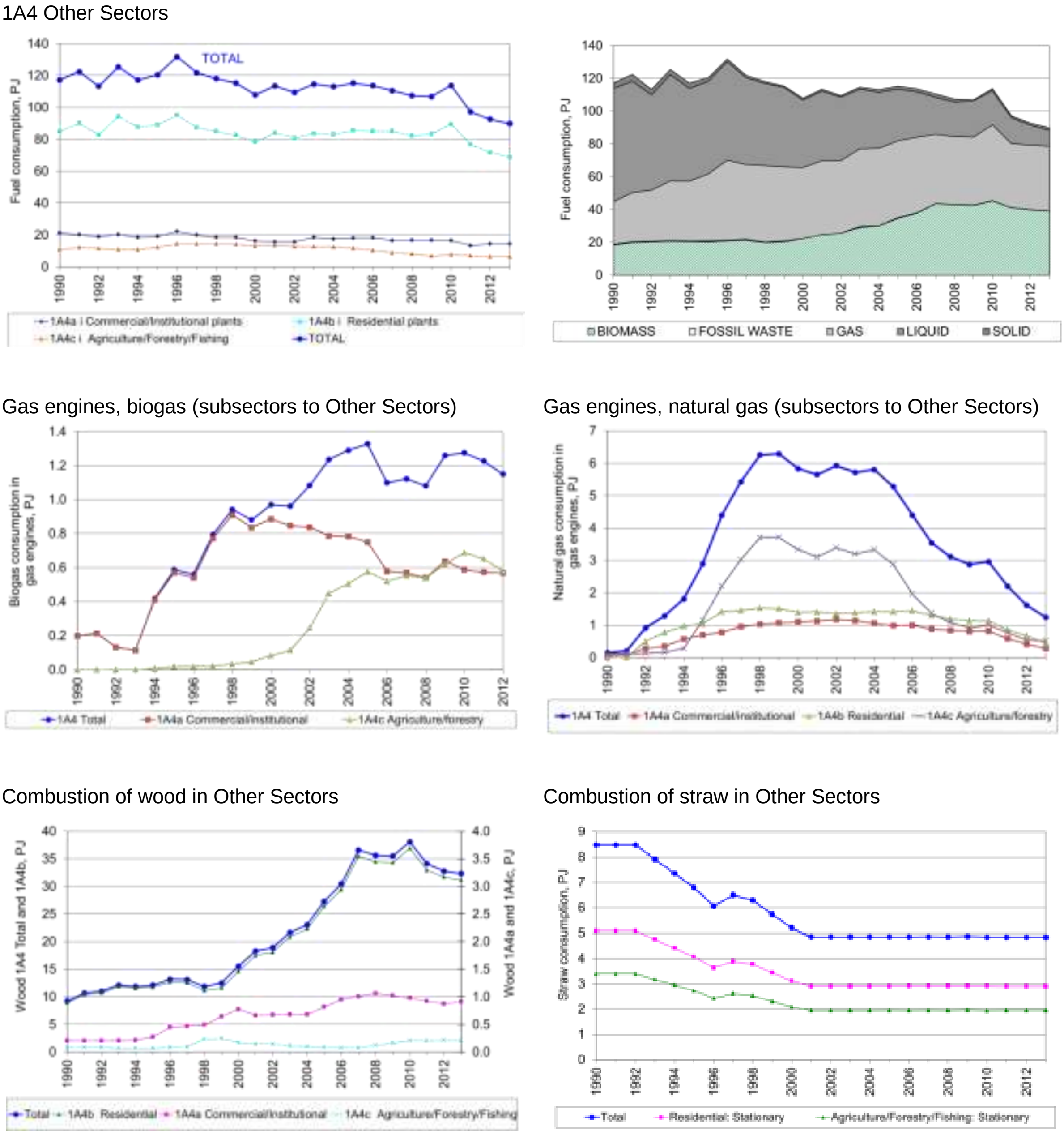


Figure 3.2.30 Time series for fuel consumption, 1A4 Other Sectors.

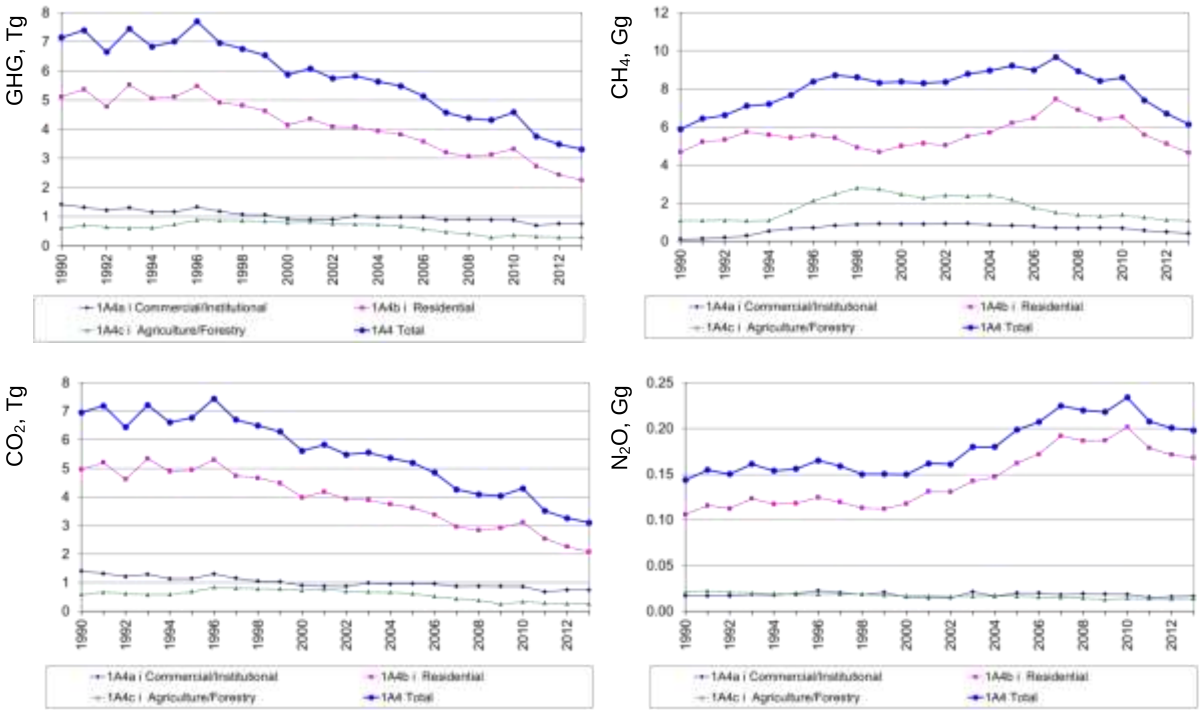


Figure 3.2.31 Time series for greenhouse gas emission, 1A4 Other Sectors.

1A4a Commercial and institutional plants

The subcategory *Commercial and institutional plants* consists of both stationary and mobile sources. In this chapter, only stationary sources are included. Figure 3.2.32 shows the time series for fuel consumption and emissions.

The subcategory *Commercial and institutional plants* has low fuel consumption and emissions compared to the other stationary combustion emission source categories.

The fuel consumption in commercial/institutional plants has decreased 32 % since 1990 and the fuels applied have changed. The fuel consumption consists mainly of gas oil and natural gas. The consumption of gas oil has decreased whereas the consumption of natural gas has increased since 1990. The consumption of wood and biogas has also increased. The wood consumption in 2013 was 4.5 times the consumption in 1990.

The CO_2 emission has decreased 47 % since 1990. Both the decrease of fuel consumption and the change of fuels – from gas oil to natural gas - contribute to the decreased CO_2 emission.

The CH_4 emission in 2013 was 3.7 times the 1990 level. The increase is mainly a result of the increased emission from natural gas fuelled engines. The emissions from biogas fuelled engines and from combustion of wood also contribute to the increase. The time series for consumption of natural gas and biogas are shown in Figure 3.2.32.

The N_2O emission in 2013 was 2 % lower than in 1990. The fluctuations of the N_2O emission are mainly a result of fluctuations in consumption of natural gas and waste.

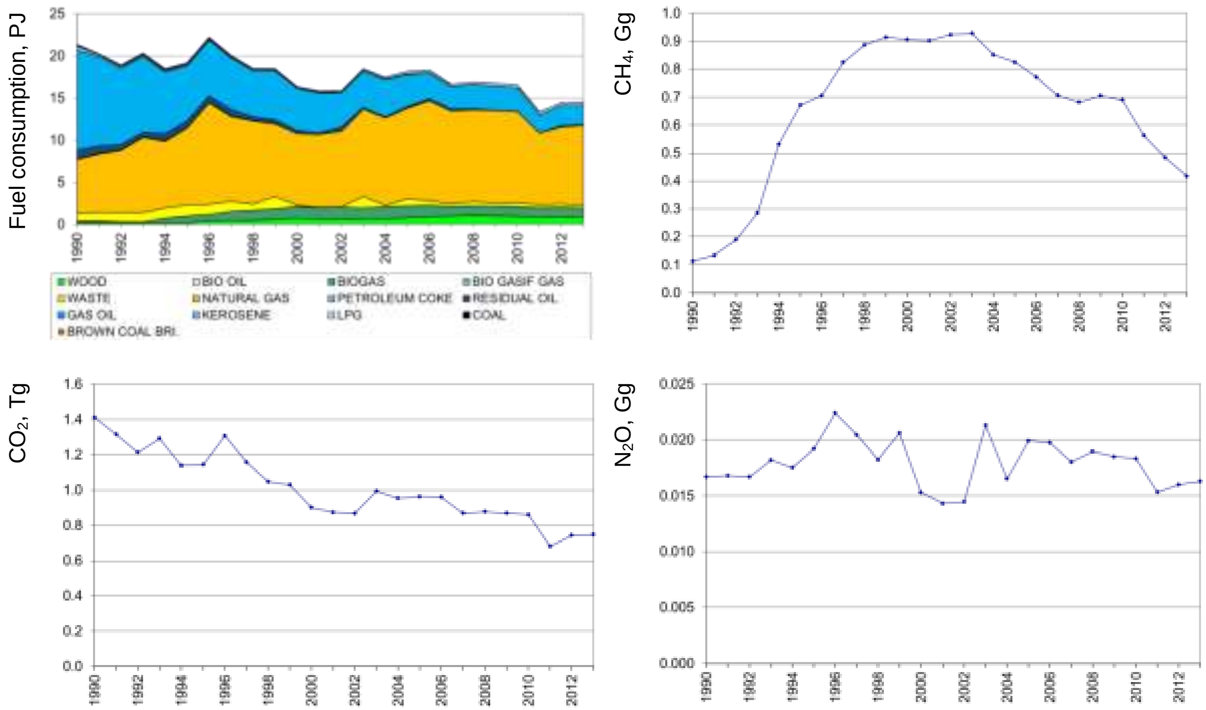


Figure 3.2.32 Time series for 1A4a Commercial /institutional.

1A4b Residential plants

The emission source category *Residential plants* consists of both stationary and mobile sources. In this chapter, only stationary sources are included. Figure 3.2.33 shows the time series for fuel consumption and emissions.

For residential plants, the total fuel consumption was 19 % lower in 2013 than in 1990. The consumption of gas oil has decreased since 1990 whereas the consumption of wood has increased considerably (3.5 times the 1990 level). The consumption of natural gas has also increased since 1990.

The CO_2 emission has decreased by 58 % since 1990. This decrease is mainly a result of the considerable change in fuels used from gas oil to wood and natural gas.

The CH_4 emission from residential plants was 1 % lower in 2013 than in 1990. Residential wood combustion is a large source of CH_4 emission and the consumption of wood has increased whereas the emission factor has decreased since 1990.

The change of fuel from gas oil to wood has resulted in a 59 % increase of N_2O emission since 1990 due to a higher emission factor for wood than for gas oil.

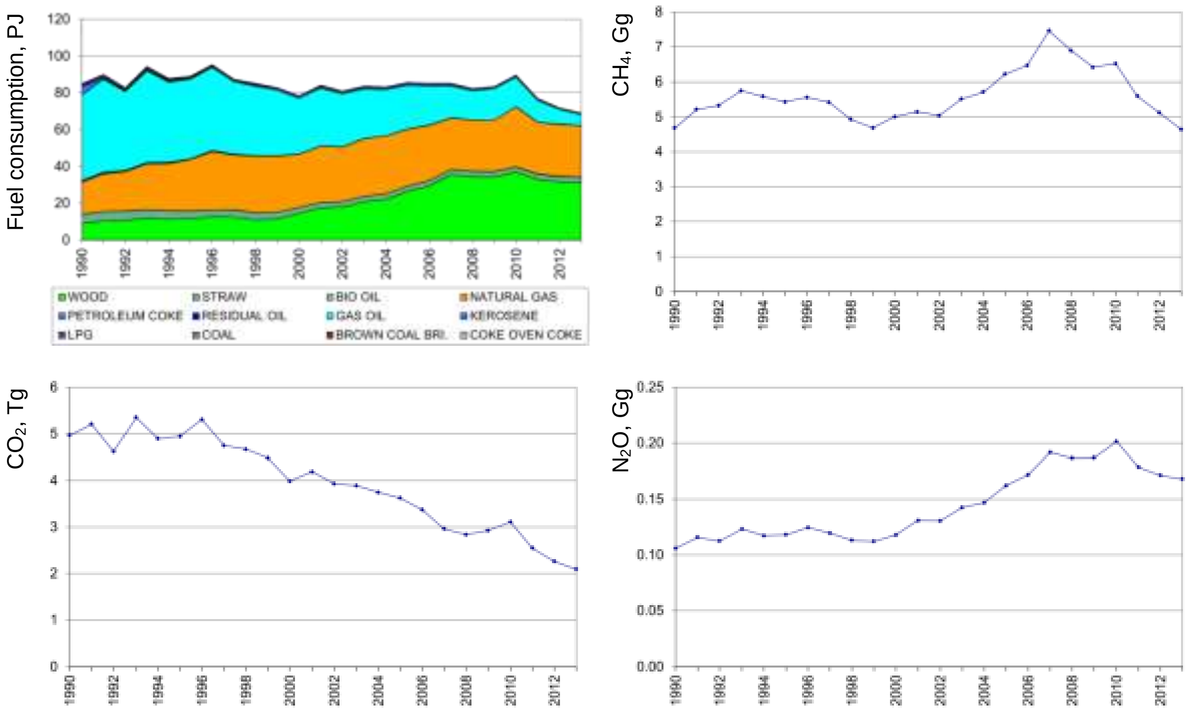


Figure 3.2.33 Time series for 1A4b Residential plants.

1A4c Agriculture/forestry

The emission source category *Agriculture/forestry* consists of both stationary and mobile sources. In this chapter, only stationary sources are included. Figure 3.2.34 shows the time series for fuel consumption and emissions.

For plants in agriculture/forestry, the fuel consumption has decreased 41 % since 1990. A remarkable decrease of fuel consumption has taken place since year 2000.

The type of fuel that has been applied has changed since 1990. In the years 1994-2004, the consumption of natural gas was high, but in recent years, the consumption decreased again. A large part of the natural gas consumption has been applied in gas engines (Figure 3.2.30). Most CHP plants in agriculture/forestry based on gas engines came in operation in 1995-1999. The decrease in later years is a result of the liberalisation of the electricity market.

The consumption of straw has decreased since 1990. The consumption of both residual oil and gas oil has increased after 1990 but has decreased again in recent years.

The CO_2 emission in 2013 was 55 % lower than in 1990. The CO_2 emission increased from 1990 to 1996 due to increased fuel consumption. Since 1996, the CO_2 emission has decreased in line with the decrease in fuel consumption.

The CH_4 emission in 2013 was equal to the emission in 1990. The emission follows the time series for natural gas combusted in gas engines (Figure 3.2.30). The emission from combustion of straw has decreased as a result of the decreasing consumption of straw in the sector.

The emission of N_2O has decreased by 35 % since 1990. The decrease is a result of the lower fuel consumption as well as the change of fuel. The decreasing consumption of straw contributes considerably to the decrease of emission.

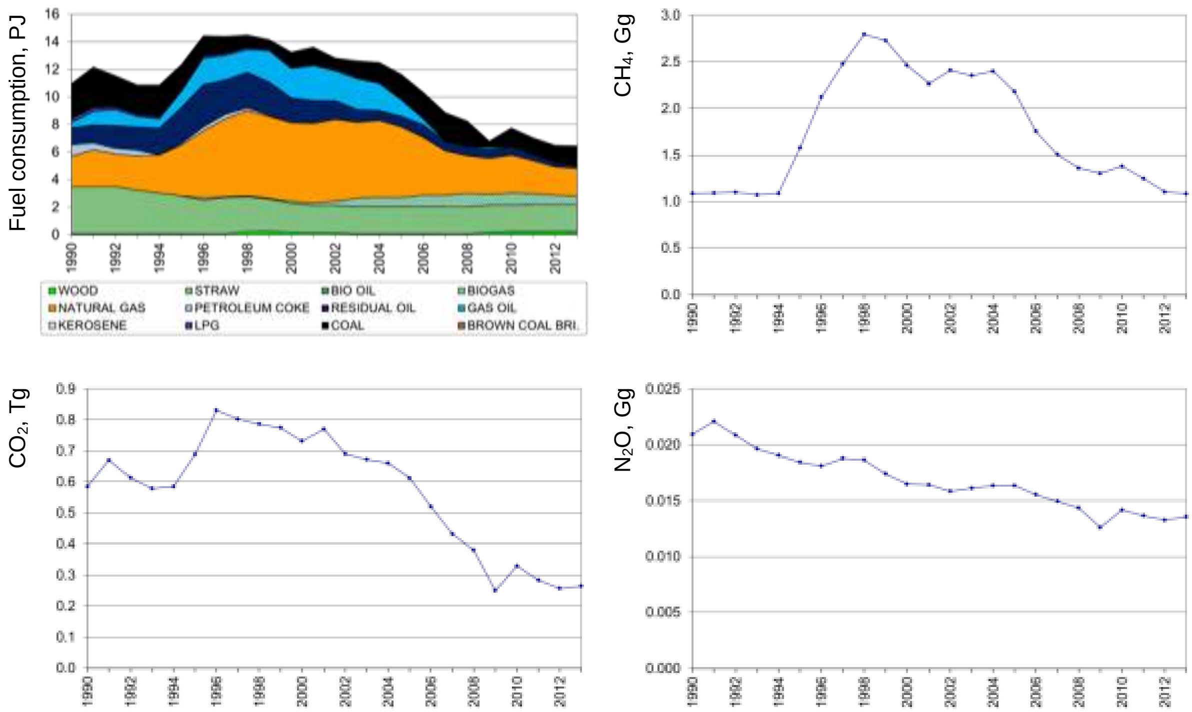


Figure 3.2.34 Time series for 1A4c Agriculture/Forestry.

3.2.5 Methodological issues

The Danish emission inventory is based on the CORINAIR (CORe INventory on AIR emissions) system, which is a European program for air emission inventories. CORINAIR includes methodology structure and software for inventories. The methodology is described in the EMEP/EEA Guidebook (EEA, 2013). Emission data are stored in an Access database, from which data are transferred to the reporting formats.

In the Danish emission database all activity rates and emissions are defined in SNAP sector categories (Selected Nomenclature for Air Pollution) according the CORINAIR system. The emission inventories are prepared from a complete emission database based on the SNAP source categories. Aggregation to the source category codes used in CRF is based on a correspondence list enclosed in Annex 3A-1.

The emission inventory for stationary combustion is based on activity rates from the Danish energy statistics. General emission factors for various fuels, plants and sectors have been determined. Some large plants, such as power plants, are registered individually as large point sources and plant-specific emission data are used.

Tiers

The type of emission factor and the applied tier level for each emission source are shown in Table 3.2.8 below. The tier levels have been determined based on the IPCC Guidelines (IPCC, 2006).

The fuel consumption data for transformation are technology specific. For end-use of fuels, the disaggregation to specific technologies is less detailed. However, for residential wood combustion technology specific fuel consumption rates have been estimated.

The tier level definitions have been interpreted as follows:

- Tier 1: The emission factor is an IPCC default tier 1 value.
- Tier 2: The emission factors are country-specific and based on a limited number of emission measurements or a technology specific IPCC tier 2 emission factor.
- Tier 3: Emission data are based on:
  - Plant specific emission measurements or
  - Technology specific fuel consumption data and country-specific emission factors based on a considerable number of emission measurements from Danish plants.

Table 3.2.8 gives an overview of the calculation methods and type of emission factor. The table also shows which of the source categories are key in any of the key category analysis (including LULUCF, approach 1/approach 2, level/trend)[5].

[5] Key category according to the KCA approach 1 or approach 2 for Denmark (excluding Greenland and Faroe Islands), including LULUCF, level 1990/ level 2013/ trend.

Table 3.2.8 Methodology and type of emission factor, 2013.

		Tier	EMF[1)]	Key category[2)]
1A Stationary combustion, Coal, ETS data	CO_2	Tier 3	PS	Yes
1A Stationary combustion, Coal, no ETS data	CO_2	Tier 3 / Tier 1 [3)]	CS (1A1) or D (1A2, 1A4)	Yes
1A Stationary combustion, BKB	CO_2	Tier 1	D	No
1A Stationary combustion, Coke oven coke	CO_2	Tier 1	D	No
1A Stationary combustion, Fossil waste, ETS data	CO_2	Tier 3	PS	Yes
1A Stationary combustion, Fossil waste, no ETS data	CO_2	Tier 2	CS	Yes
1A Stationary combustion, Petroleum coke, ETS data	CO_2	Tier 3	PS	Yes
1A Stationary combustion, Petroleum coke, no ETS data	CO_2	Tier 2	CS	Yes
1A Stationary combustion, Residual oil, ETS data	CO_2	Tier 3	PS	Yes
1A Stationary combustion, Residual oil, no ETS data	CO_2	Tier 2 / Tier 1 [4)]	CS (1A1a) / D (1A2, 1A4)	Yes
1A Stationary combustion, Gas oil	CO_2	Tier 2 / Tier 3 [5)]	CS / PS	Yes
1A Stationary combustion, Kerosene	CO_2	Tier 1	D	Yes
1A Stationary combustion, LPG	CO_2	Tier 1	D	No
1A1b Stationary combustion, Petroleum refining, Refinery gas	CO_2	Tier 3	CS	Yes
1A Stationary combustion, Natural gas, onshore	CO_2	Tier 3	CS	Yes
1A1c_ii Stationary combustion, Oil and gas extraction, Off shore gas turbines, Natural gas	CO_2	Tier 3	CS	Yes
1A1 Stationary Combustion, Solid fuels	CH_4	Tier 2	D(2)	No
1A1 Stationary Combustion, Liquid fuels	CH_4	Tier 1 / Tier 2	D / D(2) / CS	No
1A1 Stationary Combustion, not engines, gaseous fuels	CH_4	Tier 2	CS / D(2)	No
1A1 Stationary Combustion, Waste	CH_4	Tier 2	CS	No
1A1 Stationary Combustion, not engines, Biomass	CH_4	Tier 3 / Tier 2 / Tier 1	CS / D(2) / D	No
1A2 Stationary Combustion, solid fuels	CH_4	Tier 1	D	No
1A2 Stationary Combustion, Liquid fuels	CH_4	Tier 1 / Tier 2	D / D(2) / CS	No
1A2 Stationary Combustion, not engines, gaseous fuels	CH_4	Tier 2	CS / D(2)	No
1A2 Stationary Combustion, Waste	CH_4	Tier 1	D	No
1A2 Stationary Combustion, not engines, Biomass	CH_4	Tier 2 / Tier 1	D(2) / D	No
1A4 Stationary Combustion, Solid fuels	CH_4	Tier 1	D	No
1A4 Stationary Combustion, Liquid fuels	CH_4	Tier 1 / Tier 2	D / D(2)	No
1A4 Stationary Combustion, not engines, gaseous fuels	CH_4	Tier 2	D(2)	No
1A4 Stationary Combustion, Waste	CH_4	Tier 1	D	No
1A4 Stationary Combustion, not engines, not residential wood and not residential/agricultural straw, Biomass	CH_4	Tier 1 / Tier 2	D / D(2) / CS	No
1A4b_i Stationary combustion, Residential wood combustion	CH_4	Tier 2	CS	Yes
1A4b_i/1A4c_i Stationary Combustion, Residential and agricultural straw combustion	CH_4	Tier 1	D	Yes
1A Stationary combustion, Natural gas fuelled engines, gaseous fuels	CH_4	Tier 3	CS	No
1A Stationary combustion, Biogas fuelled engines, Biomass	CH_4	Tier 3	CS	No
1A1 Stationary Combustion, Solid fuels	N_2O	Tier 2	CS / D(2)	Yes
1A1 Stationary Combustion, Liquid fuels	N_2O	Tier 2 / Tier 1	D(2) / CS / D	No
1A1 Stationary Combustion, Gaseous fuels	N_2O	Tier 3 / Tier 2	CS / D(2)	Yes
1A1 Stationary Combustion, Waste	N_2O	Tier 2	CS	Yes
1A1 Stationary Combustion, Biomass	N_2O	Tier 2 / Tier 1	CS / D(2) / D	Yes
1A2 Stationary Combustion, Solid fuels	N_2O	Tier 1	D	No
1A2 Stationary Combustion, Liquid fuels	N_2O	Tier 2 / Tier 1	D(2) / CS / D	Yes
1A2 Stationary Combustion, Gaseous fuels	N_2O	Tier 3 / Tier 2	CS / D(2)	Yes
1A2 Stationary Combustion, Waste	N_2O	Tier 1	D	No
1A2 Stationary Combustion, Biomass	N_2O	Tier 1 / Tier 2	D / CS	No
1A4 Stationary Combustion, Solid fuels	N_2O	Tier 1	D	No
1A4 Stationary Combustion, Liquid fuels	N_2O	Tier 2 / Tier 1	D(2) / CS / D	Yes
1A4 Stationary Combustion, Gaseous fuels	N_2O	Tier 3 / Tier 2	CS / D(2)	Yes
1A4 Stationary Combustion, Waste	N_2O	Tier 1	D	No
1A4 Stationary Combustion, not residential wood and not residential/agricultural straw, Biomass	N_2O	Tier 1 / Tier 2	D / CS	No
1A4b_i Stationary Combustion, Residential wood combustion	N_2O	Tier 1	D	Yes
1A4b_i/1A4c_i Stationary Combustion, Residential and agricultural straw combustion	N_2O	Tier 1	D	No

1) D: IPCC (2006) default, tier 1. D(2): IPCC (2006) default, tier 2. CS: Country specific. PS: Plant specific.

2) KCA approach 1 or approach 2 for Denmark (excluding Greenland and Faroe Islands), including LULUCF, level 1990 or level 2013 or trend 1990-2013

3) Tier 1 for 64 % of the emission in this emission source category in 2013, but less than 2 % of the total coal consumption.

4) Tier 1 for 80 % of the emission source category in 2013, but less than 20 % of the total residual oil consumption.

5) Tier 3 for 8 % of the gas oil consumption in 2013.

Large point sources

Large emission sources such as power plants, industrial plants and refineries are included as large point sources in the Danish emission database. Each point source may consist of more than one part, e.g. a power plant with several units. By registering the plants as point sources in the database, it is possible to use plant-specific emission factors.

In the inventory for the year 2013, 78 stationary combustion plants are specified as large point sources. Plant specific emission data are available from 73 of the plants. The point sources include:

- Power plants and decentralised CHP plants.
- Waste incineration plants.
- Large industrial combustion plants.
- Petroleum refining plants.

The criteria for selection of point sources consist of the following:

- All centralized power plants, including smaller units.
- All units with a capacity of above 25 MW_e.
- All district heating plants with an installed effect of 50 MW_{th} or above and significant fuel consumption.
- All waste incineration plants obligated to report environmental data annually according to Danish law (DEPA, 2010).
- Industrial plants,
  - With an installed effect of 50 MW_{th} or above and significant fuel consumption.
  - With a significant process related emission.

The fuel consumption of stationary combustion plants registered as large point sources in the 2013 inventory was 265 PJ. This corresponds to 57 % of the overall fuel consumption for stationary combustion.

A list of the large point sources for 2013 is provided in Annex 3A-5. The number of large point sources registered in the databases increased from 1990 to 2013. Aggregated fuel consumption rates for the large point sources are also shown in Annex 3A-5.

The emissions from a point source are based either on plant specific emission data or, if plant specific data are not available, on fuel consumption data and the general Danish emission factors.

Emission measurement data for CH_4 and N_2O are applied for estimating emission factors but not implemented as plant specific data. The plant-specific emission data from the EU ETS data represent 70 % of the total CO_2 emission from stationary combustion.

CO_2 emission factors are plant specific for the major power plants, refineries, off shore gas turbines and for cement production. Plant-specific emission data are obtained from CO_2 data reported under the EU Emission Trading Scheme (ETS).

The EU ETS data are discussed in the chapter Emission factors (see page 147).

Annual environmental reports for the plants include a considerable number of emission data sets. Emission data from annual environmental reports are, in general, based on emission measurements, but some emissions have potentially been calculated from general emission factors.

If plant-specific emission factors are not available, general area source emission factors are used.

Emissions of the greenhouse gases CH_4 and N_2O from the large point sources are all based on the area source emission factors.

Area sources

Fuels not combusted in large point sources are included as source category specific area sources in the emission database. Plants such as residential boilers, small district heating plants, small CHP plants and some industrial boilers are defined as area sources. Emissions from area sources are based on fuel consumption data and emission factors. Further information on emission factors is provided below in the chapter Emission factors (see page 147).

Activity rates, fuel consumption

The fuel consumption rates are based on the official Danish energy statistics prepared by the Danish Energy Agency (DEA). DCE aggregates fuel consumption rates to SNAP categories. Some fuel types in the official Danish energy statistics are added to obtain a less detailed fuel aggregation level cf. Annex 3A-3. The calorific values on which the energy statistics are based are also enclosed in Annex 3A-3. The correspondence list between the energy statistics and SNAP categories is enclosed in Annex 4.

The fuel consumption of the CRF category *Manufacturing industries and construction* (corresponding to SNAP category 03) is disaggregated into industrial subsectors based on the DEA data set aggregated for the Eurostat reporting (DEA, 2014c).

The fuel consumption data flow is shown in Figure 3.2.35.

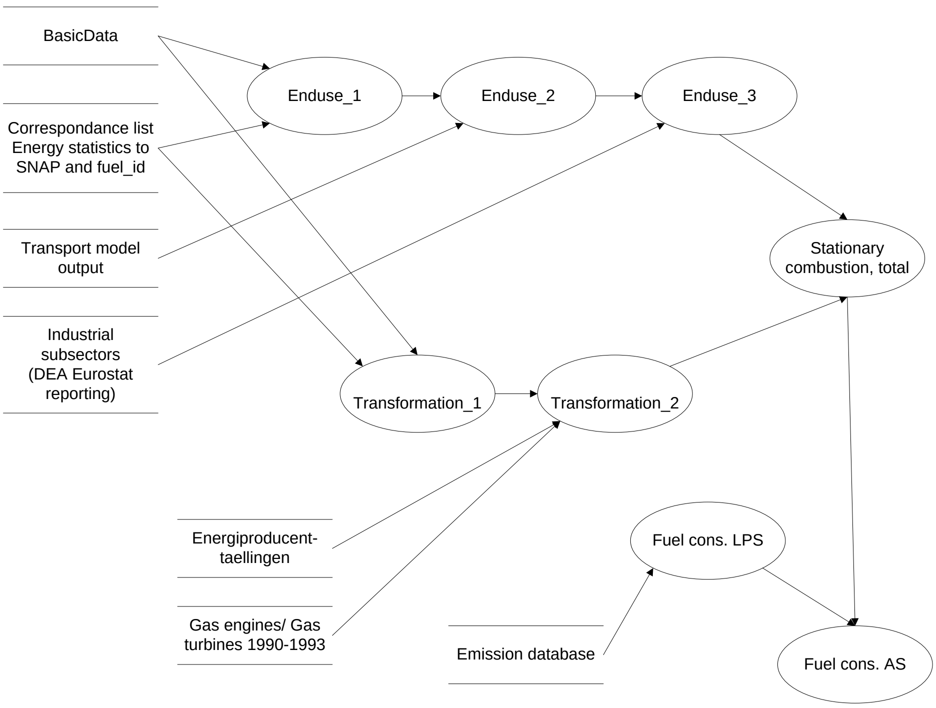


Figure 3.2.35 Fuel consumption data flow.

Both traded and non-traded fuels are included in the Danish energy statistics. Thus, for example, estimation of the annual consumption of non-traded wood is included.

Petroleum coke purchased abroad and combusted in Danish residential plants (border trade of 628 TJ in 2013) is not included in the Danish inventory. This is in agreement with the IPCC Guidelines (IPCC, 2006).

The fuel consumption data for large point sources refer to the EU Emission Trading Scheme (EU ETS) data for plants for which the CO_2 emission also refer to EU ETS, see page 147.

For all other large point sources, the fuel consumption refers to a DEA database (DEA, 2014b). The DEA compiles a database for the fuel consumption of each district heating and power-producing plant, based on data reported by plant operators. The consistency between EU ETS reporting and the DEA database (DEA, 2014b) is checked by the DEA and any discrepancies are corrected prior to the use in the emission inventory.

The fuel consumption of area sources is calculated as total fuel consumption in the energy statistics minus fuel consumption of large point sources.

In Denmark, all waste incineration are utilised for heat and power production. Thus, incineration of waste is included as stationary combustion in the source category *Fuel combustion* (subcategories *1A1*, *1A2* and *1A4)*.

Fuel consumption data are presented in Chapter 3.2.2.

Fuels used for non-energy purposes

The Danish national energy statistics includes three fuels used for non-energy purposes; bitumen, white spirit and lubricants. The total consumption for non-energy purposes is relatively low, e.g. 11.6 PJ in 2013. The use of fuels for non-energy purposes is included in the inventory in sector 2D Non-energy products from fuels and solvent use, see Chapter 4.5.

The non-energy use of fuels is included in the reference approach for Climate Convention reporting and appropriately corrected in line with the IPCC Guidelines (IPCC, 2006).

Town gas

Town gas has been included in the fuel category natural gas. The consumption of town gas in Denmark is very low, e.g. 0.6 PJ in 2013. In 1990, the town gas consumption was 1.6 PJ and the consumption has been steadily decreasing throughout the time series.

In Denmark, town gas is produced based on natural gas. The use of coal for town gas production ceased in the early 1980s.

An indicative composition of town gas according to the largest supplier of town gas in Denmark is shown in Table 3.2.9 (KE, 2015).

Table 3.2.9 Composition of town gas currently used (KE, 2015).

Component	Town gas, % (mol.)
Methane	43.9
Ethane	2.9
Propane	1.1
Butane	0.5
Carbon dioxide	0.4
Nitrogen	40.5
Oxygen	10.7

The lower heating value of the town gas currently used is 19.3 MJ per Nm^3 and the CO_2 emission factor 56.1 kg per GJ. This is very close to the emission factor used for natural gas of 56.79 kg per GJ. According to the supplier, both the composition and heating value will change during the year. It has not been possible to obtain a yearly average.

In earlier years, the composition of town gas was somewhat different. Table 3.2.10 shows data for town gas composition in 2000-2005. These data are constructed with the input from Københavns Energi (KE) (Copenhagen Energy) and Danish Gas Technology Centre (DGC), (Jeppesen, 2007; Kristensen, 2007). The data refer to three measurements performed several years apart; the first in 2000 and the latest in 2005.

Table 3.2.10 Composition of town gas, data from 2000-2005.

Component	Town gas, % (mol.)
Methane	22.3-27.8
Ethane	1.2-1.8
Propane	0.5-0.9
Butane	0.13-0.2
Higher hydrocarbons	0-0.6
Carbon dioxide	8-11.6
Nitrogen	15.6-20.9
Oxygen	2.3-3.2
Hydrogen	35.4-40.5
Carbon monoxide	2.6-2.8

The lower calorific value has been between 15.6 and 17.8 MJ per Nm^3. The CO_2 emission factors - derived from the few available measurements - are in the range of 52-57 kg per GJ.

The Danish approach includes town gas as part of the fuel category natural gas and thus indirectly assumes the same CO_2 emission factor. This is a conservative approach ensuring that the CO_2 emissions are not underestimated.

Due to the scarce data available and the very low consumption of town gas compared to consumption of natural gas (< 0.5 %), the methodology will be applied unchanged in future inventories.

Waste

All waste incineration in Denmark is utilised for heat and/or power production and thus included in the energy sector. The waste incinerated in Denmark for energy production consists of the waste fractions shown in Figure 3.2.36. In 2009[6], 3 % of the incinerated waste was hazardous waste[7].

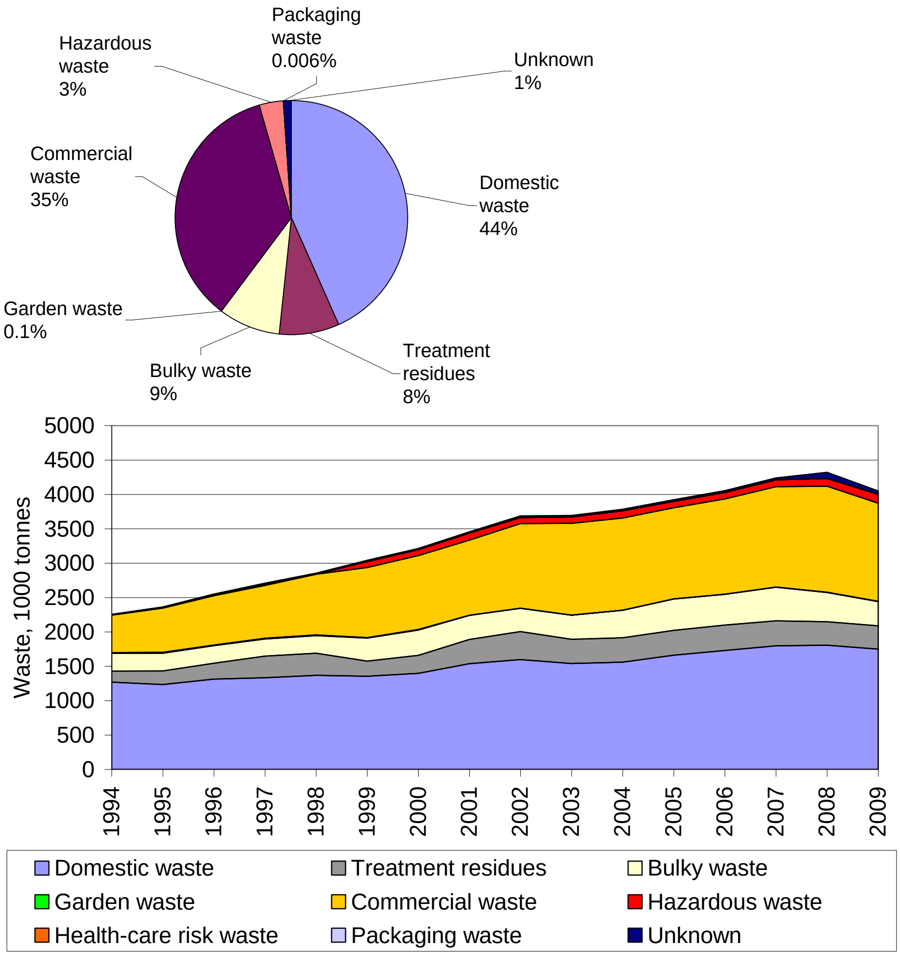


Figure 3.2.36 Waste fractions (weight) for incinerated waste in 2009 and the corresponding time series 1994-2009 (ISAG, 2012).

In connection to the project estimating an improved CO_2 emission factor for waste (Astrup et al., 2012), the fossil energy fraction was calculated. The fossil fraction was not measured or estimated as part of the project, but the flue

[6] Currently, data are only available for 1994-2009.
[7] In 2001 onwards, health-care risk waste is included in hazardous waste in the ISAG database.

gas measurements combined with data from Fellner & Rechberger (2010) indicated a fossil energy part of 45 %. The energy statistics also applies this fraction in the national statistics.

Biogas

Biogas includes landfill gas, sludge gas and manure/organic waste gas[8]. The Danish energy statistics specifies production and consumption of each of the biogas types. In 2013, 74 % of the applied biogas was based on manure /organic waste.

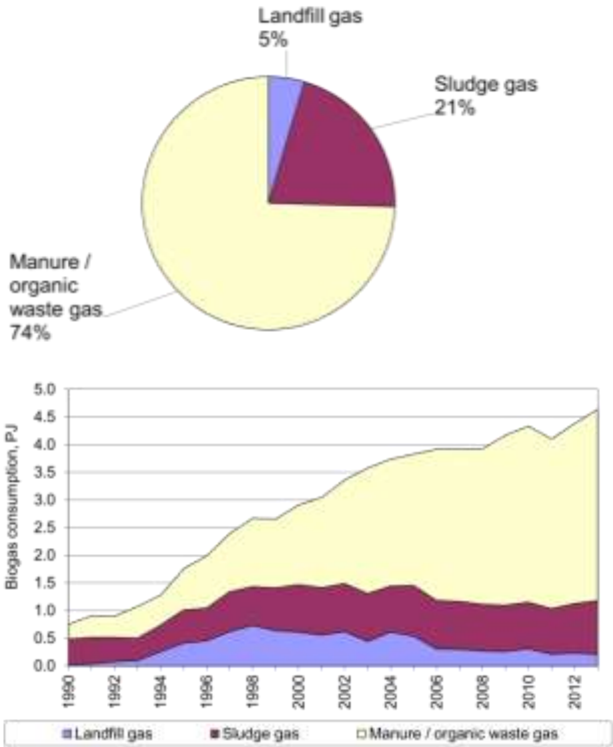


Figure 3.2.37 Biogas types 2013 and the corresponding time series 1990-2013 (DEA, 2014a).

Emission factors

For each fuel and SNAP category (sector and e.g. type of plant), a set of general area source emission factors has been determined. The GHG emission factors are either nationally referenced or based on IPCC Guidelines (2006)[9].

An overview of the type of CO_2 emission factor is shown in Table 3.2.17. A complete list, of emission factors including time series and references, is provided in Annex 3A-4.

EU ETS data for CO_2

The CO_2 emission factors for some large power plants and for combustion in the cement industry and refineries are plant specific and based on the reporting to the EU Emission Trading Scheme (EU ETS). In addition, emission factors for offshore gas turbines and refinery gas is based on EU ETS data[10]. The EU ETS data have been applied for the years 2006 - 2013.

[8] Based on manure with addition of other organic waste.
[9] However, the CO_2 emission factor for gas oil refers to the EMEP/EEA Guidebook (EEA, 2007).
[10] See page 134 and 134.

The EU ETS data are also applied for other source categories and are further discussed in Chapter 1.4.10.

ETS data, methodology, criteria for implementation and QA/QC

The Danish emission inventory for stationary combustion only includes data from plants using higher tier methods as defined in the EU decision (EU Commission, 2007), where the specific methods for determining carbon contents, oxidation factor and calorific value are specified. The EU decision includes rules for measuring, reporting and verification.

For each of the plants included individually in the Danish inventory all applied methodologies are specified in individual monitoring plans that are approved by Danish authorities (DEA) prior to the reporting of the emissions. The plants/fuels included individually in the Danish inventory all apply the Tier 3 methodology for calculating the CO_2 emission factor. This selection criteria results in a dataset for which the emission factor values are based on fuel quality measurements[11], not default values from the Danish UNFCCC reporting. All fuel analyses are performed according to ISO 17025.

The data sets are selected based on emission factor methodology. The data applied for the selected data sets are: activity data, net calorific value (NCV), emission factor and oxidation factor listed below.

Coal

The CO_2 emission factor for coal is based on analysis of C content of the coal (g C per kg) and coal weight measurements. However, NCV values are also measured according to high tier methods in spite of the fact that this value is not input data for the calculation of total CO_2 emission.

- Fuel flow: Tier 4 methodology (± 1.5 %). For coal, the activity data (weight) is based on measurements on belt conveyor scale. The uncertainty is below the required ± 1.5 %.
- NCV: Tier 3 methodology. Data are based on measurements according to ISO 13909 / ISO 18283 (sampling) and ISO 1928 (NCV). The uncertainty for data is below ± 0.5 %.
- Emission factor: The emission factor is C-content of the coal. Tier 3 methodology (± 0.5 %) is applied and the measurements are performed according to ISO 13909 (sampling) and ISO/TS 12902 (C-content).
- Oxidation factor: Based on Tier 3 methodology except for four plants that applies Tier 1 methodology[12]. The Tier 3 methodology is based on measurements of C-content in bottom ash and fly ash according to ISO/TS 12902 or on burning loss measurements according to ISO 1171. The uncertainty has been estimated to 0.5 %. For Tier 1 the oxidation factor is assumed to be 1.

Residual oil

- Fuel flow: Tier 4 methodology (± 1.5 %) for most plants. However, a few of the included plants apply Tier 3 methodology (± 2.5 %).
- NCV: Tier 3 methodology. Data are based on sampling according to API Manual of Petroleum Measurement Standards / ASTM D 270 and fuel analysis (NCV) according to ASTM D 240 / ISO 1928 / data stated by the fuel supplier.

[11] Applying specific methods defined in the EU decision.

[12] In addition, DCE have assumed the oxidation factor to be 1 for a plant for which the stated oxidation factor was rejected in the QC work.

- Emission factor: Tier 3 methodology according to API Manual of Petroleum Measurement Standards / ASTM D 4057 (sampling) and ISO 12902 / ASTM D 5291 (C-content).
- Oxidation factor: Based on Tier 2 or Tier 3 methodology, both resulting in the oxidation factor 1 with an uncertainty of 0.8 %.

For coal and residual oil fuel analyses are required for each 20,000 tonnes or at least six times each year. The fuel analyses are performed by accredited laboratories[13].

QC of EU ETS data
DCE performs QC checks on the reported emission data, see Chapter 1.4.10.

EU ETS data presentation
The EU ETS data include plant specific emission factors for coal, residual oil, gas oil, natural gas, refinery gas, petroleum coke and fossil waste. The EU ETS data accounted for 70 % of the CO_2 emission from stationary combustion in 2013.

EU ETS data for coal

EU ETS data for 2013 were available from 13 coal fired plants. The plant specific information accounts for 97 % of the Danish coal consumption and 49 % of the total (fossil) CO_2 emission from stationary combustion plants. The average CO_2 emission factor for coal for these 13 units was 93.95 kg per GJ (Table 3.2.11). The plants all apply bituminous coal.

Table 3.2.11 EU ETS data for 13 coal fired plants, 2013.

	Average	Min	Max
Heating value, GJ per tonne	24.5	23.5	31.5
CO_2 implied emission factor, kg per GJ[1)]	93.95	92.90	96.88
Oxidation factor	0.996	0.990	1.000

1) Including oxidation factor.

Table 3.2.12 CO_2 implied emission factor time series for coal fired plants based on EU ETS data.

Year	CO_2 implied emission factor, kg per GJ[1)]
2006	94.4
2007	94.3
2008	94.0
2009	93.6
2010	93.6
2011	94.7
2012	94.3
2013	93.9

1) Including oxidation factor.

EU ETS data for residual oil

EU ETS data for 2013 based on higher tier methodologies were available from 13 plants combusting residual oil. Aggregated data and time series are shown in Table 3.2.13 and Table 3.2.14. The EU ETS data accounts for 76 % of the residual oil consumption in stationary combustion.

Table 3.2.13 EU ETS data for 13 plants combusting residual oil.

	Average	Min	Max
Heating value, GJ per tonne	40.6	39.5	40.8
CO_2 implied emission factor, kg per GJ	79.28	78.82	82.43
Oxidation factor	1.000	1.000	1.000

[13] EN ISO 17025.

Table 3.2.14 CO_2 implied emission factor time series for residual oil fired power plant units based on EU ETS data.

Year	CO_2 implied emission factor, kg per GJ[1)]
2006	78.2
2007	78.1
2008	78.5
2009	78.9
2010	79.2
2011	79.25
2012	79.21
2013	79.28

1) Including oxidation factor.

EU ETS data for gas oil combusted in power plants or refineries

EU ETS data for 2013 based on higher tier methodologies were included from 6 plants combusting gas oil. Aggregated data and time series are shown in Table 3.2.15 and Table 3.2.16. The EU ETS data accounts for 8 % of the gas oil consumption in stationary combustion.

Table 3.2.15 EU ETS data for gas oil applied in power plants/refineries.

	Average	Min	Max
Heating value, GJ per tonne	42.7	35.9	43.0
CO_2 implied emission factor, kg per GJ	72.66	72.37	74.37
Oxidation factor	1.000	1.000	1.000

Table 3.2.16 CO_2 implied emission factor time series for gas oil based on EU ETS data.

Year	CO_2 implied emission factor, kg per GJ[1)]
2006	75.1
2007	74.9
2008	73.7
2009	75.1
2010	74.8
2011	74.7
2012	73.9
2013	72.7

1) Including oxidation factor.

EU ETS data for waste

EU ETS data for 2013 based on higher tier methodologies were included from 9 waste incineration plants. The EU ETS data for waste incineration are based on emission measurements. The average emission factor value for the plants is 43 kg/GJ. The emission factors are in the interval 33.0 kg/GJ to 57.7 kg/GJ. The EU ETS data accounts for 60 % of the incinerated waste.

EU ETS data for petroleum coke, coke oven coke and industrial waste

The implemented EU ETS data set also includes CO_2 emission factors for industrial waste, petroleum coke and coke oven coke combusted in industrial plants. The industrial plants with additional EU ETS data include cement industry, sugar production, glass wood production, lime production, and vegetable oil production.

EU ETS data for natural gas applied in offshore gas turbines

EU ETS data have been applied to estimate an average CO_2 emission factor for natural gas combusted in offshore gas turbines, see page 156.

EU ETS data for refinery gas

EU ETS data are also applied for the two refineries in Denmark. The emission factor for refinery gas is based on EU ETS data, see page 155.

CO_2 emission factors

The CO_2 emission factors that are not included in EU ETS data or that are included but based on lower tier methodologies are not plant specific in the Danish inventory. The emission factors that are not plant specific accounts for 30 % of the fossil CO_2 emission.

The CO_2 emission factors applied for 2013 are presented in Table 3.2.17. Time series have been estimated for:

- Coal applied for production of electricity and district heating
- Residual oil applied for production of electricity and district heating
- Refinery gas
- Natural gas applied in off shore gas turbines
- Natural gas, other
- Industrial waste, biomass part

For all other fuels, the same emission factor has been applied for 1990-2013.

In the reporting to the UNFCCC, the CO_2 emission is aggregated to six fuel types: solid fuels, liquid fuels, gaseous fuels, other fossil fuels, peat, and biomass. Peat is not applied in Denmark. The correspondence list between the DCE fuel categories and the IPCC fuel categories is also provided in Table 3.2.17.

Only emissions from fossil fuels are included in the total national CO_2 emission. The biomass emission factors are also included in the table, because emissions from biomass are reported to the UNFCCC as a memo item.

The CO_2 emission from incineration of waste (37 + 75.1 kg per GJ) is divided into two parts: The emission from combustion of the fossil content of the waste, which is included in the national total, and the emission from combustion of the biomass part, which is reported as a memo item. In the CRF, the fuel consumption and emissions from the fossil content of the waste is reported in the fuel category other fossil fuels.

Table 3.2.17 CO_2 emission factors, 2013.

Fuel	Emission factor kg per GJ		Reference type	IPCC fuel category
	Bio-mass	Fossil fuel		
Coal, source category 1A1a Public electricity and heat production		93.95 [1]	Country specific	Solid
Coal, Other source categories		94.6[3]	IPCC (2006)	Solid
Brown coal briquettes		**r** 97.5	IPCC (2006)	Solid
Coke oven coke		**r** 107 [3]	IPCC (2006)	Solid
Other solid fossil fuels [6]		**r** 118[1]	Country specific	Solid
Fly ash fossil (from coal)		95.4	Country specific	Solid
Petroleum coke		93 [3]	Country-specific	Liquid
Residual oil, source category 1A1a Public electricity and heat production		79.28 [1]	Country-specific	Liquid
Residual oil, other source categories		77.4[3]	IPCC (2006)	Liquid
Gas oil		74 [1]	EEA (2007)	Liquid
Kerosene		71.9	IPCC (2006)	Liquid
Orimulsion		80 [2]	Country-specific	Liquid
LPG		63.1	IPCC (2006)	Liquid
Refinery gas		58.274	Country-specific	Liquid
Natural gas, off shore gas turbines		57.295	Country-specific	Gas
Natural gas, other		56.79	Country-specific	Gas
Waste	75.1 [3][4]	+ 37[3][4]	Country-specific	Biomass and Other fuels
Straw	**r** 100		IPCC (2006)	Biomass
Wood	**r** 112		IPCC (2006)	Biomass
Bio oil	70.8		IPCC (2006)	Biomass
Biogas	84.1		Country-specific	Biomass
Biomass gasification gas	142.9[5]		Country-specific	Biomass

1) Plant specific data from EU ETS incorporated for individual plants.
2) Not applied in 2013. Orimulsion was applied in Denmark in 1995 – 2004.
3) Plant specific data from EU ETS incorporated for cement industry and sugar, lime and mineral wool production.
4) The emission factor for waste is (37+75.1) kg CO_2 per GJ waste. The fuel consumption and the CO_2 emission have been disaggregated to the two IPCC fuel categories *Biomass* and *Other fossil fuels* in CRF. The IEF[14] for CO_2, Other fuels is 82.22 kg CO_2 per GJ fossil waste.
5) Includes a high content of CO_2 in the gas.
6) Anodic carbon.

Coal

As mentioned above[15], EU ETS data have been utilised for the years 2006 - 2013 in the emission inventory. The emission factor for coal is the implied emission factor for plants that report EU ETS data that are based on fuel analysis. Data for industrial plants have been included. In 2013, the implied emission factor (including oxidation factor) was 93.95 kg per GJ. The implied emission factor values were between 92.90 and 96.88 kg per GJ.

In 2013, only 3 % of the CO_2 emission from coal consumption was based on the emission factor, whereas 97 % of the coal consumption was covered by EU ETS data. All coal applied in Denmark is bituminous coal (DEA, 2014c).

The emission factors for coal combustion in *Public electricity and heat production* in the years 2006-2013 refer to the implied emission factors of the EU ETS data estimated for each year. For the years 1990-2005, the emission factor for coal combusted in public electricity and heat production plants refer to the average IEF for 2006-2009.

[14] Not including cement production.
[15] EU ETS data for CO2 on page 60.

Time series for net calorific value (NCV) of coal are available in the Danish energy statistics. NCV for *Electricity plant coal* fluctuates in the interval 24.23-25.8 GJ per tonne.

The correlation between NCV and CO_2 IEF (including the oxidation factor) in the EU ETS data (2006-2009) have been analysed and the results are shown in Annex 3A-9. However, a significant correlation between NCV and IEF have not been found in the dataset and thus an emission factor time series based on the NCV time series was not relevant. In addition, the correlation of NCV and CO_2 emission factors has been analysed. This analysis is also shown in Annex 3A-9. As expected, the correlation was better in this dataset, but still insufficient for estimating a time series for the CO_2 emission factor based on the NCV time series.

As mentioned above all coal applied in Denmark is bituminous coal and within the range of coal qualities applied in the plants reporting data to EU ETS a correlation could not be documented.

For other sectors apart from 1A1a, the applied emission factor 94.6 kg per GJ refers to IPCC Guidelines (IPCC, 2006). This emission factor has been applied for all years.

Time series for the CO_2 emission factor are shown in Table 3.2.18.

Table 3.2.18 CO_2 emission factors for coal, time series.

Year	1A1a Public electricity and heat production kg per GJ	Other source categories kg per GJ
1990-2005	94.0	94.6
2006	94.4	94.6
2007	94.3	94.6
2008	94.0	94.6
2009	93.6	94.6
2010	93.6	94.6
2011	93.73	94.6
2012	94.25	94.6
2013	93.95	94.6

Brown coal briquettes

The emission factor for brown coal briquettes, 97.5 kg per GJ refers to the IPCC Guidelines, 2006 (IPCC, 2006). The oxidation factor has been assumed equal to 1. The same emission factor has been applied for 1990-2013.

The emission factor has been revised this year according to the revised IPCC Guidelines.

Coke oven coke

The emission factor for coke oven coke, 107 kg per GJ, refers to the IPCC Guidelines 2006 (IPCC, 2006). The oxidation factor has been assumed equal to 1. The same emission factor has been applied for 1990-2013.

The emission factor has been revised this year according to the revised IPCC Guidelines.

Other solid fossil fuels (Anodic carbon)

Anodic carbon has been applied in Denmark in 2009-2013 in two mineral wool production units. The emission factor 118 kg/GJ refer to EU ETS data from one of the plants in 2012. EU ETS data are available for both plants in 2013 and thus the area source emission factor have not been applied.

Fly ash fossil (from coal)

Fly ash from coal combustion is applied in some power plants. The emission factor 95.4 kg/GJ refer to plant specific EU ETS data for 2011 and 2012 assuming full oxidation.

The emission factor is not applied due to the fact that plant specific data are available from the EU ETS dataset.

Petroleum coke

The emission factor for petroleum coke has been recalculated in this inventory. The improved emission factor 93 kg per GJ is based on EU ETS data for 2006-2010. The data includes one power plant and the cement production plant.

Plant specific EU ETS data have been utilised for the cement production for the years 2006 - 2013.

EU ETS data were available for more than 98 % of the petroleum coke consumption in 2013.

Residual oil

The emission factor for residual oil applied in public electricity and heat production is based on EU ETS data.

As mentioned above[16] EU ETS data have been utilised for the 2006 - 2013 emission inventories. In 2013, the implied emission factor (including oxidation factor) for the power plants and refineries combusting residual oil was 79.28 kg per GJ. The implied emission factor values were between 78.82 and 82.43 kg per GJ.

In 2013, 24 % of the CO_2 emission from residual oil consumption was based on the emission factor, whereas 76 % of the residual oil consumption was covered by EU ETS data[17].

The emission factors for residual oil combustion in *Public electricity and heat production* in the years 2006-2013 refer to the implied emission factors of the EU ETS data estimated for each year. For the years 1990-2005, the emission factor for residual oil in *Public electricity and heat production* refer to the average IEF for 2006-2009.

For other source categories apart from 1A1a, the applied emission factor 77.4 kg per GJ refers to the IPCC Guidelines (IPCC, 2006). This emission factor has been applied for all years.

Time series for the CO_2 emission factor are shown in Table 3.2.19.

[16] EU ETS data for CO2 on page 61.
[17] Including EU ETS data for cement production.

Table 3.2.19 CO_2 emission factors for residual oil, time series.

Year	Source category 1A1a Public electricity and heat production kg per GJ	Other source categories kg per GJ
1990-2005	78.4	77.4
2006	78.2	77.4
2007	78.1	77.4
2008	78.5	77.4
2009	78.9	77.4
2010	79.2	77.4
2011	79.25	77.4
2012	79.21	77.4
2013	79.28	77.4

Gas oil

The emission factor for gas oil, 74 kg per GJ, refers to EEA (2007). The emission factor is consistent with the IPCC default emission factor for gas oil (74.1 kg per GJ assuming full oxidation). The CO_2 emission factor has been confirmed by the two major power plant operators in 1996 (Christiansen, 1996 and Andersen, 1996). The same emission factor has been applied for 1990-2013.

Plant specific EU ETS data have been utilised for a few plants in the 2006 - 2013 emission inventories. In 2013, the implied emission factor for the power plants using gas oil was 72.7 kg per GJ. The EU ETS CO_2 emission factors were in the interval 72.4 – 74.4 kg per GJ. In 2013, 8 % of the CO_2 emission from gas oil consumption was based on EU ETS data.

Kerosene

The emission factor for kerosene, 71.9 kg per GJ, refers to IPCC Guidelines (IPCC, 2006). The same emission factor has been applied for 1990-2013.

Orimulsion

The emission factor for orimulsion, 80 kg per GJ, refers to the Danish Energy Agency (DEA, 2014a). The IPCC default emission factor is almost the same: 80.7 kg per GJ assuming full oxidation. The CO_2 emission factor has been confirmed by the only major power plant operator using orimulsion (Andersen, 1996). The same emission factor has been applied for all years. Orimulsion was used in Denmark in 1995-2004.

LPG

The emission factor for LPG, 63.1 kg per GJ, refers to IPCC Guidelines (IPCC, 2006). The same emission factor has been applied for 1990-2013.

Refinery gas

The emission factor applied for refinery gas refers to EU ETS data for the two refineries in operation in Denmark. Since 2006, implied emission factors for Denmark have been estimated annually based on the EU ETS data. The average implied emission factor (57.6 kg per GJ) for 2006-2009 have been applied for the years 1990-2005. This emission factor is consistent to the emission factor stated in the 2006 IPCC Guidelines (IPCC, 2006). The time series is shown in Table 3.2.20.

Table 3.2.20 CO_2 emission factors for refinery gas, time series.

Year	CO_2 emission factor, kg per GJ
1990-2005	57.6
2006	57.812
2007	57.848
2008	57.948
2009	56.814
2010	57.134
2011	57.861
2012	58.108
2013	58.274

Natural gas, offshore gas turbines

EU ETS data for the fuel consumption and CO_2 emission for offshore gas turbines are available for the years 2006-2013. Based on data for each oilfield implied emission factors have been estimated for 2006-2013. The average value for 2006-2009 has been applied for the years 1990-2005. The time series is shown in Table 3.2.21.

Table 3.2.21 CO_2 emission factors for offshore gas turbines, time series.

Year	CO_2 emission factor, kg per GJ
1990-2005	57.469
2006	57.879
2007	57.784
2008	56.959
2009	57.254
2010	57.314
2011	57.379
2012	57.423
2013	57.295

Natural gas, other source categories

The emission factor for natural gas is estimated by the Danish gas transmission company, Energinet.dk[18]. The calculation is based on gas analysis carried out daily by Energinet.dk at Egtved.

In 2013, the natural gas import was 50 PJ, the natural gas export 83 PJ and a consumption that added up to 138 PJ. Before 2010, only natural gas from the Danish gas fields was utilised in Denmark. If the import of natural gas increases further, the methodology for estimating the CO_2 emission factor might have to be revised in future inventories. DCE has an on-going dialog with the Danish Energy Agency and Energinet.dk about this. However, Energinet.dk have stated that the difference between the emission factor for 2011 based on measurements at Egtved and the average value at Froeslev very close to the border differed less than 0.3 % for 2011 (Bruun, 2012).

Energinet.dk and the Danish Gas Technology Centre have calculated emission factors for 2000-2013. The emission factor applied for 1990-1999 refers to Fenhann & Kilde (1994). This emission factor was confirmed by the two major power plant operators in 1996 (Christiansen, 1996 and Andersen, 1996). The time series for the CO_2 emission factor is provided in Table 3.2.22.

[18] Former Gastra and before that part of DONG. Historical data refer to these companies.

Table 3.2.22 CO_2 emission factor time series for natural gas.

Year	CO_2 emission factor, kg per GJ
1990-1999	56.9
2000	57.1
2001	57.25
2002	57.28
2003	57.19
2004	57.12
2005	56.96
2006	56.78
2007	56.78
2008	56.77
2009	56.69
2010	56.74
2011	56.97
2012	57.03
2013	56.79

Waste

The CO_2 emission from incineration of waste is divided into two parts: The emission from combustion of the fossil content of the waste, which is included in the national total, and the emission from combustion of the rest of the waste – the biomass part, which is reported as a memo item.

The CO_2 emission factor is based on the project, *Biogenic carbon in Danish combustible waste* that included emission measurements from five Danish waste incineration plants (Astrup et al., 2012). The average fossil emission factors for waste have been estimated to be 37 kg/GJ waste and the interval for the five plants was 25 – 51 kg/GJ. The five plants represented 44 % of the incinerated waste in 2010. The emission factor 37 kg/ GJ waste corresponds to 82.22 kg/GJ fossil waste.

The total CO_2 emission factor for waste refers to a Danish study (Jørgensen & Johansen, 2003). Based on emission measurements on five waste incineration plants the total CO_2 emission factor for waste incineration has been determined to 112.1 kg per GJ. Thus, the biomass emission factor has been determined to 75.1 kg/GJ waste.

In the 2006 - 2013 emission inventories, plant specific EU ETS data have been utilised for industrial waste combusted in cement production.

This year, plant specific EU ETS data have been reported by CHP plants incinerating waste and these data have been implemented in the emission inventory. In 2013, the average emission factor for the 9 plants was 43 kg fossil CO_2 per GJ total waste. This is above the current emission factor, but the emission factors vary between plants due to waste supply differences. The 9 plants reporting data to EU ETS represent 60 % of the incinerated waste.

Wood

The emission factor for wood, 112 kg per GJ refers IPCC (2006). The same emission factor has been applied for 1990-2013.

The emission factor has been revised this year according to the IPCC Guidelines, 2006 (IPCC, 2006).

Straw

The emission factor for wood, 100 kg per GJ refers IPCC (2006) for other primary solid biomass. The same emission factor has been applied for 1990-2013.

The emission factor has been revised this year according to the IPCC Guidelines, 2006 (IPCC, 2006).

Bio oil

The emission factor, 70.8 kg per GJ refers to the IPCC (2006). The emission factor has been revised this year. The consumption of bio oil is below 2 PJ.

Biogas

In Denmark, 3 different types of biogas are applied: Manure/organic waste based biogas, landfill based biogas and wastewater treatment biogas (sludge gas). Manure / organic waste based biogas represent 74 % of the consumption, see page 147.

The emission factor for biogas, 84.1 kg per GJ refer to Kristensen (2014) and is based on a biogas with 65 % (vol.) CH_4 and 35 % (vol.) CO_2. Danish Gas Technology Centre has stated that this is a typical manure-based biogas as utilised in stationary combustion plants (Kristensen, 2014). The same emission factor has been applied for 1990-2013.

Biomass gasification gas

Biomass gasification gas applied in Denmark is based on wood. The gas composition is known for three different plants and the applied emission factor have been estimated by Danish Gas Technology Centre (Kristensen, 2010) based on the gas composition measured on the plant with the highest consumption.

The consumption of biomass producer gas is below 0.5 PJ for all years.

CH_4 emission factors

The CH_4 emission factors applied for 2013 are presented in Table 3.2.23. In general, the same emission factors have been applied for 1990-2013. However, time series have been estimated for both natural gas fuelled engines and biogas fuelled engines, residential wood combustion, natural gas fuelled gas turbines[19] and waste incineration plants[19].

Emission factors for CHP plants < 25 MW_e refer to emission measurements carried out on Danish plants (Nielsen et al., 2010; Nielsen & Illerup, 2003; Nielsen et al., 2008). The emission factors for residential wood combustion are based on technology dependent data.

Emission factors that are not nationally referenced all refer to the IPCC Guidelines (IPCC, 2006).

Gas engines combusting natural gas or biogas account for more than half the CH_4 emission from stationary combustion plants. The relatively high emission factor for gas engines is well-documented and further discussed below.

[19] A minor emission source.

Table 3.2.23 CH_4 emission factors, 2013.

Fuel group	Fuel	CRF source category	CRF source category	SNAP	Emission factor, g per GJ	Reference
SOLID	COAL	1A1a	Public electricity and heat production	0101 0102	0.9	IPCC (2006), Tier 3, Table 2-6, Utility Boiler, Pulverised bituminous coal combustion, Wet bottom.
		1A2 a-f	Industry	03	10	IPCC (2006), Tier 1, Table 2-3, Manufacturing industries.
		1A4b i	Residential	0202	300	IPCC (2006), Tier 1, Table 2.5, Residential, Bituminous coal.
		1A4c i	Agriculture/ Forestry	0203	10	IPCC (2006), Tier 1, Table 2-4, Commercial, coal.[1)]
	BROWN COAL BRI.	1A4b i	Residential	0202	300	IPCC (2006), Tier 1, Table 2-5, Residential, brown coal briquettes
	COKE OVEN COKE	1A2 A-f	Industry	03	10	IPCC (2006), Tier 1, Table 2-4, Commercial, coke oven coke.
		1A4b i	Residential	0202	300	IPCC (2006), Tier 1, Table 2-5, Residential, coke oven coke.
	ANODIC CARBON	1A2a-f	Industry	03	10	IPCC (2006), Tier 1, Table 2-3, Manufacturing industries.
	FOSSIL FLY ASH	1A1a	Public electricity and heat production	0101	0.9	IPCC (2006), Tier 3, Table 2-6, Utility Boiler, Pulverised bituminous coal combustion, Wet bottom.
LIQUID	PETROLEUM COKE	1A2a-f	Industry	03	**r** 3	IPCC (2006), Tier 1, Table 2-3, Industry, petroleum coke.
	RESIDUAL OIL	1A1a	Public electricity and heat production	010101	**r** 0.8	IPCC (2006), Tier 3, Table 2-6, Utility Boiler, Residual fuel oil.
				010102 010103	1.3	Nielsen et al. (2010)
				010104	3	IPCC (2006), Tier 1, Table 2-2, Energy industries, residual oil.
				010203	**r** 0.8	IPCC (2006), Tier 3, Table 2-6, Utility Boiler, Residual fuel oil.
		1A1b	Petroleum refining	010306	3	IPCC (2006), Tier 1, Table 2-2, Energy industries, residual fuel oil.
		1A2 a-f	Industry	03	1.3	Nielsen et al. (2010)
				Engines	4	IPCC (2006), Tier 3, Table 2-6, Utility, Large diesel engines
		1A4a	Commercial/ Institutional	0201	1.4	IPCC (2006), Tier 3, Table 2-10, Commercial, residual fuel oil boilers.
		1A4b	Residential	0202	1.4	IPCC (2006), Tier 3, Table 2-9, Residential, residual fuel oil.
		1A4c	Agriculture/ Forestry	0203	1.4	IPCC (2006), Tier 3, Table 2-10, Commercial, residual fuel oil boilers.[1)].
	GAS OIL	1A1a	Public electricity and heat production	010101 010102 010103	0.9	IPCC (2006), Tier 3, Table 2-6, Utility, gas oil, boilers.
				010104	3	IPCC (2006), Tier 1, Table 2-2, Energy industries, gas oil.
				010105	24	Nielsen et al. (2010)
				010202 010203	0.9	IPCC (2006), Tier 3, Table 2-6, Utility, gas oil, boilers.
		1A1b	Petroleum refining	010306	3	IPCC (2006), Tier 1, Table 2-2, Energy industries, gas oil.
		1A1c	Oil and gas extraction	010504	3	IPCC (2006), Tier 1, Table 2-2, Energy industries, gas oil.
		1A2 a-f	Industry	03	0.2	IPCC (2006), Tier 3, Table 2-7, Industry, gas oil, boilers.
				Turbines	**r** 3	IPCC (2006), Tier 1, Table 2-3, Industry, gas oil.
				Engines	24	Nielsen et al. (2010)
		1A4a	Commercial/ Institutional	0201	0.7	IPCC (2006), Tier 3, Table 2-10, Commercial, gas oil.
				020105	24	Nielsen et al. (2010)
		1A4b i	Residential	0202	0.7	IPCC (2006), Tier 3, Table 2.9,

Fuel group	Fuel	CRF source category	CRF source category	SNAP	Emission factor, g per GJ	Reference
						Residential, gas oil.
		1A4c	Agriculture/ Forestry	0203	0.7	IPCC (2006), Tier 3, Table 2-10, Commercial, gas oil[1].
	KEROSENE	1A2 a-f	Industry	all	**r** 3	IPCC (2006), Tier 1, Table 2-3, Industry, other kerosene.
		1A4a	Commercial/ Institutional	0201	**r** 10	IPCC (2006), Tier 1, Table 2-4, Commercial, other kerosene.
		1A4b i	Residential	0202	**r** 10	IPCC (2006), Tier 1, Table 2-5, Residential/agricultural, other kerosene.
		1A4c i	Agriculture/ Forestry	0203	**r** 10	IPCC (2006), Tier 1, Table 2-5, Residential/agricultural, other kerosene.
	LPG	1A1a	Public electricity and heat production	0101 0102	**r** 1	IPCC (2006), Tier 1, Table 2-2, Energy Industries, LPG.
		1A1b	Petroleum refining	0103	**r** 1	IPCC (2006), Tier 1, Table 2-2, Energy Industries, LPG.
		1A2 a-f	Industry	03	**r** 1	IPCC (2006), Tier 1, Table 2-3, Industry, LPG
		1A4a	Commercial/ Institutional	0201	**r** 5	IPCC (2006), Tier 1, Table 2-4, Commercial, LPG.
		1A4b i	Residential	0202	**r** 5	IPCC (2006), Tier 1, Table 2-5, Residential / agricultural, LPG.
		1A4c i	Agriculture/ Forestry	0203	**r** 5	IPCC (2006), Tier 1, Table 2-5, Residential / agricultural, LPG.
	REFINERY GAS	1A1b	Petroleum refining	010304	1.7	Assumed equal to natural gas fuelled gas turbines. Nielsen et al. (2010)
				010306	1	IPCC (2006), Tier 1, Table 2-2, refinery gas.
GAS	NATURAL GAS	1A1a	Public electricity and heat production	010101 010102 010103	**r** 1	IPCC (2006), Tier 3, Table 2-6, Utility, natural gas, boilers.
				010104	1.7	Nielsen et al. (2010)
				010105	481	Nielsen et al. (2010)
				010202 010203	**r** 1	IPCC (2006), Tier 3, Table 2-6, Utility, natural gas, boilers.
		1A1c	Oil and gas extraction	010504	1.7	Nielsen et al. (2010)
		1A2 a-f	Industry	Other	**r** 1	IPCC (2006), Tier 3, Table 2-7, Industry, natural gas boilers.
				Gas turbines	1.7	Nielsen et al. (2010)
				Engines	481	Nielsen et al. (2010)
		1A4a	Commercial/ Institutional	0201	**r** 1	IPCC (2006), Tier 3, Table 2-10, Commercial, natural gas boilers.
				020105	481	Nielsen et al. (2010)
		1A4b i	Residential	0202	**r** 1	IPCC (2006), Tier 3, Table 2-9. Residential, natural gas boilers.
				020204	481	Nielsen et al. (2010)
		1A4c i	Agriculture/ Forestry	0203	**r** 1	IPCC (2006), Tier 3, Table 2-10, Commercial, natural gas boilers[1].
				020304	481	Nielsen et al. (2010)
WASTE	WASTE	1A1a	Public electricity and heat production	0101 0102	0.34	Nielsen et al. (2010)
		1A2a-f	Industry	03	30	IPCC (2006), Tier 1, Table 2-3, Industry, municipal wastes.
		1A4a	Commercial/ Institutional	0201	30	IPCC (2006), Tier 1, Table 2-3, Industry, municipal wastes [2].
	INDUSTRIAL WASTE	1A2f	Industry	0316	30	IPCC (2006), Tier 1, Table 2-3, Industry, industrial wastes.
BIO-MASS	WOOD	1A1a	Public electricity and heat production	0101	3.1	Nielsen et al. (2010)
				0102	**r** 11	IPCC (2006), Tier 3, Table 2-6, Utility boilers, wood
		1A2 a-f	Industry	03	**r** 11	IPCC (2006), Tier 3, Table 2-7, Industry, wood, boilers.

Fuel group	Fuel	CRF source category	CRF source category	SNAP	Emission factor, g per GJ	Reference
		1A4a	Commercial/ Institutional	0201	**r** 11	IPCC (2006), Tier 3, Table 2-10, Commercial, wood.
		1A4b i	Residential	0202	129.3	DCE estimate based on technology distribution [3]
		1A4c i	Agriculture/ Forestry	0203	**r** 11	IPCC (2006), Tier 3, Table 2-10, Commercial, wood.[1].
	STRAW	1A1a	Public electricity and heat production	0101	0.47	Nielsen et al. (2010)
				0102	30	IPCC (2006), Tier 1, Table 2-2, Energy industries, other primary solid biomass
		1A4b i	Residential	0202	300	IPCC (2006), Tier 1, Table 2-5, Residential, other primary solid biomass.
		1A4c i	Agriculture/ Forestry	020300	300	IPCC (2006), Tier 1, Table 2-5, Agriculture, other primary solid biomass.
				020302	30	IPCC (2006), Tier 1, Table 2-2, Energy industries, other primary solid biomass (large agricultural plants considered equal to this plant category)
	BIO OIL	1A1a	Public electricity and heat production	010102	**r** 3	IPCC (2006), Tier 1, Table 2-2, Energy industries, biodiesels.
				010105	24	Nielsen et al. (2010) assumed same emission factor as for gas oil fuelled engines.
				0102	**r** 3	IPCC (2006), Tier 1, Table 2-2, Energy industries, biodiesels.
		1A2 a-f	Industry	03	**r** 3	IPCC (2006), Tier 1, Table 2-3, Industry, biodiesels.
		1A4b i	Residential	0202	**r** 10	IPCC (2006), Tier 1, Table 2-5, Residential, biodiesels.
	BIOGAS	1A1a	Public electricity and heat production	0101	1	IPCC (2006), Tier 1, Table 2-2, Energy industries, other biogas.
				010105	434	Nielsen et al. (2010)
				0102	1	IPCC (2006), Tier 1, Table 2-2, Energy industries, other biogas.
		1A2 a-f	Industry	03	1	IPCC (2006), Tier 1, Table 2-3, Industry, other biogas.
				Engines	434	Nielsen et al. (2010)
		1A4a	Commercial/ Institutional	0201	5	IPCC (2006), Tier 1, Table 2-4, Commercial, other biogas.
				020105	434	Nielsen et al. (2010)
		1A4c i	Agriculture/ Forestry	0203	5	IPCC (2006), Tier 1, Table 2-5, Agriculture, other biogas.
				020304	434	Nielsen et al. (2010)
	BIO PROD GAS	1A1a	Public electricity and heat production	010105	13	Nielsen et al. (2010)
		1A4a	Commercial/Institutional	020105	13	Nielsen et al. (2010)

1) Assumed same emission factors as for commercial plants. Plant capacity and technology are similar for Danish plants.
2) Assumed same emission factor as for industrial plants. Plant capacity and technology is similar to industrial plants rather than to residential plants.
3) Aggregated emission factor based on the technology distribution in the sector (DEPA, 2013) and technology specific emission factors that refer to: Paulrud et al. (2005), Johansson et al. (2004) and Olsson & Kjällstrand (2005). The emission factor is within the IPCC (2006) interval for residential wood combustion (100-900 g/GJ).

CHP plants

A considerable part of the electricity production in Denmark is based on decentralised CHP plants, and well-documented emission factors for these plants are, therefore, of importance. In a project carried out for the electricity transmission company, Energinet.dk, emission factors for CHP plants <$25MW_e$ have been estimated. The work was reported in 2010 (Nielsen et al., 2010).

The work included waste incineration plants, CHP plants combusting wood and straw, natural gas and biogas-fuelled (reciprocating) engines, natural gas fuelled gas turbines, gas oil fuelled engines, gas oil fuelled gas turbines, steam turbines fuelled by residual oil and engines fuelled by biomass producer gas. CH_4 emission factors for these plants all refer to Nielsen et al. (2010). The estimated emission factors were based on existing emission measurements as well as on emission measurements carried out within the project. The number of emission data sets was comprehensive. Emission factors for subgroups of each plant type were estimated, e.g. the CH_4 emission factor for different gas engine types has been determined.

Time series for the CH_4 emission factors are based on a similar project estimating emission factors for year 2000 (Nielsen & Illerup, 2003).

Natural gas, gas engines

SNAP 010105, 030905, 030705, 031005, 031205, 031305, 031405, 031605, 032005, 020105, 020204 and 020304

The emission factor for natural gas engines refers to the Nielsen et al. (2010). The emission factor includes the increased emission during start/stop of the engines estimated by Nielsen et al. (2008). Emission factor time series for the years 1990-2007 have been estimated based on Nielsen & Illerup (2003). These three references are discussed below.

Nielsen et al. (2010):

> *CH_4 emission factors for gas engines were estimated for 2003-2006 and for 2007-2010. The dataset was split in two due to new emission limits for the engines from October 2006. The emission factors were based on emission measurements from 366 (2003-2006) and 157 (2007-2010) engines respectively. The engines from which emission measurements were available for 2007-2010 represented 38 % of the gas consumption. The emission factors were estimated based on fuel consumption for each gas engine type and the emission factor for each engine type. The majority of emission measurements that were not performed within the project related solely to the emission of total unburned hydrocarbon (CH_4 + NMVOC). A constant disaggregation factor was estimated based on 9 emission measurements including both CH_4 and NMVOC.*

Nielsen & Illerup (2003):

> *The emission factor for natural gas engines was based on 291 emission measurements in 114 different plants. The plants from which emission measurements were available represented 44 % of the total gas consumption in gas engines in year 2000.*

Nielsen et al. (2008):

> *This study calculated a start/stop correction factor. This factor was applied to the time series estimated in Nielsen & Illerup (2003). Further, the correction factors were applied in Nielsen et al. (2010).*

The emission factor for lean-burn gas engines is relatively high, especially for pre-chamber engines, which account for more than half the gas consumption in Danish gas engines. However, the emission factors for different pre-chamber engine types differ considerably.

The installation of natural gas engines in decentralised CHP plants in Denmark has taken place since 1990. The first engines installed were relatively small open-chamber engines but later mainly pre-chamber engines were installed. As mentioned above, pre-chamber engines have a higher emission factor than open-chamber engines; therefore, the emission factor has increased during the period 1990-1995. After that technical improvements of the engines have been implemented as a result of upcoming emission limits that most installed gas engines had to meet in late 2006 (DEPA, 2005).

The time series were based on:

- Full load emission factors for different engine types in year 2000 (Nielsen & Illerup, 2003), 2003-2006 and 2007-2010 (Nielsen et al., 2010).
- Data for year of installation for each engine and fuel consumption of each engine 1994-2002 from the Danish Energy Agency (DEA, 2003).
- Research concerning the CH_4 emission from gas engines carried out in 1997 (Nielsen & Wit, 1997).
- Correction factors including increased emission during start/stop of the engines (Nielsen et al., 2008).

Table 3.2.24 Time series for the CH_4 emission factor for natural gas fuelled engines.

Year	Emission factor, g per GJ
1990	266
1991	309
1992	359
1993	562
1994	623
1995	632
1996	616
1997	551
1998	542
1999	541
2000	537
2001	522
2002	508
2003	494
2004	479
2005	465
2006	473
2007-2013	481

Gas engines, biogas

SNAP 010105, 030905, 020105 and 020304

The emission factor for biogas engines was estimated to 434 g per GJ in 2013. The emission factor is lower than the factor for natural gas mainly because most biogas fuelled engines are lean-burn open-chamber engines - not pre-chamber engines.

Time series for the emission factor have been estimated. The emission factors for biogas engines were based on Nielsen et al. (2010) and Nielsen & Illerup (2003). The two references are discussed below. The time series are shown in Table 3.2.25.

Nielsen et al. (2010):

CH_4 emission factors for gas engines were estimated for 2006 based on emission measurements performed in 2003-2010. The emission factor was based on emission measurements from 10 engines. The engines from which emission measurements were available represented 8 % of the gas consumption. The emission factor was estimated based on fuel consumption for each gas engine type and the emission factor for each engine type. The majority of emission measurements that were not performed within the project related solely to the emission of total unburned hydrocarbon (CH_4 + NMVOC). A constant disaggregation factor was estimated based on 3 emission measurements including both CH_4 and NMVOC.

Nielsen & Illerup (2003):

The emission factor for natural gas engines was based on 18 emission measurements from 13 different engines. The engines from which emission measurements were available represented 18 % of the total biogas consumption in gas engines in year 2000.

Table 3.2.25 Time series for the CH_4 emission factor for biogas fuelled engines.

Year	Emission factor, g per GJ
1990	239
1991	251
1992	264
1993	276
1994	289
1995	301
1996	305
1997	310
1998	314
1999	318
2000	323
2001	342
2002	360
2003	379
2004	397
2005	416
2006	434
2007-2013	434

Gas turbines, natural gas

SNAP 010104, 010504, 030604 and 031104

The emission factor for gas turbines was estimated to be below 1.7 g per GJ in 2005 (Nielsen et al., 2010). The emission factor was based on emission measurements on five plants. The emission factor in year 2000 was 1.5 g per GJ (Nielsen & Illerup, 2003). A time series have been estimated.

CHP, wood

SNAP 010101, 010102, 010103 and 010104

The emission factor for CHP plants combusting wood was estimated to be below 3.1 g per GJ (Nielsen et al., 2010) and the emission factor 3.1 g per GJ has been applied for all years. The emission factor was based on emission measurements on two plants.

CHP, straw

SNAP 010101, 010102, 010103 and 010104

The emission factor for CHP plants combusting straw was estimated to be below 0.47 g per GJ (Nielsen et al., 2010) and the emission factor 0.47 g per GJ has been applied for all years. The emission factor was based on emission measurements on four plants.

CHP, waste

SNAP 010102, 010103, 010104 and 010203

The emission factor for CHP plants combusting waste was estimated to be below 0.34 g per GJ in 2006 (Nielsen et al., 2010) and 0.59 g per GJ in year 2000 (Nielsen & Illerup, 2003). A time series have been estimated. The emission factor was based on emission measurements on nine plants.

The emission factor has also been applied for district heating plants.

Residential wood combustion

SNAP 020200, 020202 and 020204

The emission factor for residential wood combustion is based on technology specific data. The emission factor time series is shown in Table 3.2.26.

Table 3.2.26 CH_4 emission factor time series for residential wood combustion.

Year	Emission factor, g per GJ
1990	316
1991	310
1992	304
1993	298
1994	291
1995	284
1996	274
1997	266
1998	256
1999	235
2000	222
2001	198
2002	189
2003	187
2004	184
2005	175
2006	165
2007	166
2008	157
2009	144
2010	137
2011	129
2012	123
2013	113

The emission factors for each technology and the corresponding reference are shown in Table 3.2.27. The emission factor time series are estimated based on time series (1990-2013) for wood consumption in each technology (DEPA, 2013). The time series for wood consumption in the ten different technologies are illustrated in Figure 3.2.38. The consumption in pellet boilers and new stoves has increased.

Table 3.2.27 Technology specific CH_4 emission factors for residential wood combustion.

Technology	Emission factor, g per GJ	Reference
Old stove	430	Methane emissions from residential biomass combustion, Paulrud et al. (2005) (SMED report, Sweden)
New stove	215	Assumed ½ the emission factor for old stoves.
Stove according to resent Danish legislation (2008)	125	Estimated based on the emission factor for new stoves and the emission factors for NMVOC.
Eco labelled stove	2	Low emissions from wood burning in an ecolabelled residential boiler. Olsson & Kjällstrand (2005).
Other stove	430	Assumed equal to old stove.
Old boilers with hot water storage	211	Methane emissions from residential biomass combustion, Paulrud et al., 2005 (SMED report, Sweden)
Old boilers without hot water storage	256	Methane emissions from residential biomass combustion, Paulrud et al., 2005 (SMED report, Sweden)
New boilers with hot water storage	50	Emission characteristics of modern and old-type residential boilers fired with wood logs and wood pellets. Johansson et al. (2004)
New boilers without hot water storage	50	Emission characteristics of modern and old-type residential boilers fired with wood logs and wood pellets. Johansson et al. (2004)
Pellet boilers/stoves	3	Methane emissions from residential biomass combustion, Paulrud et al., 2005 (SMED report, Sweden)

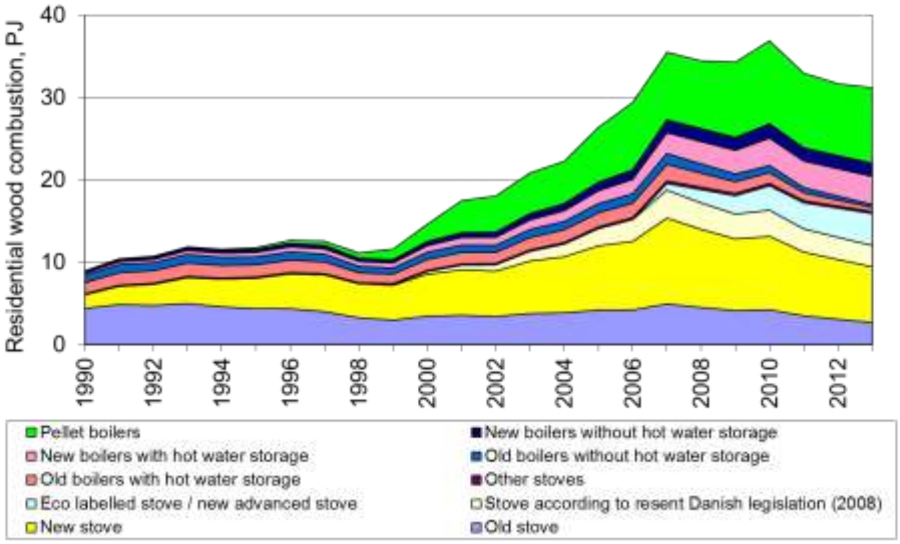


Figure 3.2.38 Technology specific wood consumption in residential plants.

Other stationary combustion plants

Emission factors for other plants refer to the IPCC Guidelines (IPCC, 2006).

N_2O emission factors

The N_2O emission factors applied for the 2013 inventory are listed in Table 3.2.28. Time series have been estimated for natural gas fuelled gas turbines and refinery gas fuelled turbines. All other emission factors have been applied unchanged for 1990-2013.

Emission factors for natural gas fuelled reciprocating engines, natural gas fuelled gas turbines, CHP plants < 300 MW combusting wood, straw or residual oil, waste incineration plants, engines fuelled by gas oil and gas engines fuelled by biomass producer gas all refer to emission measurements carried out on Danish plants, Nielsen et al. (2010).

The emission factor for coal-powered plants in public power plants refers to research conducted by Elsam (now part of DONG Energy).

The emission factor for off shore gas turbines has been assumed to follow the time series for natural gas fuelled gas turbines in Danish CHP plants. There is no evidence to suggest that off-shore gas turbines have different emission characteristics for N_2O compared to on-shore natural gas turbines and the emission factor is considered applicable[20].

The emission factor for natural gas fuelled gas turbines has been applied for refinery gas fuelled gas turbines. Refinery gas has similar properties as natural gas, i.e. similar nitrogen content in the fuel, which means that N_2O formation will be similar under similar combustion conditions.

All emission factors that are not nationally referenced refer to the IPCC Guidelines (IPCC, 2006).

[20] This information is related to a review comment.

Table 3.2.28 N_2O emission factors 2013.

Fuel group	Fuel	CRF source category	CRF source category	SNAP	Emission factor, g per GJ	Reference
SOLID	COAL	1A1a	Public electricity and heat production	0101	0.8	Elsam (2005)
				0102	1.4	IPCC (2006), Tier 3, Table 2.6, Utility source, pulverised bituminous coal, wet bottom boiler.
		1A2 a-f	Industry	03	1.5	IPCC (2006), Tier 1, Table 2-3, Manufacturing industries, coal
		1A4b i	Residential	0202	1.5	IPCC (2006), Tier 1, Table 2-5, Residential, coal
		1A4c i	Agriculture/ Forestry	0203	1.5	IPCC (2006), Tier 1, Table 2-4, Commercial, coal[1)]
	BROWN COAL BRI.	1A4b i	Residential	0202	1.5	IPCC (2006), Tier 1, Table 2-5, Residential, brown coal briquettes
	COKE OVEN COKE	1A2 a-f	Industry	03	1.5	IPCC (2006), Tier 1, Table 2-3, Industry, coke oven coke
		1A4b i	Residential	020200	1.5	IPCC (2006), Tier 1, Table 2-5, Residential, coke oven coke
	ANODIC CARBON	1A2 a-f	Industry	03	1.5	IPCC (2006), Tier 1, Table 2-3, manufacturing industries, other bituminous coal
LIQUID	PETROLEUM COKE	1A2a-f	Industry – other	03	0.6	IPCC (2006), Tier 1, Table 2-3, Industry, petroleum coke
	RESIDUAL OIL	1A1a	Public electricity and heat production	010101	0.3	IPCC (2006), Tier 3, Table 2-6, Utility, residual fuel oil
				010102 010103	5	Nielsen et al. (2010)
				010104	0.6	IPCC (2006), Tier 1, Table 2-2, Energy industries, residual fuel oil
				010203	0.3	IPCC (2006), Tier 3, Table 2-6, Utility, residual fuel oil
		1A1b	Petroleum refining	010306	0.6	IPCC (2006), Tier 1, Table 2-2, Energy industries, residual fuel oil
		1A2 a-f	Industry	03	5	Nielsen et al. (2010)
				Engines	0.6	IPCC (2006), Tier 1, Table 2-3, manufacturing industries and construction, residual fuel oil.
		1A4a	Commercial/ Institutional	0201	0.3	IPCC (2006), Tier 3, Table 2-10, Commercial, fuel oil boilers
		1A4b i	Residential	0202	0.6	IPCC (2006), Tier 1, Table 2-5, Residential, residual fuel oil
		1A4c i	Agriculture/ Forestry	0203	0.3	IPCC (2006), Tier 3, Table 2-10, Commercial, fuel oil boilers[1)]
	GAS OIL	1A1a	Public electricity and heat production	010101 010102 010103	0.4	IPCC (2006), Tier 3, Table 2-6, Utility, gas oil boilers
				010104	0.6	IPCC (2006), Tier 1, Table 2-2, Energy industries, gas oil
				010105	2.1	Nielsen et al. (2010)
				0102	0.4	IPCC (2006), Tier 3, Table 2-6, Utility, gas oil boilers
		1A1b	Petroleum refining	010306	0.6	IPCC (2006), Tier 1, Table 2-2, Energy industries, gas oil
		1A2 a-f	Industry	03	0.4	IPCC (2006), Tier 3, Table 2-7, Industry, gas oil boilers
				Turbines	0.6	IPCC (2006), Tier 1, Table 2-3, Industry, gas oil
				Engines	2.1	Nielsen et al. (2010)
		1A4a	Commercial/ Institutional	0201	0.4	IPCC (2006), Tier 3, Table 2-10, Commercial, gas oil boilers

Fuel group	Fuel	CRF source category	CRF source category	SNAP	Emission factor, g per GJ	Reference
				Engines	2.1	Nielsen et al. (2010)
		1A4b i	Residential	0202	0.6	IPCC (2006), Tier 1, Table 2-5, Residential, gas oil
		1A4c	Agriculture/ Forestry	0203	0.4	IPCC (2006), Tier 3, Table 2-10, Commercial, gas oil boilers[1)]
	KEROSENE	1A2 a-f	Industry	03	**r** 0.6	IPCC (2006), Tier 1, Table 2-3, Industry, other kerosene
		1A4a	Commercial/ Institutional	0201	**r** 0.6	IPCC (2006), Tier 1, Table 2-4, Commercial, other kerosene
		1A4b i	Residential	0202	**r** 0.6	IPCC (2006), Tier 1, Table 2-5, Residential, other kerosene
		1A4c i	Agriculture/ Forestry	0203	**r** 0.6	IPCC (2006), Tier 1, Table 2-4, Commercial, other kerosene [1)]
	LPG	1A1a	Public electricity and heat production	0101 0102	**r** 0.1	IPCC (2006), Tier 1, Table 2-2, Energy industries, LPG
		1A1b	Petroleum refining	010306	**r** 0.1	IPCC (2006), Tier 1, Table 2-2, Energy industries, LPG
		1A2 a-f	Industry	03	**r** 0.1	IPCC (2006), Tier 1, Table 2-3, Industry, LPG
		1A4a	Commercial/ Institutional	0201	**r** 0.1	IPCC (2006), Tier 1, Table 2-4, Commercial, LPG
		1A4b i	Residential	0202	**r** 0.1	IPCC (2006), Tier 1, Table 2-5, Residential, LPG
		1A4c i	Agriculture/ Forestry	0203	**r** 0.1	IPCC (2006), Tier 1, Table 2-5, Residential/Agricultural, LPG
	REFINERY GAS	1A1b	Petroleum refining	010304	1	Assumed equal to natural gas fuelled turbines. Based on Nielsen et al. (2010).
				010306	0.1	IPCC (2006), Tier 1, Table 2-2, Energy industries, refinery gas
GAS	NATURAL GAS	1A1a	Public electricity and heat production	010101 010102 010103	**r** 1	IPCC (2006), Tier 3, Table 2-6, Natural gas, Utility, boiler
				010104	1	Nielsen et al. (2010)
				010105	0.58	Nielsen et al. (2010)
				0102	**r** 1	IPCC (2006), Tier 3, Table 2-6, Natural gas, Utility, boiler
		1A1c	Oil and gas extraction	010504	1	Nielsen et al. (2010)
		1A2 a-f	Industry	03	**r** 1	IPCC (2006), Tier 3, Table 2-7, Industry, natural gas boilers
				Gas turbines	1	Nielsen et al. (2010)
				Engines	0.58	Nielsen et al. (2010)
		1A4a	Commercial/ Institutional	020100 020103	**r** 1	IPCC (2006), Tier 3, Table 2-10, Commercial, natural gas boilers
				Engines	0.58	Nielsen et al. (2010)
		1A4b i	Residential	0202	**r** 1	IPCC (2006), Tier 3, Table 2-9, Residential, natural gas boilers
				Engines	0.58	Nielsen et al. (2010)
		1A4c i	Agriculture/ Forestry	0203	**r** 1	IPCC (2006), Tier 3, Table 2-10, Commercial, natural gas boilers [1)]
				Engines	0.58	Nielsen et al. (2010)
WASTE	WASTE	1A1a	Public electricity and heat production	0101 0102	1.2	Nielsen et al. (2010)
		1A2 a-f	Industry	03	4	IPCC (2006), Tier 1, Table 2-3, Industry, wastes
		1A4a	Commercial/ Institutional	0201	4	IPCC (2006), Tier 1, Table 2-4, Commercial, municipal wastes
	INDUSTR. WASTE	1A2a-f	Industry	03	4	IPCC (2006), Tier 1, Table 2-3, Industry, industrial wastes

Fuel group	Fuel	CRF source category	CRF source category	SNAP	Emission factor, g per GJ	Reference
BIO-MASS	WOOD	1A1a	Public electricity and heat production	0101	0.8	Nielsen et al. (2010)
				0102	4	IPCC (2006), Tier 1, Table 2-2, Energy industries, wood
		1A2 a-f	Industry	03	4	IPCC (2006), Tier 1, Table 2-3, Industry, wood
		1A4a	Commercial/ Institutional	0201	4	IPCC (2006), Tier 1, Table 2-4, Commercial, wood
		1A4b i	Residential	0202	4	IPCC (2006), Tier 1, Table 2-5, Residential, wood
		1A4c i	Agriculture/ Forestry	0203	4	IPCC (2006), Tier 1, Table 2-5, Agriculture, wood
	STRAW	1A1a	Public electricity and heat production	0101	1.1	Nielsen et al. (2010)
				0102	4	IPCC (2006), Tier 1, Table 2-2, Energy industries, other primary solid biomass
		1A4b i	Residential	0202	4	IPCC (2006), Tier 1, Table 2-5, Residential, other primary solid biomass
		1A4c i	Agriculture/ Forestry	0203	4	IPCC (2006), Tier 1, Table 2-5, Agriculture, other primary solid biomass
	BIO OIL	1A1a	Public electricity and heat production	0101 0102	**r** 0.6	IPCC (2006), Tier 3, Table 2-2, Utility, biodiesels
				Engines	2.1	Assumed equal to gas oil. Based on Nielsen et al. (2010)
		1A2 a-f	Industry	03	**r** 0.6	IPCC (2006), Tier 1, Table 2-3, Industry, biodiesels
		1A4b i	Residential	0202	0.6	IPCC (2006), Tier 1, Table 2-5, Residential, biodiesels
	BIOGAS	1A1a	Public electricity and heat production	0101 0102	0.1	IPCC (2006), Tier 1, Table 2-2, Energy industries, other biogas
				Engines	1.6	Nielsen et al. (2010)
		1A2 a-f	Industry	03	0.1	IPCC (2006), Tier 1, Table 2-3, Industry, other biogas
				Engines	1.6	Nielsen et al. (2010)
		1A4a	Commercial/ Institutional	0201	0.1	IPCC (2006), Tier 1, Table 2,4, Commercial, other biogas
				Engines	1.6	Nielsen et al. (2010)
		1A4c i	Agriculture/ Forestry	0203	0.1	IPCC (2006), Tier 1, Table 2-5, Agriculture, other biogas
				Engines	1.6	Nielsen et al. (2010)
	BIO PROD GAS	1A1a	Public electricity and heat production	010105	2.7	Nielsen et al. (2010)
		1A4a	Commercial/ Institutional	020105	2.7	Nielsen et al. (2010)

1) In Denmark, plants in Agriculture/Forestry are similar to Commercial plants.

3.2.6 Uncertainty

Uncertainty estimates include uncertainty with regard to the total emission inventory as well as uncertainty with regard to trends.

Methodology

The uncertainty for greenhouse gas emissions have been estimated according to the IPCC Guidelines (IPCC, 2006). The uncertainty has been estimated by two approaches; tier 1 and tier 2. Both approaches are further described in Chapter 1.7.

The **tier 1** approach is based on a normal distribution and a confidence interval of 95 %.

The input data for the tier 1 approach are:

- Emission data for the base year and the latest year.
- Uncertainties for emission factors
- Uncertainty for fuel consumption rates.

The **tier 2** approach is a Monte Carlo approach based on a lognormal distribution. The input data for the model is also based on 95 % confidence interval. The input data for the tier 2 approach are:

- Fuel consumption data for the base year and the latest year.
- Emission factors or implied emission factors (IEF) for the base year and the latest year
- Uncertainties for emission factors for the base year and the latest year. If the same uncertainty is applied for both years, the data can be indicated as statistically dependent or independent.
- Uncertainties for fuel consumption rates in the base year and the latest year. If the same uncertainty is applied for both years, the data can be indicated as statistically dependent or independent.

The same emission source categories and emission data have been applied for both approaches. The emission source categories applied are listed in Table 3.2.29.

<u>Source categories</u>

Due to large differences in data uncertainty some emission source categories have been further disaggregated than suggested in the IPCC Guidelines (2006):

- For five different fuels, CO_2 emissions based on ETS data and on non-ETS data have been considered two different emission sources.
- CH_4 emission from natural gas fuelled engines
- CH_4 emission from biogas fuelled engines
- CH_4 emission from residential wood combustion
- CH_4 emission from residential and agricultural combustion of straw
- N_2O emission from residential wood combustion
- N_2O emission from residential and agricultural combustion of straw

The separate uncertainty estimation for gas engine CH_4 emission and CH_4 emission from other plants is applied, because in Denmark, the CH_4 emission from gas engines is much larger than the emission from other stationary combustion plants, and the CH_4 emission factor for gas engines is estimated with a much smaller uncertainty level than for other stationary combustion plants.

In general, the same uncertainty levels have been applied for both approaches. However, the tier 2 approach allows different uncertainty levels for 1990 and 2013. The 2013 uncertainty levels have been applied in the tier 1 approach.

<u>Fuel</u>

The uncertainty of the fuel consumption data has in general been assumed to be statistically independent. However, a considerable part of the residential wood consumption is non-traded and the uncertainty of wood applied residential plants has been assumed statistically dependent. Fuel consumption data are also considered statistically dependent for residential/agricultural straw combustion.

Table 3.2.29 Uncertainties for fuel consumption, 1990 and 2013.

IPCC Source category	1990	2013	Reference
1A1, 1A2, 1A4 St. comb. Coal, ETS data, CO_2	0.5%	0.5%	ETS data
1A1, 1A2, 1A4 St. comb. Coal, no ETS data, CO_2	0.9%	1.0%	Estimated based on IPCC (2006) values.
1A1, 1A2, 1A4 St. comb., BKB, CO_2	2.9%	3.0%	Estimated based on IPCC (2006) values.
1A1, 1A2, 1A4 St. comb., Coke oven coke, CO_2	1.8%	1.7%	Estimated based on IPCC (2006) values.
1A1, 1A2, 1A4 St. comb., Fossil waste, ETS data, CO_2	2%	2%	DCE assumption
1A1, 1A2, 1A4 St. comb., Fossil waste, no ETS data, CO_2	10%	5%	DCE assumption
1A1, 1A2, 1A4 St. comb., Petroleum coke, ETS data, CO_2	0.5%	0.5%	ETS data
1A1, 1A2, 1A4 St. comb., Petroleum coke, no ETS data, CO_2	1.7%	2.0%	Estimated based on IPCC (2006) values.
1A1, 1A2, 1A4 St. comb., Residual oil, ETS data, CO_2	0.5%	0.5%	ETS data
1A1, 1A2, 1A4 St. comb., Residual oil, no ETS data, CO_2	1.2%	1.4%	Estimated based on IPCC (2006) values.
1A1, 1A2, 1A4 St. comb., Gas oil, CO_2	2.9%	2.4%	Estimated based on IPCC (2006) values.
1A1, 1A2, 1A4 St. comb., Kerosene, CO_2	2.9%	2.8%	Estimated based on IPCC (2006) values.
1A1, 1A2, 1A4 St. comb., LPG, CO_2	1.7%	2.5%	Estimated based on IPCC (2006) values.
1A1b,St. comb., Refinery gas, CO_2	1.0%	1.0%	Estimated based on IPCC (2006) values.
1A1, 1A2, 1A4, Stationary combustion, Natural gas, onshore, CO_2	1.4%	1.2%	Estimated based on IPCC (2006) values. Offshore gas turbines not included in this category.
1A1c Off shore gas turbines, Natural gas, CO_2	1.0%	0.5%	ETS data for 2013, IPCC (2006) for 1990.
1A1, Stationary Combustion, SOLID, CH_4	1.0%	1.0%	IPCC (2006), less than 1%
1A1, Stationary Combustion, LIQUID, CH_4	1.0%	1.0%	IPCC (2006), less than 1%
1A1, Stationary Combustion, not engines, GAS, CH_4	1.0%	1.0%	IPCC (2006), less than 1%
1A1, Stationary Combustion, WASTE, CH_4	5.0%	3.0%	DCE assumption. The uncertainty for the total consumption of waste is lower than the uncertainty for the fossil part.
1A1, Stationary Combustion, not engines, BIOMASS, CH_4	5.0%	3.0%	DCE assumption
1A2, Stationary Combustion, SOLID, CH_4	2.0%	2.0%	IPCC (2006)
1A2, Stationary Combustion, LIQUID, CH_4	2.0%	2.0%	IPCC (2006)
1A2, Stationary Combustion, not engines, GAS, CH_4	2.0%	2.0%	IPCC (2006)
1A2, Stationary Combustion, WASTE, CH_4	5.0%	3.0%	DCE assumption. The uncertainty for the total consumption of waste is lower than the uncertainty for the fossil part.
1A2, Stationary Combustion, not engines, BIOMASS, CH_4	10.0%	10.0%	IPCC (2006)
1A4, Stationary Combustion, SOLID, CH_4	3.0%	3.0%	IPCC (2006)
1A4, Stationary Combustion, LIQUID, CH_4	3.0%	3.0%	IPCC (2006)
1A4, Stationary Combustion, not engines, GAS, CH_4	3.0%	3.0%	IPCC (2006)
1A4, Stationary Combustion, WASTE, CH_4	5.0%	3.0%	DCE assumption. The uncertainty for the total consumption of waste is lower than the uncertainty for the fossil part.
1A4, Stationary Combustion, not engines, not residential wood and not residential/agricultural straw, BIOMASS, CH_4	10.0%	10.0%	IPCC (2006)
1A4, Stationary Combustion, Residential wood combustion, CH_4	20.0%	20.0%	DCE assumption
1A4, Stationary Combustion, Residential and agricultural straw combustion, CH_4	15.0%	15.0%	DCE assumption
1A1, 1A2, 1A4 Natural gas fuelled engines, GAS, CH_4	1.0%	1.0%	Lindgren (2010)
1A1, 1A2, 1A4 Biogas fuelled engines, GAS, CH_4	3.0%	3.0%	DCE assumption
1A1, Stationary Combustion, SOLID, N_2O	1.0%	1.0%	IPCC (2006), less than 1%
1A1, Stationary Combustion, LIQUID, N_2O	1.0%	1.0%	IPCC (2006), less than 1%
1A1, Stationary Combustion, GAS, N_2O	1.0%	1.0%	IPCC (2006), less than 1%
1A1, Stationary Combustion, WASTE, N_2O	5.0%	3.0%	DCE assumption
1A1, Stationary Combustion, BIOMASS, N_2O	5.0%	3.0%	DCE assumption
1A2, Stationary Combustion, SOLID, N_2O	2.0%	2.0%	IPCC (2006)
1A2, Stationary Combustion, LIQUID, N_2O	2.0%	2.0%	IPCC (2006)
1A2, Stationary Combustion, GAS, N_2O	2.0%	2.0%	IPCC (2006)
1A2, Stationary Combustion, WASTE, N_2O	5.0%	3.0%	DCE assumption
1A2, Stationary Combustion, BIOMASS, N_2O	10.0%	10.0%	IPCC (2006)
1A4, Stationary Combustion, SOLID, N_2O	3.0%	3.0%	IPCC (2006)
1A4, Stationary Combustion, LIQUID, N_2O	3.0%	3.0%	IPCC (2006)
1A4, Stationary Combustion, GAS, N_2O	3.0%	3.0%	IPCC (2006)
1A4, Stationary Combustion, WASTE, N_2O	5.0%	3.0%	DCE assumption
1A4, Stationary Combustion, not residential wood and not residential/agricultural straw, BIOMASS, N_2O	10.0%	10.0%	IPCC (2006)
1A4b, Stationary Combustion, Residential wood combustion, N_2O	20.0%	20.0%	DCE assumption
1A4b/c, Stationary Combustion, Residential and agricultural straw combustion, N_2O	15.0%	15.0%	DCE assumption

Emission factors

Uncertainties for emission factors are shown in Table 3.2.30.

The CO_2 emission factor for the fossil part of waste is less uncertain for 2013 than for 1990.

The uncertainty of the CH_4 emission factors for gas engines have been assumed higher in 1990 than in 2013 due to the emission measurement programmes on which the emission factors in later years are based.

Table 3.2.30 Uncertainties for emission factors, 1990 and 2013.

IPCC Source category	1990	2013	Reference
1A1, 1A2, 1A4 St. comb. Coal, ETS data, CO_2	0.3%	0.3%	ETS data, 2013 estimate
1A1, 1A2, 1A4 St. comb. Coal, no ETS data, CO_2	2.0%	1.0%	DCE assumption
1A1, 1A2, 1A4 St. comb., BKB, CO_2	5.0%	5.0%	IPCC (2000), chapter 2.1.1.6.
1A1, 1A2, 1A4 St. comb., Coke oven coke, CO_2	5.0%	5.0%	IPCC (2000), chapter 2.1.1.6.
1A1, 1A2, 1A4 St. comb., Fossil waste, ETS data, CO_2	5.0%	5.0%	ETS data, DCE estimate based on Astrup et al. (2012).
1A1, 1A2, 1A4 St. comb., Fossil waste, no ETS data, CO_2	20.0%	10.0%	Non-ETS data, DCE estimate based on Astrup et al. (2012).
1A1, 1A2, 1A4 St. comb., Petroleum coke, ETS data, CO_2	0.5%	0.5%	ETS data, 2013 estimate
1A1, 1A2, 1A4 St. comb., Petroleum coke, no ETS data, CO_2	5.0%	5.0%	IPCC (2000), chapter 2.1.1.6.
1A1, 1A2, 1A4 St. comb., Residual oil, ETS data, CO_2	0.5%	0.5%	ETS data, 2013 estimate
1A1, 1A2, 1A4 St. comb., Residual oil, no ETS data, CO_2	2.0%	2.0%	Jensen & Lindroth (2002).
1A1, 1A2, 1A4 St. comb., Gas oil, CO_2	1.5%	1.5%	Based on interval in IPCC (2006).
1A1, 1A2, 1A4 St. comb., Kerosene, CO_2	3.0%	3.0%	Based on interval in IPCC (2006).
1A1, 1A2, 1A4 St. comb., LPG, CO_2	4.0%	4.0%	Based on interval in IPCC (2006).
1A1b,St. comb., Refinery gas, CO_2	5.0%	2.0%	1990: IPCC (2000), chapter 2.1.1.6. 2013: DCE assumption based on the fact that data are based on EU ETS data
1A1, 1A2, 1A4, Stationary combustion, Natural gas, onshore, CO_2	0.4%	0.4%	Lindgren (2010). Personal communication.
1A1c Off shore gas turbines, Natural gas, CO_2	1.0%	0.5%	ETS data for 2013, but not for 1990
1A1, Stationary Combustion, SOLID, CH_4	100%	100%	Based on interval in IPCC (2006), table 2.12
1A1, Stationary Combustion, LIQUID, CH_4	100%	100%	Based on interval in IPCC (2006), table 2.12
1A1, Stationary Combustion, not engines, GAS, CH_4	100%	100%	Based on interval in IPCC (2006), table 2.12
1A1, Stationary Combustion, WASTE, CH_4	100%	100%	Based on interval in IPCC (2006), table 2.12
1A1, Stationary Combustion, not engines, BIOMASS, CH_4	100%	100%	Based on interval in IPCC (2006), table 2.12
1A2, Stationary Combustion, SOLID, CH_4	100%	100%	Based on interval in IPCC (2006), table 2.12
1A2, Stationary Combustion, LIQUID, CH_4	100%	100%	Based on interval in IPCC (2006), table 2.12
1A2, Stationary Combustion, not engines, GAS, CH_4	100%	100%	Based on interval in IPCC (2006), table 2.12
1A2, Stationary Combustion, WASTE, CH_4	100%	100%	Based on interval in IPCC (2006), table 2.12
1A2, Stationary Combustion, not engines, BIOMASS, CH_4	100%	100%	Based on interval in IPCC (2006), table 2.12
1A4, Stationary Combustion, SOLID, CH_4	100%	100%	Based on interval in IPCC (2006), table 2.12
1A4, Stationary Combustion, LIQUID, CH_4	100%	100%	Based on interval in IPCC (2006), table 2.12
1A4, Stationary Combustion, not engines, GAS, CH_4	100%	100%	Based on interval in IPCC (2006), table 2.12
1A4, Stationary Combustion, WASTE, CH_4	100%	100%	Based on interval in IPCC (2006), table 2.12
1A4, Stationary Combustion, not engines, not residential wood and not residential/agricultural straw, BIOMASS, CH_4	100%	100%	Based on interval in IPCC (2006), table 2.12
1A4, Stationary Combustion, Residential wood combustion, CH_4	150%	150%	Upper value in IPCC (2006), table 2.12.
1A4, Stationary Combustion, Residential and agricultural straw combustion, CH_4	150%	150%	Upper value in IPCC (2006), table 2.12.
1A1, 1A2, 1A4 Natural gas fuelled engines, GAS, CH_4	10%	2%	1990: DCE estimate based on Nielsen et al. (2010). 2013: Jørgensen et al. (2010). Uncertainty data for NMVOC + CH_4.
1A1, 1A2, 1A4 Biogas fuelled engines, GAS, CH_4	20%	10%	DCE estimate based on Nielsen et al. (2010).
1A1, Stationary Combustion, SOLID, N_2O	400%[1)]	400%[1)]	DCE, rough estimate based on a default value of 400 % when the emission factor is based on emission measurements from plants in Denmark.
1A1, Stationary Combustion, LIQUID, N_2O	1000%[1)]	1000%[1)]	IPCC (2000) [13)]
1A1, Stationary Combustion, GAS, N_2O	750%[1)]	750%[1)]	DCE, rough estimate based on a default value of 400 % when the emission factor is based on emission measurements from plants in Denmark and 1000 % if not.
1A1, Stationary Combustion, WASTE, N_2O	400%[1)]	400%[1)]	DCE, rough estimate based on a default value of 400 % when the emission factor is based on emission measurements from plants in Denmark.
1A1, Stationary Combustion, BIOMASS, N_2O	400%[1)]	400%[1)]	DCE, rough estimate based on a default value of 400 % when the emission factor is based on emission measurements from plants in Denmark.
1A2, Stationary Combustion, SOLID, N_2O	400%[1)]	400%[1)]	DCE, rough estimate based on a default value of 400 % when the emission factor is based on emission measurements from plants in Denmark.
1A2, Stationary Combustion, LIQUID, N_2O	1000%[1)]	1000%[1)]	IPCC (2000) [13)]
1A2, Stationary Combustion, GAS, N_2O	750%[1)]	750%[1)]	DCE, rough estimate based on a default value of 400 % when the emission factor is based on emission measurements from plants in Denmark and 1000 % if not.
1A2, Stationary Combustion, WASTE, N_2O	400%[1)]	400%[1)]	DCE, rough estimate based on a default value of 400 % when the emission factor is based on emission measurements from plants in Denmark.

Continued			
1A2, Stationary Combustion, BIOMASS, N_2O	400%[1)]	400%[1)]	DCE, rough estimate based on a default value of 400 % when the emission factor is based on emission measurements from plants in Denmark.
1A4, Stationary Combustion, SOLID, N_2O	400%[1)]	400%[1)]	DCE, rough estimate based on a default value of 400 % when the emission factor is based on emission measurements from plants in Denmark.
1A4, Stationary Combustion, LIQUID, N_2O	1000%[1)]	1000%[1)]	IPCC (2000) [13)]
1A4, Stationary Combustion, GAS, N_2O	750%[1)]	750%[1)]	DCE, rough estimate based on a default value of 400 % when the emission factor is based on emission measurements from plants in Denmark and 1000 % if not.
1A4, Stationary Combustion, WASTE, N_2O	400%[1)]	400%[1)]	DCE, rough estimate based on a default value of 400 % when the emission factor is based on emission measurements from plants in Denmark.
1A4, Stationary Combustion, not residential wood and not residential/agricultural straw, BIOMASS, N_2O	400%[1)]	400%[1)]	DCE, rough estimate based on a default value of 400 % when the emission factor is based on emission measurements from plants in Denmark.
1A4b, Stationary Combustion, Residential wood combustion, N_2O	500%[1)]	500%[1)]	DCE estimate.
1A4b/c, Stationary Combustion, Residential and agricultural straw combustion, N_2O	500%[1)]	500%[1)]	DCE estimate.

1) With a truncation of twice the uncertainty rate. The truncation is relevant for the very large uncertainty rates for N_2O emission factors due to the log-normal distribution applied in the tier 2 model.

Results

The tier 1 uncertainty estimates for stationary combustion emission inventories are shown in Table 3.2.31. Detailed calculation sheets are provided in Annex 3A-7.

The tier 2 uncertainty estimates are shown in Table 3.2.32 and detailed results are provided in Annex 3A-7.

The tier 1 uncertainty interval for greenhouse gas is estimated to be ±1.5 % and trend in greenhouse gas emission is -33.1 % ± 0.9 %-age points. The main sources of uncertainty for greenhouse gas emission 2013 are the N_2O and CH_4 emission from residential wood combustion, and N_2O emission from of biomass and gaseous fuels applied in energy industries (1A1). The main sources of uncertainty in the trend in greenhouse gas emission are the CO_2 emission from coal and natural gas, N_2O emission from residential wood combustion and N_2O emissions from liquid fuels combusted in the industrial sector.

The tier 2 approach points out N_2O and CH_4 emissions from residential wood combustion and N_2O emission from combustion of biomass in energy industries as the main contributors to the total uncertainty for greenhouse gas emission from stationary combustion.

Table 3.2.31 Danish uncertainty estimates, tier 1 approach, 2013.

Pollutant	Uncertainty Total emission, %	Trend 1990-2013, %	Uncertainty trend, %-age points
GHG	±1.5	-33.1	±0.9
CO_2	±0.6	-33.8	±0.6
CH_4	±48	+78	±78
N_2O	±173	+9	±188

Table 3.2.32 Danish uncertainty estimates, tier 2 approach, 2013.

Pollutant	Uncertainty of total emission, %		Trend 1990-2013, %	Uncertainty of trend, %-age points	
GHG	-1.1%	+2.7%	-32.9%	-1.8%	+1.7%
CO_2	-0.6%	+1.1%	-34%	-2%	+2%
CH_4	-28%	+154%	+68%	-112%	+140%
N_2O	-57%	+376%	+4.1%	-103%	+94%

The results are illustrated and compared in figure 3.2.39. The uncertainties are in the same level for each pollutant. The emission data shown for the tier 1 approach are the CRF emission data. The tier 2 emission levels are median values based on the Monte Carlo approach.

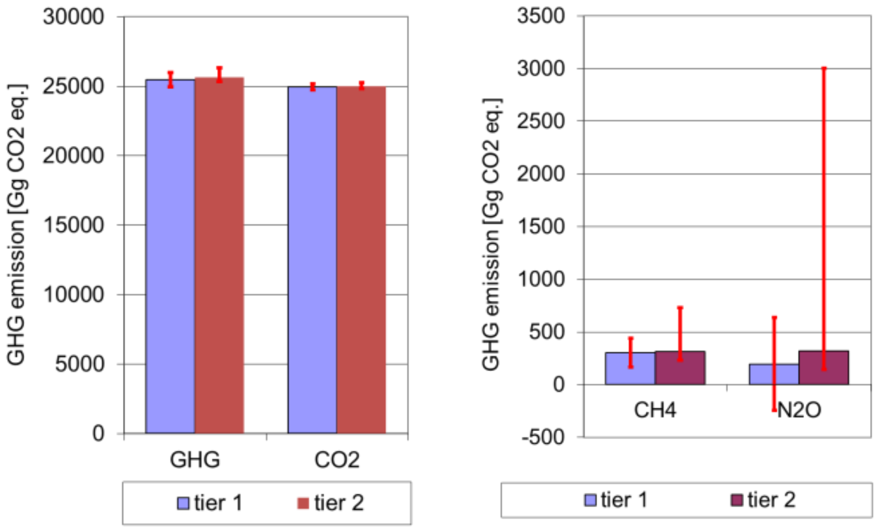


Figure 3.2.39 Uncertainty level, the two approaches are compared for 2013.

3.2.7 Source specific QA/QC and verification

An updated quality manual for the Danish emission inventories has been published in 2013 (Nielsen et al., 2013). The quality manual describes the concepts of quality work and definitions of sufficient quality, critical control points and a list of Point for Measuring (PM).

Documentation concerning verification of the Danish GHG emission inventories has been published by (Fauser et al., 2013). In addition, the IPCC reference approach for CO_2 emission is an important verification of the CO_2 emission from the energy sector. The reference approach for the energy sector is shown in Chapter 3.4.

Information on the Danish QA/QC plan is included in Chapter 1.6. Source specific QA/QC and PM's are shown below.

National external review

The 2004, 2006, 2009 and 2014 updates of the sector report for stationary combustion has been reviewed by external experts (Nielsen & Illerup, 2004; Nielsen & Illerup, 2006; Nielsen et al., 2009, Nielsen et al., 2014). The national external review forms a vital part of the QA activities for stationary combustion.

The 2004, 2006, 2009 and 2014 updates of this report were reviewed by Jan Erik Johnsson from the Technical University of Denmark, Bo Sander from Elsam Engineering, Annemette Geertinger from FORCE Technology and Vibeke Vestergaard Nielsen, AU DCE.

Data storage, level 1

Table 3.2.33 lists the sector specific PM's for data storage level 1.

Table 3.2.33 List of PM, data storage level 1.

Level	CCP	Id	Description	Sectoral/general	Stationary combustion
Data Storage level 1	1. Accuracy	DS.1.1.1	General level of uncertainty for every data-set including the reasoning for the specific values.	Sectoral	Uncertainties are estimated and references given in NIR chapter 3.2.6.
	2. Comparability	DS1.2.1	Comparability of the emission factors / calculation parameters with data from international guidelines, and evaluation of major discrepancies.	Sectoral	In general, if national referenced emission factors differ considerably from IPCC Guideline/EEA Guidebook values this is discussed in NIR chapter 3.2.5. This documentation is improved annually based on reviews. At CRF level, a project has been carried out comparing the Danish inventories with those of other countries (Fauser et al., 2013).
	3.Completeness	DS.1.3.1	Ensuring that the best possible national data for all sources are included, by setting down the reasoning behind the selection of datasets.	Sectoral	A list of external data are shown and discussed below.
	4.Consistency	DS.1.4.1	The original external data has to be archived with proper reference.	Sectoral	It is ensured that all external data are archived at DCE. Subsequent data processing takes place in other spreadsheets or databases. The datasets are archived annually in order to ensure that the basic data for a given report are always available in their original form.
	6.Robustness	DS.1.6.1	Explicit agreements between the external institution holding the data and DCE about the conditions of delivery	Sectoral	For stationary combustion, a data delivery agreement is made with the DEA. NERI (now DCE) and DEA have renewed the data delivery agreement in 2014. Most of the other external data sources are available due to legislation. See Table 3.2.34.
	7.Transparency	DS.1.7.1	Listing of all archived datasets and external contacts.	Sectoral	A list of external datasets and external contacts is shown in Table 3.2.34 below.

Table 3.2.34 List of external data sources.

Dataset	Description	Activity data or emission factor	Reference	Contact(s)	Data agreement/ Comment
Energiproducenttællingen.xls	Data set for all electricity and heat producing plants.	Activity data	The Danish Energy Agency (DEA)	Kaj Stærkind	Data agreement 2014.
Gas consumption for gas engines and gas turbines 1990-1994	Historical data set for gas engines and gas turbines.	Activity data	The Danish Energy Agency (DEA)	Kaj Stærkind	No data agreement. Historical data
Basic data (Grunddata.xls)	The Danish energy statistics. Data set applied for both the reference approach and the national approach.	Activity data	The Danish Energy Agency (DEA)	Jane Rusbjerg	Data agreement 2014. However, the data set is also published as part of national energy statistics.
Energy statistics for industrial subsectors	Disaggregation of the industrial fuel consumption.	Activity data	The Danish Energy Agency (DEA)	Jane Rusbjerg	Included in data delivery agreement 2014.
SO_2 & NO_x data, plants>25 MW_e	Annual emission data for all power plants > 25 MW_e. Includes information on methodology: measurements or emission factor.	Emissions	Energinet.dk	Christian F.B. Nielsen	No data agreement.
Emission factors	Emission factors refer to a large number of sources.	Emission factors	See chapter regarding emission factors		Some of the annually updated CO_2 emission factors are based on EU ETS data, see below. For other emission factors no formal data delivery agreement.
Annual environmental reports / environmental data	Emissions from plants defined as large point sources	Emissions	Various plants		No data agreement necessary. Plants are obligated by law to report data (DEPA 2010) and data are published on the Danish EPA homepage.
EU ETS data	Plant specific CO_2 emission factors	Emission factors and fuel consumption	The Danish Energy Agency (DEA)	Dorte Maimann Helen Falster	Plants are obligated by law. The availability of detailed information is part of the data agreement with DEA (2014 update).

Energiproducenttaellingen - statistic on fuel consumption from district heating and power plants (DEA)

The data set includes all plants producing power or district heating. The spreadsheet from DEA is listing fuel consumption of all plants included as large point sources in the emission inventory. The statistic on fuel consumption from district heating and power plants is regarded as complete and with no significant uncertainty since the plants are bound by law to report their fuel consumption and other information.

Gas consumption for gas engines and gas turbines 1990-1994 (DEA)

For the years 1990-1994, DEA has estimated consumption of natural gas and biogas in gas engines and gas turbines (DEA, 2003). Estimated fuel consumption data for 1990-1993 was based on engine specific data for year of installation and for fuel consumption in 1994. DCE assesses that the DEA estimate is the best available data.

Basic data (DEA)

The Danish energy statistics. The spreadsheet from DEA is used for the CO_2 emission calculation in accordance with the IPCC reference approach and is also the first data set applied in the national approach. The data set is included in the data delivery agreement with DEA, but it is also published annually on DEA's homepage.

Energy statistics for industrial subsectors (DEA)

The data includes disaggregation of the fuel consumption for industrial plants. The data set is estimated for the reporting to Eurostat. The data are included in the 2014 update of the agreement with DEA.

SO_2 and NO_x emission data from electricity producing plants > 25MW$_e$ (Energinet.dk)

Plants larger than 25 MW$_e$ are obligated to report emission data for SO_2 and NO_x to the DEA annually. Data are collected by Energinet.dk and forwarded to DEA. Data are on production unit level and classified. The data on plant level are part of the plants annually environmental reports. DCE's QC of the data consists of a comparison with data from previous years and with data from the plants' annual environmental reports.

Emission factors

For specific references, see the Chapter 3.2.5 regarding emission factors. Some of the annually updated CO_2 emission factors are based on EU ETS data, se below.

Annual environmental reports (DEPA)

A large number of plants are obligated by law to report annual environmental data including emission data. DCE compares the data with those from previous years and large discrepancies are checked.

EU ETS data (DEA)

EU ETS data includes information on fuel consumption, heating values, carbon content of fuel, oxidation factor and CO_2 emissions. DCE receives the verified reports for all plants which utilises a detailed estimation methodology. DCE's QC of the received data consists of comparing to calculation using standard emission factors as well as comparing reported values with those for previous years. The data set is included in the 2014 update of the agreement with DEA.

Data processing, level 1

Table 3.2.35 lists the sector specific PM's for data processing level 1.

Table 3.2.35 List of PM, data processing level 1.

Level	CCP	Id	Description	Sectoral / general	Stationary combustion
Data Processing level 1	1. Accuracy	DP.1.1.1	Uncertainty assessment for every data source not part of DS.1.1.1 as input to Data Storage level 2 in relation to type and scale of variability.	Sectoral	Uncertainties are estimated and references given in NIR chapter 3.2.6.
	2.Comparability	DP.1.2.1	The methodologies have to follow the international guidelines suggested by UNFCCC and IPCC.	Sectoral	The methodological approach is consistent with international guidelines. An overview of tiers is given in NIR Chapter 3.2.5
	3.Completeness	DP.1.3.1	Identification of data gaps with regard to data sources that could improve quantitative knowledge.	Sectoral	The energy statistics is considered complete.
	4.Consistency	DP.1.4.1	Documentation and reasoning of methodological changes during the time series and the qualitative assessment of the impact on time series consistency.	Sectoral	The two main methodological changes in the time series; implementation of Energiproducenttaellingen (plant specific fuel consumption data) from 1994 onwards and implementation of EU ETS data from 2006 onwards is discussed in NIR chapter 3.2.5.
	5.Correctness	DP.1.5.2	Verification of calculation results using time series	Sectoral	Time series for activity data on SNAP and CRF source category level are used to identify possible errors. Time series for emission factors and the emission from CRF subcategories are also examined.
		DP.1.5.3	Verification of calculation results using other measures	Sectoral	The IPCC reference approach validates the fuel consumption rates and CO_2 emission. Both differ less than 2.0 % (1990-2013). The reference approach is further discussed in NIR Chapter 3.4.
	7.Transparency	DP.1.7.1	The calculation principle, the equations used and the assumptions made must be described.	Sectoral	This is included in NIR chapter 3.2.5.
		DP.1.7.2	Clear reference to dataset at Data Storage level 1	Sectoral	This is included in NIR chapter 3.2.5.
		DP.1.7.3	A manual log to collect information about recalculations.	Sectoral	-

Data storage, level 2

Table 3.2.36 lists the sector specific PM's for data storage level 2.

Table 3.2.36 List of PM, data storage level 2.

Level	**CCP**	**Id**	**Description**	**Sectoral / general**	**Stationary combustion**
Data Storage level 2	5.Correctness	DS.2.5.1	Check if a correct data import to level 2 has been made	Sectoral	To ensure a correct connection between data on level 2 and level 1, different controls are in place, e.g. control of sums and random tests.

Data storage level 4

Table 3.2.37 lists the sector specific PM's for data storage level 4.

Table 3.2.37 List of PM, data storage level 4.

Level	**CCP**	**Id**	**Description**	**Sectoral / general**	**Stationary combustion**
Data Storage level 4	4. Consistency	DS.4.4.3	The IEFs from the CRF are checked both regarding level and trend. The level is compared to relevant emission factors to ensure correctness. Large dips/jumps in the time series are explained.	Sectoral	Large dips/jumps in time series are discussed and explained in NIR chapter 3.2.3 and 3.2.4.

Other QC procedures

Some automated checks have been prepared for the emission databases:

- Check of units for fuel rate, emission factors and plant-specific emissions.
- Check of emission factors for large point sources. Emission factors for pollutants that are not plant-specific should be the same as those defined for area sources.
- Additional checks on database consistency.
- Emission factor references are included in this report (Chapter 3.2.5 and Appendix 3A-4).
- Annual environmental reports are kept for subsequent control of plant-specific emission data.
- QC checks of the country-specific emission factors have not been performed, but most factors are based on input from companies that have implemented some QA/QC work. The major power plant owner/operators in Denmark, DONG Energy and Vattenfall have obtained the ISO 14001 certification for an environmental management system. The Danish Gas Technology Centre and Force Technology both run accredited laboratories for emission measurements.
- The emission from each large point source is compared with the emission reported the previous year.

3.2.8 Source specific recalculations and improvements

Table 3.2.38 shows recalculations of the CO_2, CH_4 and N_2O emissions. Emissions reported this year have been compared to emissions reported last year.

Sector specific recalculations for 2012 are shown in Table 3.2.39.

The main recalculations are discussed below.

Table 3.2.38 Recalculations, emissions reported this year / emissions reported last year.

Pollutant	1990	1995	2000	2005	2006	2007	2008	2009	2010	2011	2012
						%					
CO_2	100.0	100.0	100.0	100.0	100.0	100.1	100.2	100.3	100.4	100.4	101.2
CH_4	112	103	99	99	99	99	99	98	98	98	95
N_2O	107	120	123	119	117	119	119	116	117	116	117

Table 3.2.39 Recalculations for stationary combustion, 2012.

	CO_2 , Gg CO_2	CH_4, Gg CO_2 eqv.	N_2O Gg CO_2 eqv.	CO_2 %	CH_4, %	N_2O %
1A1 Energy industries	-5.0	-5.8	7.0	0.0	-3.5	8.3
1A1a Public electricity and heat production	6.2	-5.8	7.0	0.0	-4	9
1A1b Petroleum refining	-11.3	0.0	0.0	-1.1	-3	-3
1A1c Oil and gas extraction	0.0	0.0	0.0	0.0	0	0
1A2 Industry	-12.4	-1.2	17.4	-0.4	-11.9	76.9
1A2a Iron and steel	1.6	0.0	0.3	3	-26	829
1A2b Non-ferrous metals	-3.8	0.0	0.0	-100	-100	-100
1A2c Chemicals	91.5	0.0	1.4	37	9	222
1A2d Pulp, paper and print	39.9	-0.2	1.3	34	-14	30
1A2e Food processing, beverages and tobacco	-12.4	-0.2	2.9	-1	-6	44
1A2f Non-metallic minerals	-56.6	0.1	2.5	-5	3	63
1A2gviii Other manufacturing industry	-72.6	-0.9	8.9	-14	-28	128
1A4 Other sectors	296.3	-11.7	3.7	10	-6	7
1A4ai Commercial/institutional: Stationary	90.1	-0.4	-2.4	14	-3	-33
1A4bi Residential: Stationary	198.2	-11.1	6.7	10	-8	15
1A4ci Agriculture/Forestry/Fishing: Stationary	8.1	-0.2	-0.6	3	-1	-12
Stationary combustion	**278.9**	**-18.7**	**28.1**	**1.2**	**-5**	**17**

The IPCC Guidelines 2006 update has been implemented this year. All GHG emission factors that are not nationally referenced have been revised according to IPCC (2006). For CO_2 almost all emission factors are nationally referenced, and the recalculations are small. For CH_4 the revised emission factors cause a decrease in total emission reported from stationary combustion. For N_2O the revised emission factors result in higher total emissions reported from stationary combustion.

For stationary combustion plants, the emission estimates for the years 1990-2012 have been updated according to the latest energy statistics published by the Danish Energy Agency. The update included both end use and transformation sectors as well as a source category update. The changes in the energy statistics are largest for the years 2010, 2011 and 2012.

A time series for the CH_4 emission factor for residential wood combustion have been added for 1990-2000. This cause an increased CH_4 emission estimated for residential plants in 1990-2000.

The consumption of wood in residential plants in 2012 is 4% lower in the revised energy statistics than in the energy statistics applied last year. This causes a lower emission of CH_4 reported for 2012 this year.

The increased CO_2 emission from residential plants is related to improved fuel data disaggregation between the transport sector and stationary combustion plants.

The uncertainty estimates have been improved according to IPCC (2006).

Improvements related to reviews

Review 2014, # 24: The NIR text concerning the N_2O emission factor for off shore gas turbines have been improved, see page 157.

Review 2014, # 22: The documentation box in CRF will be improved in the next inventory.

3.2.9 Source specific planned improvements

The uncertainty estimates have been improved this year and the documentation will be further improved in the next inventory.

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3.3 Transport and other mobile sources

The emission inventory basis for mobile sources is fuel consumption information from the Danish energy statistics. In addition, background data for road transport (fleet and mileage), air traffic (aircraft type, flight numbers, origin and destination airports), national sea transport (fuel surveys, ferry technical data, number of return trips, sailing time) and non-road machinery (engine no., engine size, load factor and annual working hours) are used to make the emission estimates sufficiently detailed. Emission data mainly comes from the EMEP/EEA Air Pollutant Emission Inventory Guidebook (EMEP/EEA, 2013). However, for railways, measurements specific to Denmark are used.

In the Danish emissions database, all activity rates and emissions are defined in SNAP sector categories (Selected Nomenclature for Air Pollution) according to the CORINAIR system. The emission inventories are prepared from a complete emission database based on the SNAP sectors. The aggregation to the sector codes used for both the UNFCCC and UNECE Conventions is based on a correspondence list between SNAP and IPCC classification codes (CRF), shown in Table 3.3.1 (mobile sources only).

Table 3.3.1 SNAP – CRF correspondence table for transport.

SNAP classification	CRF/NFR classification
07 Road transport	1A3bi Road transport: Passenger cars
	1A3bii Road transport:Light duty vehicles
	1A3biii Road transport:Heavy duty vehicles
	1A3biv Road transport: Mopeds & motorcycles
0801 Military	1A5b Other, Mobile
0802 Railways	1A3c Railways
0803 Inland waterways	1A5b Other, Mobile
080402 National sea traffic	1A3dii National navigation (Shipping)
080403 National fishing	1A4ciii Agriculture/Forestry/Fishing: National fishing
080404 International sea traffic	1A3di (i) International navigation (Shipping)
080501 Dom. airport traffic (LTO < 1000 m)	1A3aii (i) Civil aviation (Domestic,LTO
080502 Int. airport traffic (LTO < 1000 m)	1A3ai (i) Civil aviation (International, LTO)
080503 Dom. cruise traffic (> 1000 m)	1A3aii (ii) Civil aviation (Domestic,Cruise)
080504 Int. cruise traffic (> 1000 m)	1A3ai (ii) Civil aviation (International, Cruise)
0806 Agriculture	1A4cii Agriculture/Forestry/Fishing: Off-road agriculture/forestry
0807 Forestry	1A4cii Agriculture/Forestry/Fishing: Off-road agriculture/forestry
0808 Industry	1A2gvii Manufacturing industries/Construction (mobile)
0809 Household and gardening	1A4bii Residential: Household and gardening (mobile)
0811 Commercial and institutional	1A4aii Commercial/Institutional: Mobile

Military transport activities (land and air) refer to the CRF/NFR sector Other (1A5), the latter sector also including recreational craft (SNAP code 0803).

For aviation, LTO (Landing and Take Off)[1] refers to the part of flying which is below 1000 m. This part of the aviation emissions (SNAP codes 080501 and 080502) are included in the national emissions total as prescribed by the UNECE reporting rules. According to UNFCCC the national emissions for aviation comprise the emissions from domestic LTO (0805010) and domestic cruise (080503). The fuel consumption and emission development explained in the following are based on these latter results.

Agricultural and forestry non-road machinery (SNAP codes 0806 and 0807) is accounted for in the Agriculture/forestry/fisheries (1A4c) sector together with fishing activities (SNAP code 080403).

For mobile sources, internal database models for road transport, air traffic, sea transport and non road machinery have been set up at Department of Environmental Science (ENVS)/Danish Centre for Environment and Energy (DCE), Aarhus University (former NERI), in order to produce the emission inventories. The output results from the DCE models are calculated in a

[1] A LTO cycle consists of the flying modes approach/descent, taxiing, take off and climb out. In principle the actual times-in-modes rely on the actual traffic circumstances, the airport configuration, and the aircraft type in question.

SNAP format, as activity rates (fuel consumption) and emission factors, which are then exported directly to the central Danish CollectER database.

Apart from national inventories, the DCE models are used also as a calculation tool in research projects, environmental impact assessment studies, and to produce basic emission information which requires various aggregation levels.

3.3.1 Source category description

The following description of source categories explains the development in fuel consumption and emissions for road transport and other mobile sources.

Fuel consumption

Table 3.3.2 Fuel consumption (PJ) for domestic transport in 2013 in CRF sectors.

NFR ID	Fuel consumption (PJ)
Manufacturing industries/Construction (mobile)	14.0
Civil aviation (Domestic)	1.9
Road transport: Passenger cars	95.3
Road transport:Light duty vehicles	22.4
Road transport:Heavy duty vehicles	39.8
Road transport: Mopeds & motorcycles	0.9
Railways	3.3
National navigation (Shipping)	5.2
Commercial/Institutional: Mobile	2.3
Residential: Household and gardening (mobile)	0.9
Agriculture/Forestry/Fishing: Off-road agriculture/forestry	15.5
Agriculture/Forestry/Fishing: National fishing	6.9
Other, Mobile	3.3
Road transport total	158.3
Other mobile total	53.3
Domestic total	211.7
Civil aviation (International)	34.4
Navigation (international)	24.7

Table 3.3.2 shows the fuel consumption for domestic transport based on DEA statistics for 2013 in CRF sectors. The fuel consumption figures in time series 1985-2013 are given in Annex 2.B.16 (CRF format) and are shown for 2013 in Annex 2.B.15 (CollectER format). Road transport has a major share of the fuel consumption for domestic transport. In 2013 this sector's fuel consumption share is 75 %, while the fuel consumption shares for Off road agriculture/forestry and Manufacturing industries (mobile) are 7 %, in both cases. For the remaining sectors the total fuel consumption share is 11 %.

From 1990 to 2013, diesel (sum of diesel and biodiesel) and gasoline (sum of gasoline and E5) fuel consumption has changed by 40 % and - 15 %, respectively (Figure 3.3.1), and in 2013 the fuel consumption shares for diesel and gasoline were 66 % and 27 %, respectively (not shown). Other fuels only have a 7 % share of the domestic transport total (Figures 3.3.2). Almost all gasoline is used in road transportation vehicles. Gardening machinery and recreational craft are merely small consumers. Regarding diesel, there is considerable fuel consumption in most of the domestic transport categories, whereas a more limited use of residual oil and jet fuel is being used in the navigation sector and by aviation (civil and military flights), respectively[2].

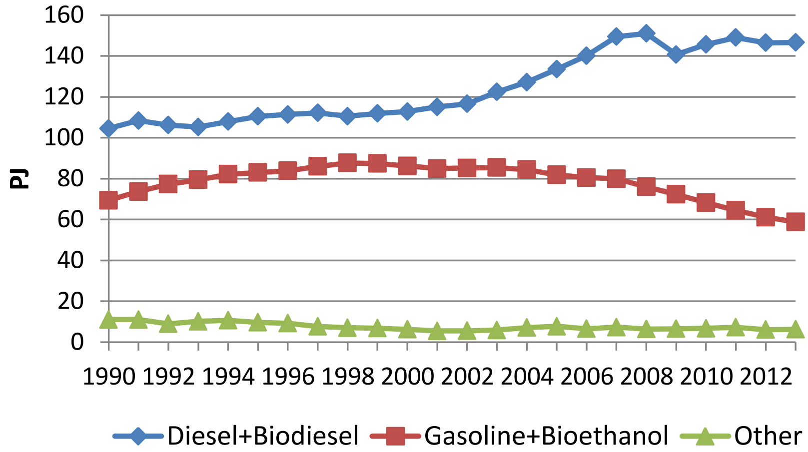


Figure 3.3.1 Fuel consumption pr fuel type for domestic transport 1990-2013.

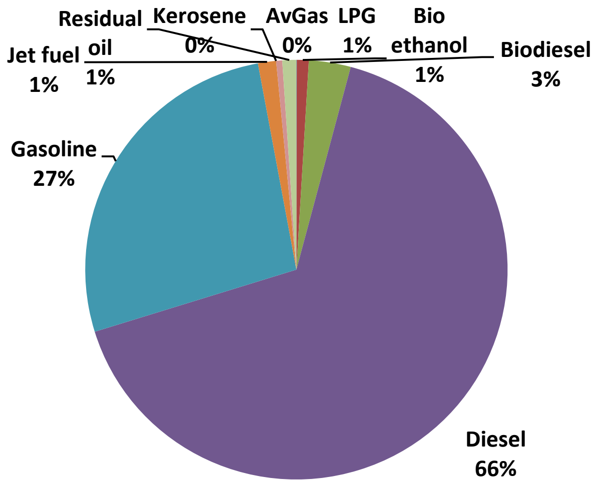


Figure 3.3.2 Fuel consumption share pr fuel type for domestic transport in 2013.

Road transport

As shown in Figure 3.3.3, the fuel consumption for road transport[3] has generally increased until 2007, except from a small fuel consumption decline noted in 2000. The impact of the global financial crisis on fuel consumption for road transport becomes visible for 2008 and 2009. The fuel consumption development is due to a decreasing trend in the use of gasoline fuels from 1999 onwards combined with a steady growth in the use of diesel until 2007. Within sub-sectors, passenger cars represent the most fuel-consuming vehicle category, followed by heavy-duty vehicles, light duty vehicles and 2-wheelers, in decreasing order (Figure 3.3.4).

[2] Biofuels are sold at gas filling stations and are assumed to be used by road transport vehicles.

[3] The sum share of bioethanol and biodiesel in the gasoline and diesel fuel blends for road transport is 5.5 %, in 2013.

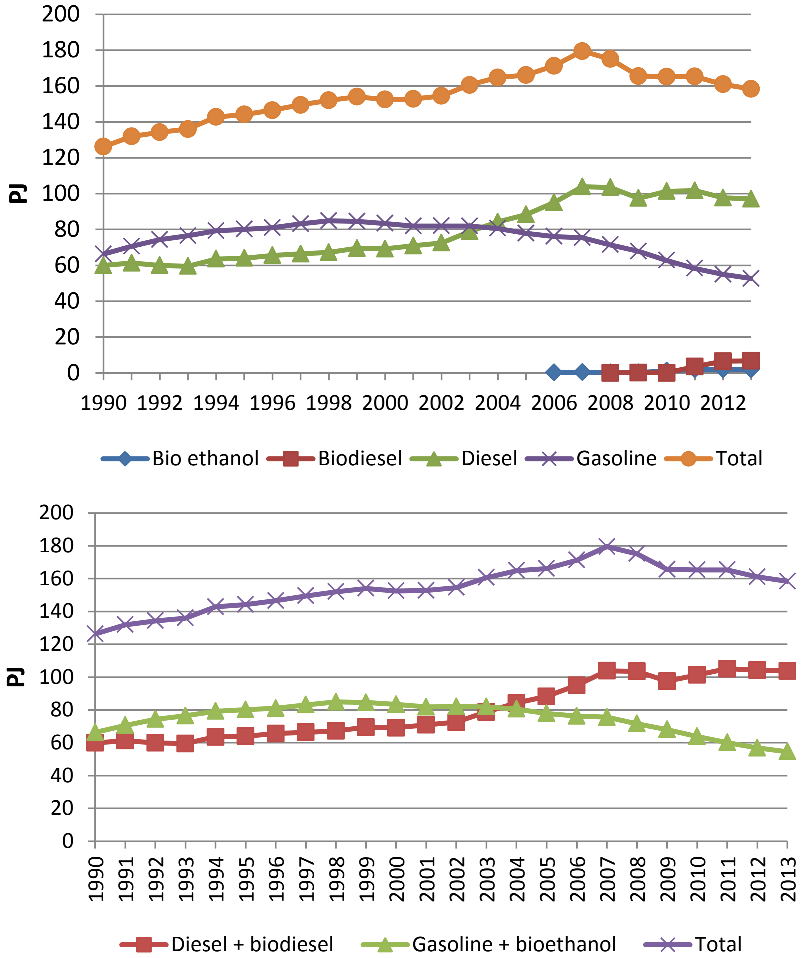


Figure 3.3.3 Fuel consumption pr fuel type and as totals for road transport 1990-2013.

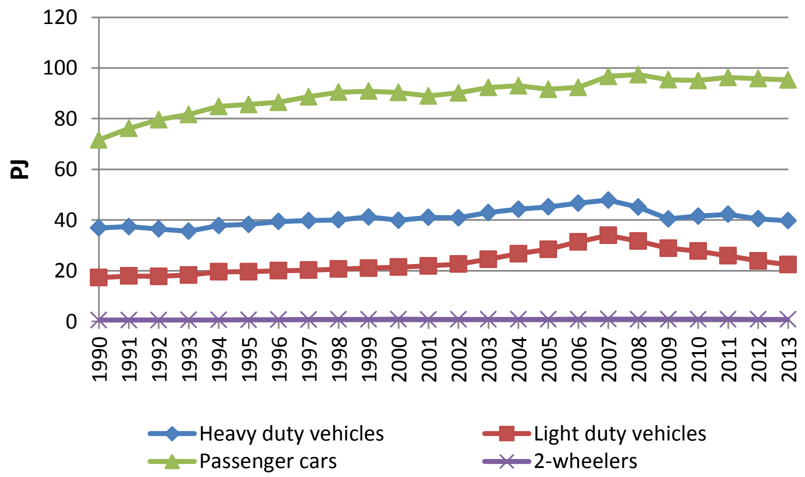


Figure 3.3.4 Total fuel consumption pr vehicle type for road transport 1990-2013.

As shown in Figure 3.3.5, fuel consumption for gasoline passenger cars dominates the overall gasoline consumption trend. The development in diesel fuel consumption in recent years (Figure 3.3.6) is characterised by increasing fuel consumption for diesel passenger cars, while declines in the fuel consumption for trucks and buses (heavy-duty vehicles) and light duty vehicles are noted for 2008- 2009, 2012-2013, and 2008-2013, respectively.

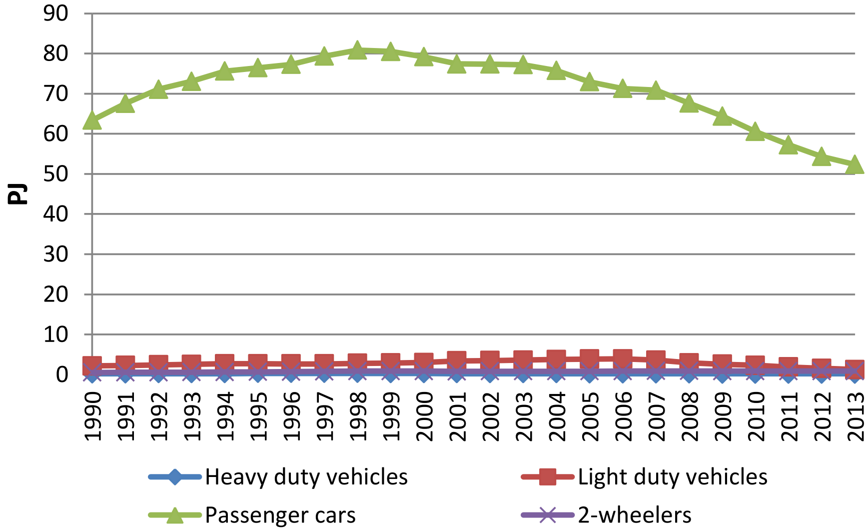


Figure 3.3.5 Gasoline fuel consumption pr vehicle type for road transport 1990-2013.

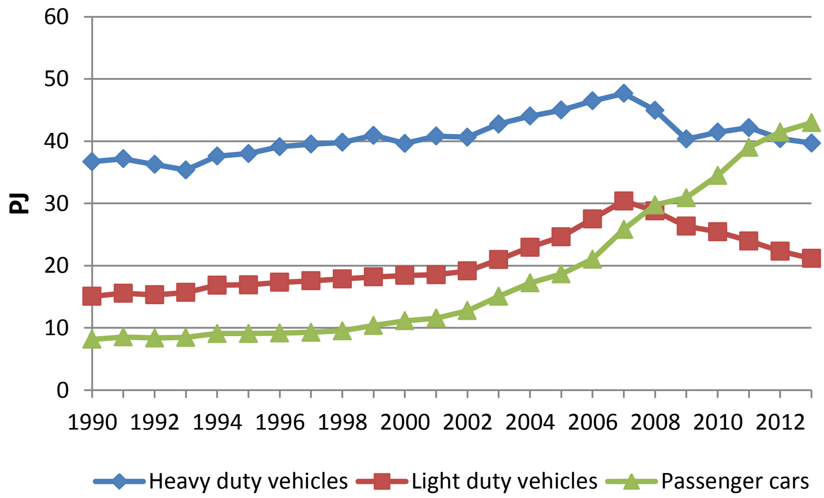


Figure 3.3.6 Diesel fuel consumption pr vehicle type for road transport 1990-2013.

In 2013, fuel consumption shares for gasoline passenger cars, diesel passenger cars, heavy-duty vehicles and gasoline light duty vehicles were 33, 27, 25, 13 and 1 %, respectively (Figure 3.3.7).

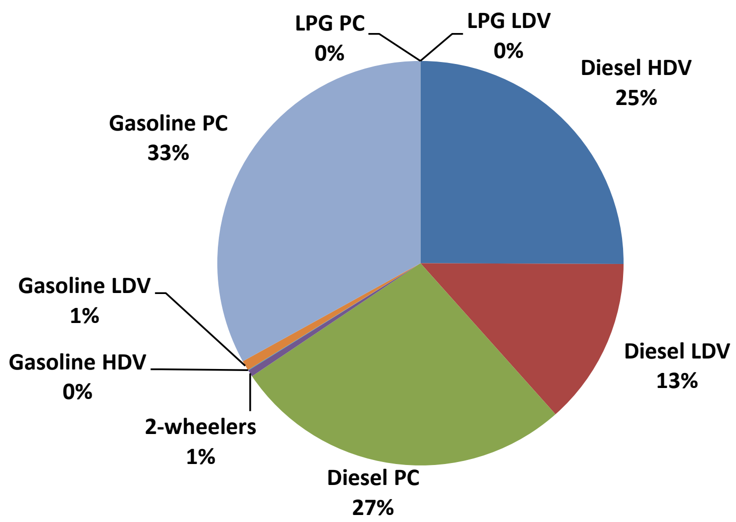


Figure 3.3.7 Fuel consumption share (PJ) pr vehicle type for road transport in 2013.

Other mobile sources

It must be noted that the fuel consumption figures behind the Danish inventory for mobile equipment in the agriculture, forestry, industry, household and gardening (residential), and inland waterways (part of navigation) sectors, are less certain than for other mobile sectors. For these types of machinery, the DEA statistical figures do not directly provide fuel consumption information, and fuel consumption totals are subsequently estimated from activity data and fuel consumption factors. For recreational craft the latest historical year is 2004.

As seen in Figure 3.3.8, classified according to CRF the most important sectors are Agriculture/forestry (1A4cii), Industry-other (mobile machinery part of 1A2g) and Navigation (1A3d). Minor fuel consuming sectors are Civil Aviation (1A3a), Railways (1A3c), Other (military mobile and recreational craft: 1A5b), Commercial/institutional (1A4a) and Residential (1A4b).

The 1985-2013 time series are shown pr fuel type in Figures 3.3.9-3.3.12 for diesel, gasoline and jet fuel, respectively.

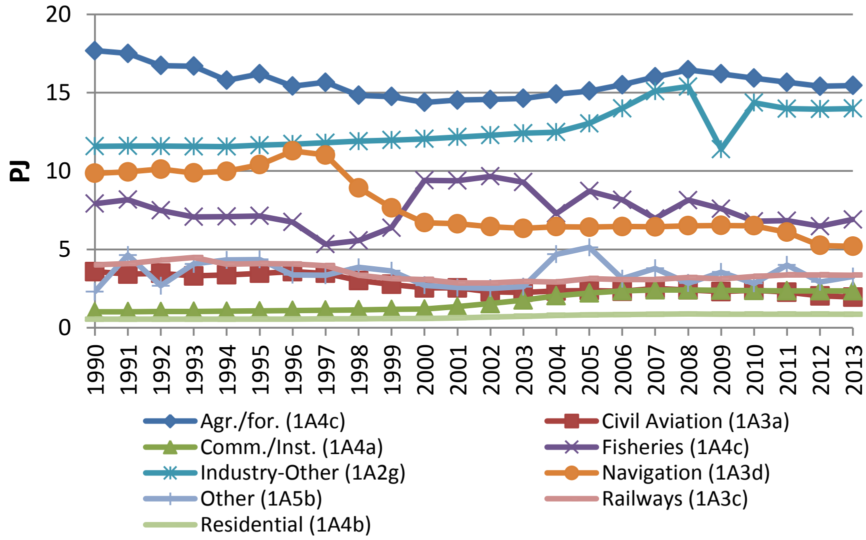


Figure 3.3.8 Total fuel consumption in CRF sectors for other mobile sources 1990-2013.

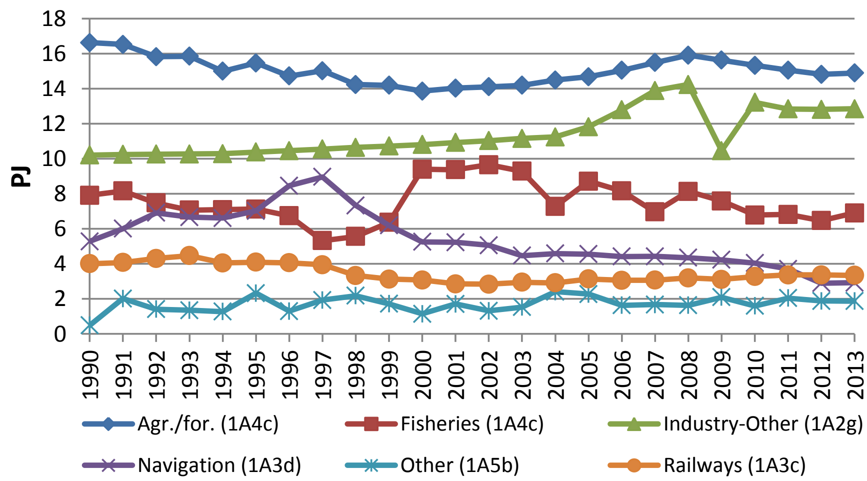


Figure 3.3.9 Diesel fuel consumption in CRF sectors for other mobile sources 1990-2013.

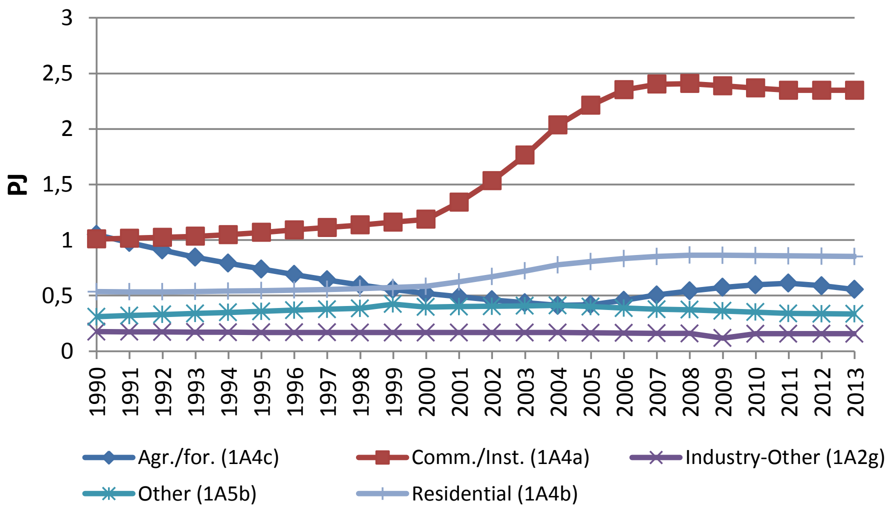


Figure 3.3.10 Gasoline fuel consumption in CRF sectors for other mobile source 1990-2013.

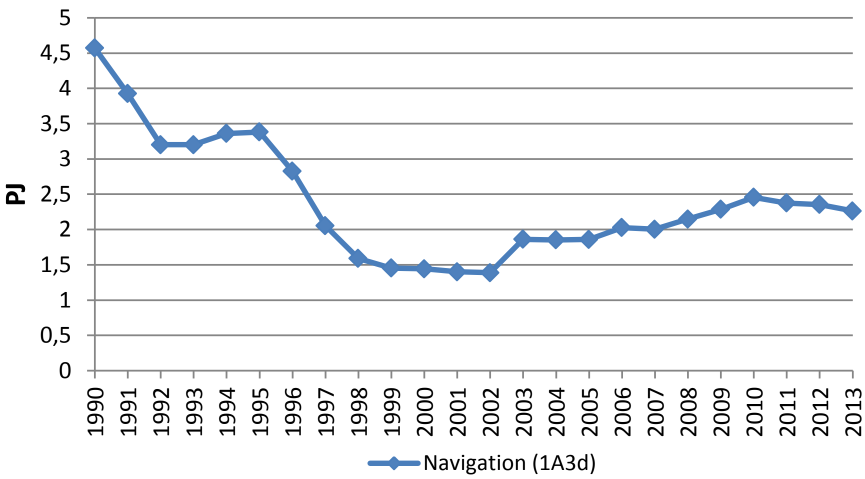


Figure 3.3.11 Residual oil fuel consumption in CRF sectors for other mobile sources 1990-2013.

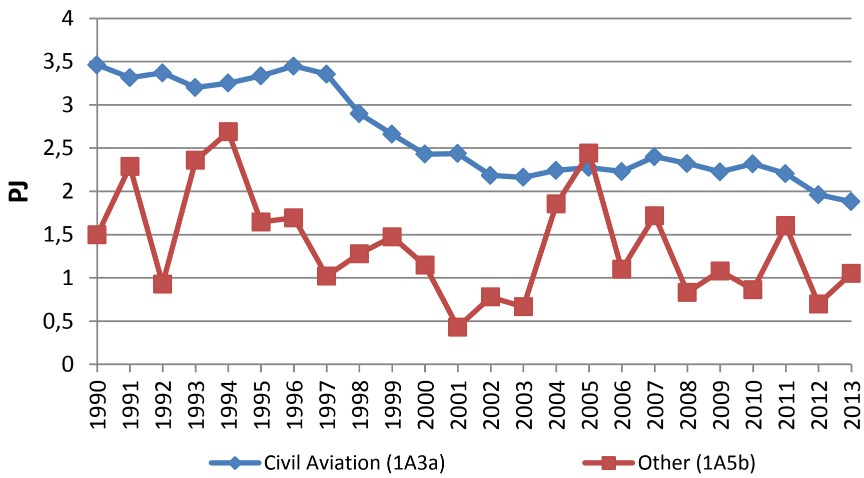


Figure 3.3.12 Jet fuel consumption in CRF sectors for other mobile sources 1990-2013.

In terms of diesel, the fuel consumption decreases for agricultural machines until 2000, due to fewer numbers of tractors and harvesters. After that, the increase in the engine sizes of new sold machines has more than outbalanced the trend towards smaller total stock numbers. The fuel consumption for industry has increased from the beginning of the 1990's, due to an increase in the activities for construction machinery. The fuel consumption increase has been very pronounced in 2005-2008, for 2009; however, the global financial crisis has a significant impact on the building and construction activities. For fisheries, the development in fuel consumption reflects the activities in this sector.

The Navigation sector comprises national sea transport (fuel consumption between two Danish ports including sea travel directly between Denmark and Greenland/Faroe Islands). For national sea transport, the diesel fuel consumption curve reflects the combination of traffic and ferries in use for regional ferries. From 1998 to 2000, a significant decline in fuel consumption is apparent. The most important explanation here is the closing of ferry service routes in connection with the opening of the Great Belt Bridge in 1997. The fuel consumption decreases in 2011 and 2012 are due to reductions in the number of round trips made by regional ferries. For railways, the gradual shift towards electrification explains the lowering trend in diesel fuel consumption and the emissions for this transport sector. The fuel consumed (and associated emissions) to produce electricity is accounted for in the stationary combustion part of the Danish inventories.

The largest gasoline fuel consumption is found for household and gardening machinery in the Commercial/Institutional (1A4a) and Residential (1A4b) sectors. Especially from 2001-2006, a significant fuel consumption increase is apparent due to considerable growth in the machinery stock. The decline in gasoline fuel consumption for Agriculture/forestry/fisheries (1A4c) is due to the gradual phasing out of gasoline-fuelled agricultural tractors.

In terms of residual oil there has been a substantial decrease in the fuel consumption for regional ferries. The fuel consumption decline is most significant from 1990-1992 and from 1997-1999.

The considerable variations from one year to another in military jet fuel consumption are due to planning and budgetary reasons, and the passing demand for flying activities. Consequently, for some years, a certain amount of jet fuel stock-building might disturb the real picture of aircraft fuel consumption. Civil aviation has decreased until 2004, since the opening of the Great Belt Bridge in 1997, both in terms of number of flights and total jet fuel consumption. After 2004 an increase in the consumption of jet fuel is noted until 2007/2008.

Bunkers

The residual oil and diesel oil fuel consumption fluctuations reflect the quantity of fuel sold in Denmark to international ferries, international warships, other ships with foreign destinations, tank vessels and foreign fishing boats. For jet petrol, the sudden fuel consumption drop in 2002 is explained by the recession in the air traffic sector due to the events of September 11, 2001 and structural changes in the aviation business. In 2009, the impact of the global financial crisis on flying activities becomes very visible.

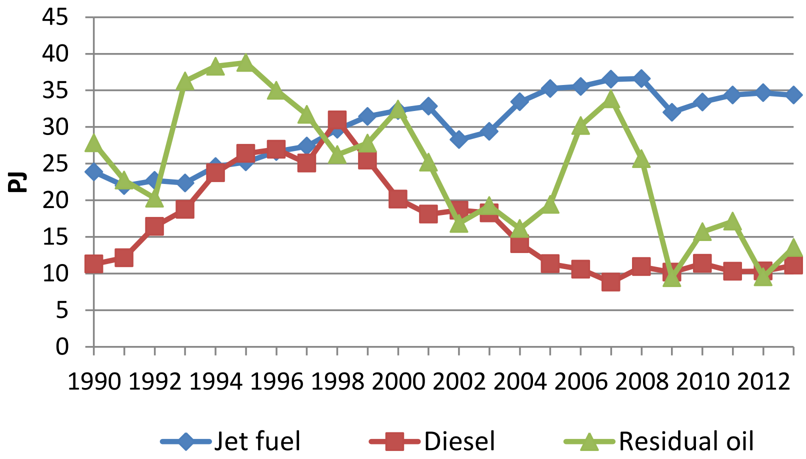


Figure 3.3.13 Bunker fuel consumption 1990-2013.

Emissions of CO_2, CH_4 and N_2O

In Table 3.3.3 the CO_2, CH_4 and N_2O emissions for road transport and other mobile sources are shown for 2013 in CRF sectors. The emission figures in time series 1990-2013 are given in Annex 3.B.16 (CRF format) and are shown for 1990 and 2013 in Annex 3.B.15 (CollectER format).

From 1990 to 2013 the road transport emissions of CO_2 and N_2O have increased by 19 and 30 %, respectively, whereas the emissions of CH_4 have decreased by 78 % (from Figures 3.3.14 - 3.3.16). From 1990 to 2013 the other mobile CO_2 emissions have decreased by 9 %, (from Figures 3.3.18 - 3.3.20).

Table 3.3.3 Emissions of CO_2, CH_4 and N_2O in 2013 for road transport and other mobile sources.

	CO_2 ktonnes	CH_4 tonnes	N_2O tonnes
Manufacturing industries/Construction (mobile)	1025	34	44
Civil aviation (Domestic)	140	2	7
Road transport: Passenger cars	6658	298	199
Road transport:Light duty vehicles	1552	14	49
Road transport:Heavy duty vehicles	2751	82	130
Road transport: Mopeds & motorcycles	60	87	1
Railways	248	6	7
National navigation (Shipping)	393	10	25
Commercial/Institutional: Mobile	171	173	3
Residential: Household and gardening (mobile)	62	42	1
Agriculture/Forestry/Fishing: Off-road agriculture/forestry	1143	108	48
Agriculture/Forestry/Fishing: National fishing	511	12	32
Other, Mobile	239	15	9
Road transport exhaust total	11021	481	379
Road transport non exhaust total	0	0	0
Other mobile sources total	3933	402	175
Domestic total	14954	884	555
Civil aviation (International)	2473	4	84
Navigation (International)	1878	47	118

Road transport

CO_2 emissions are directly fuel consumption dependent and, in this way, the development in the emission reflects the trend in fuel consumption. As shown in Figure 3.3.14, the most important emission source for road transport is passenger cars, followed by heavy-duty vehicles, light-duty vehicles and 2-wheelers in decreasing order. In 2013, the respective emission shares were 60, 25, 14 and 1 %, respectively (Figure 3.3.17).

The majority of CH_4 emissions from road transport come from gasoline passenger cars (Figure 3.3.15). The emission drop from 1992 onwards is explained by the penetration of catalyst cars into the Danish fleet. The 2013 emission shares for CH_4 were 62, 18, 17 and 3 % for passenger cars, 2-wheelers, heavy-duty vehicles and light-duty vehicles, respectively (Figure 3.3.17).

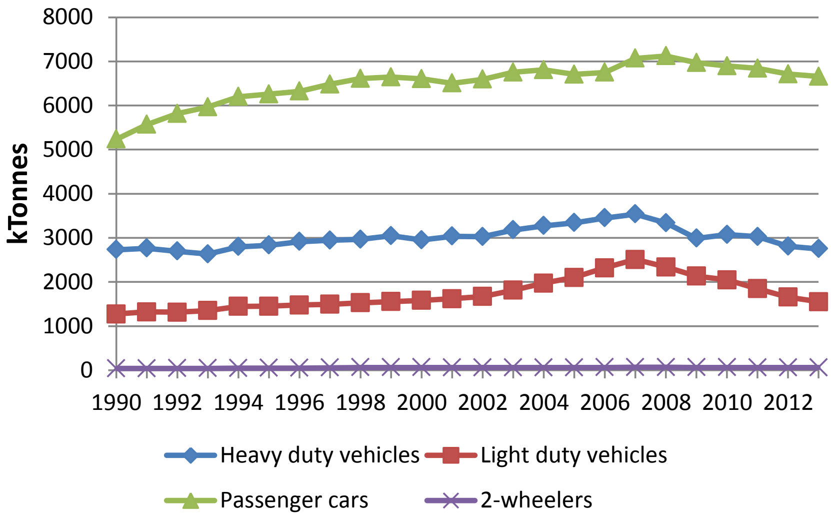


Figure 3.3.14 CO_2 emissions (k-tonnes) pr vehicle type for road transport 1990-2013.

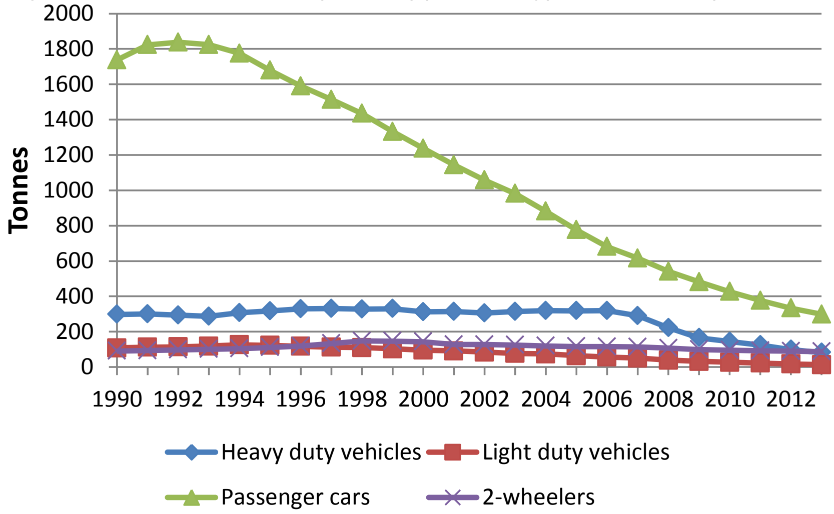


Figure 3.3.15 CH_4 emissions (tonnes) pr vehicle type for road transport 1990-2013.

An undesirable environmental side effect of the introduction of catalyst cars is the increase in the emissions of N_2O from the first generation of catalyst cars (Euro 1) compared to conventional cars. The emission factors for later catalytic converter technologies are considerably lower than the ones for Euro 1, thus causing the emissions to decrease from 1998 onwards (Figure 3.3.16). In 2013, emission shares for passenger cars, heavy and light-duty vehicles were 53, 34 and 13 %, of the total road transport N_2O, respectively (Figure 3.3.17).

Referring to the second IPCC assessment report, 1 g CH_4 and 1 g N_2O has the greenhouse effect of 21 and 310 g CO_2, respectively. In spite of the relatively large CH_4 and N_2O global warming potentials, the largest contribution to the total CO_2 emission equivalents for road transport comes from CO_2, and the CO_2 emission equivalent shares per vehicle category are almost the same as the CO_2 shares.

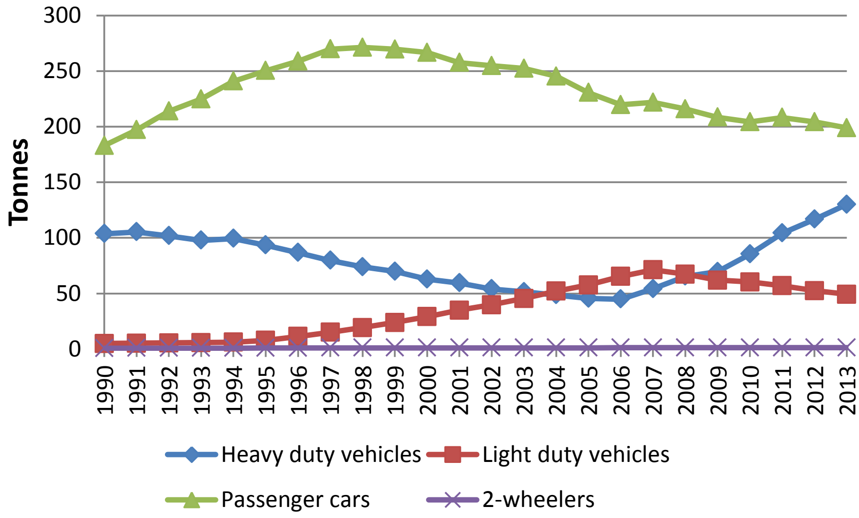


Figure 3.3.16 N_2O emissions (tonnes) pr vehicle type for road transport 1990-2013.

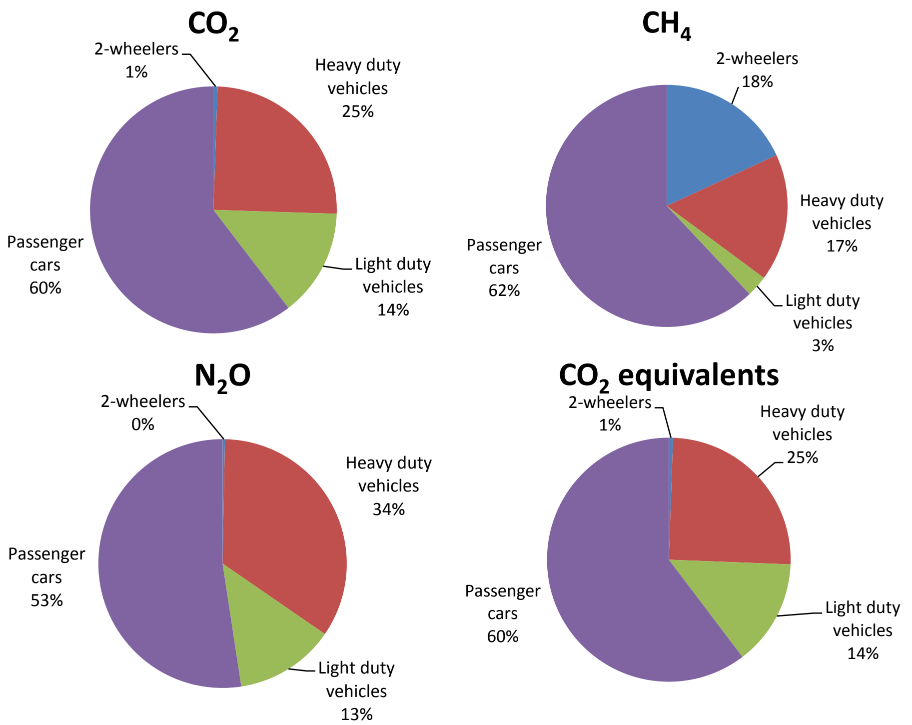


Figure 3.3.17 CO_2, CH_4 and N_2O emission shares and GHG equivalent emission distribution for road transport in 2013.

Other mobile sources

For other mobile sources, the highest CO_2 emissions in 2013 come from Agriculture/forestry/fisheries (1A4c), Industry-other (1A2g) and Navigation (1A3d), with shares of 42, 26 and 10 %, respectively (Figure 3.3.21). The 1990-2013 emission trend is directly related to the fuel consumption development in the same time-period. Minor CO_2 emission contributors are sectors such as Commercial/Institutional (1A4a), Residential (1A4b), Railways (1A3c), Civil Aviation (1A3a) and Military (1A5).

For CH_4, far the most important sources are the gasoline fuelled gardening machinery in the Commercial/Institutional (1A4a) and Residential (1A4b) sectors, see Figure 3.3.21. The emission shares are 43 % and 11 %, respectively in 2013. The 2013 emission shares for Agriculture/forestry/fisheries (1A4c) and Industry (1A2g) are 40 and 8 %, respectively, whereas the remaining sectors have emission shares of 4 % or less.

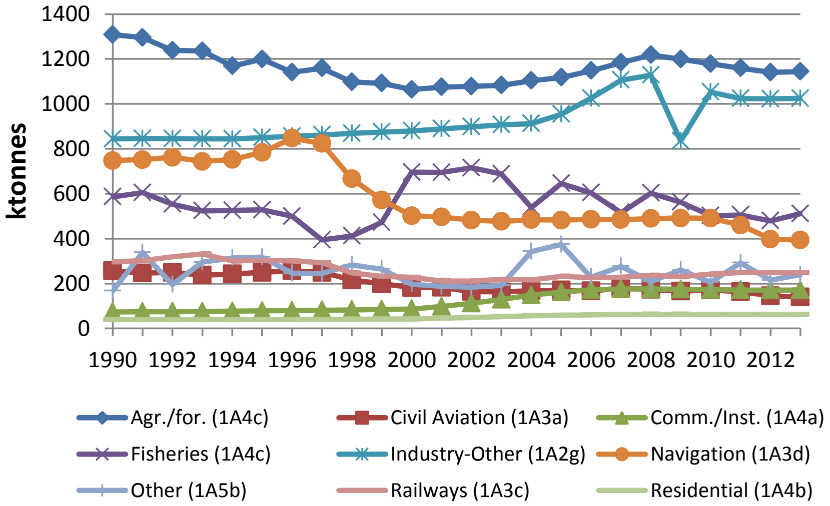


Figure 3.3.18 CO_2 emissions (ktonnes) in CRF sectors for other mobile sources 1990-2013.

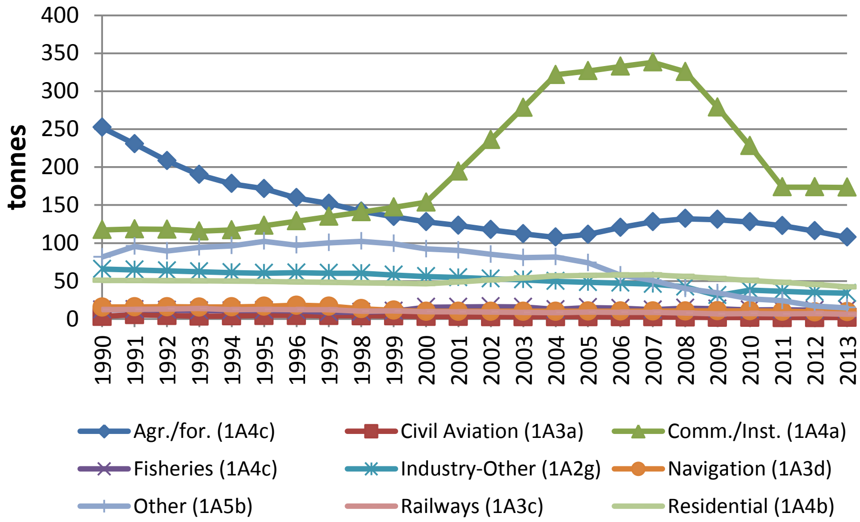


Figure 3.3.19 CH_4 emissions (tonnes) in CRF sectors for other mobile sources 1990-2013.

For N_2O, the emission trend in sub-sectors is the same as for fuel consumption and CO_2 emissions (Figure 3.3.20).

As for road transport, CO_2 alone contributes with by far the most CO_2 emission equivalents in the case of other mobile sources, and per sector the CO_2 emission equivalent shares are almost the same as those for CO_2, itself (Figure 3.3.21).

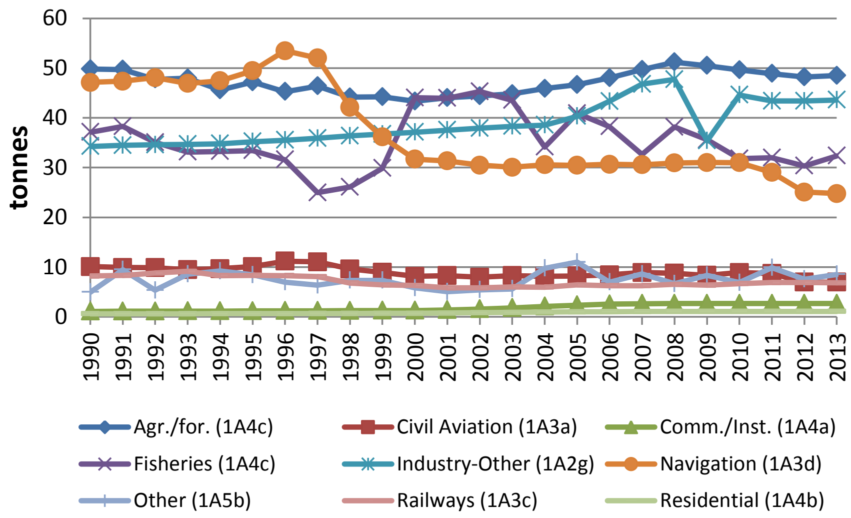


Figure 3.3.20 N$_2$O emissions (tonnes) in CRF sectors for other mobile sources 1990-2013.

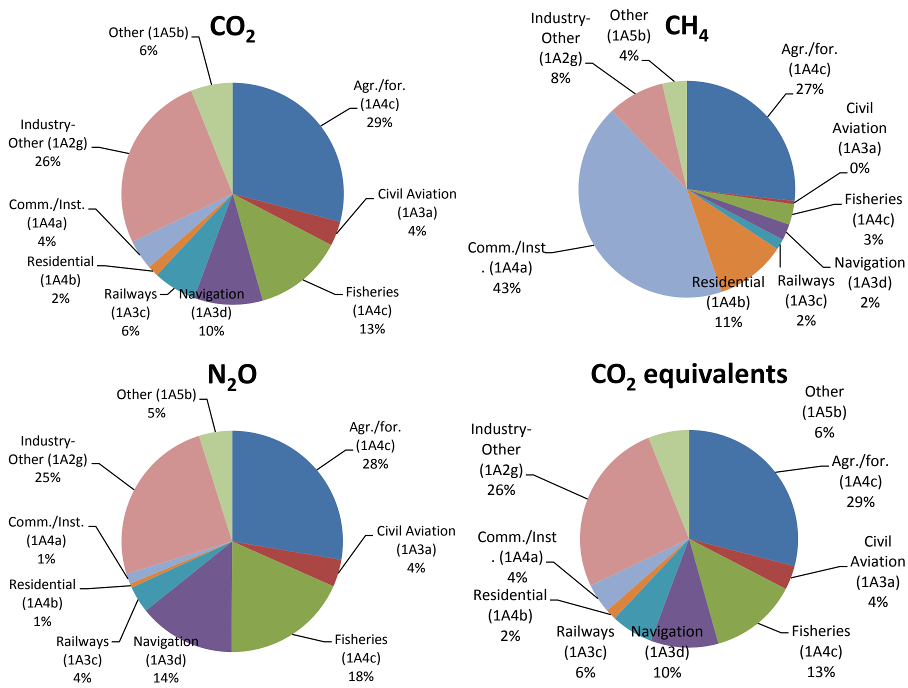


Figure 3.3.21 CO_2, CH_4 and N$_2$O emission shares and GHG equivalent emission distribution for other mobile sources in 2013.

Emissions of SO_2, NO_X, NMVOC and CO

For road transport and other mobile sources the emission figures of SO_2, NO_X, NMVOC and CO in the time series 1990-2013 are given in Annex 3.B.16 (CRF format) and are shown for 1990 and 2013 in Annex 3.B.15 (CollectER format). For further explanations of these emissions please refer to the Danish IIR report (Nielsen et al. 2015).

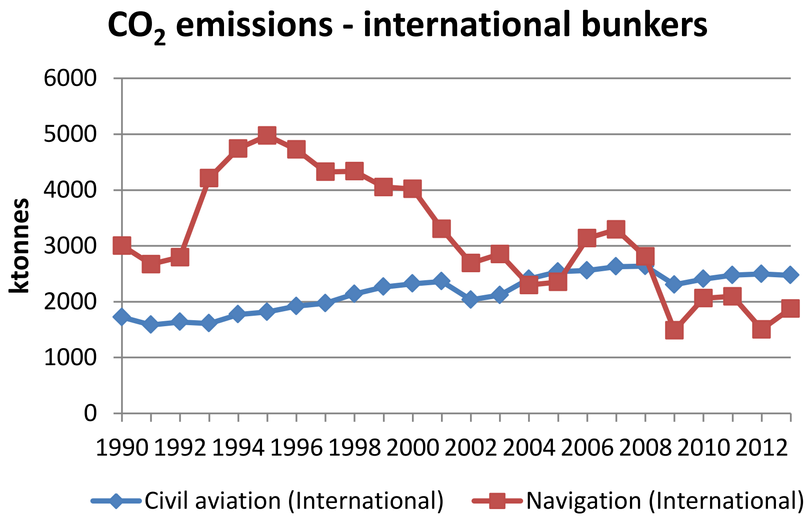
Bunkers

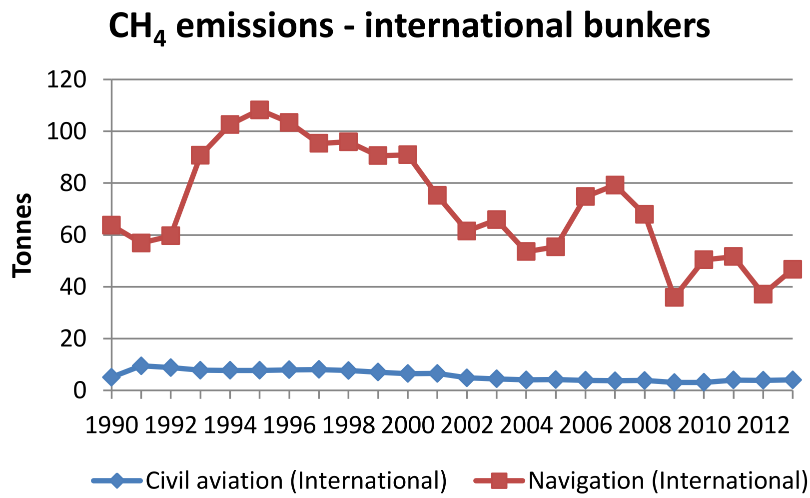
The most important emissions from bunker fuel consumption (fuel consumption for international transport) are SO_2 and NO_X. In terms of greenhouse gas emissions, the level of emissions from Danish bunker fuel consumption are 29 %, 6 % and 37 %, respectively, for CO_2, CH_4 and N_2O, compared with the emission total for mobile sources.

The bunker emission totals of CO_2, CH_4 and N_2O are shown in Table 3.3.3 for 2013, split into sea transport and civil aviation. All emission figures in the 1990-2013 time series are given in Annex 3.B.16 (CRF format). In Annex 3.B.15, the emissions are also given in CollectER format for the years 1990 and 2013.

For further explanations of SO_2 and NO_x emissions from bunkers please refer to the Danish IIR report (Nielsen et al. 2015).

The differences in CH_4 and N_2O emissions between navigation and civil aviation are much larger than the differences in fuel consumption (and derived CO_2 emissions), and display a poor emission performance for international sea transport. In broad terms, the emission trends shown in Figure 3.3.32 are similar to the fuel consumption development.





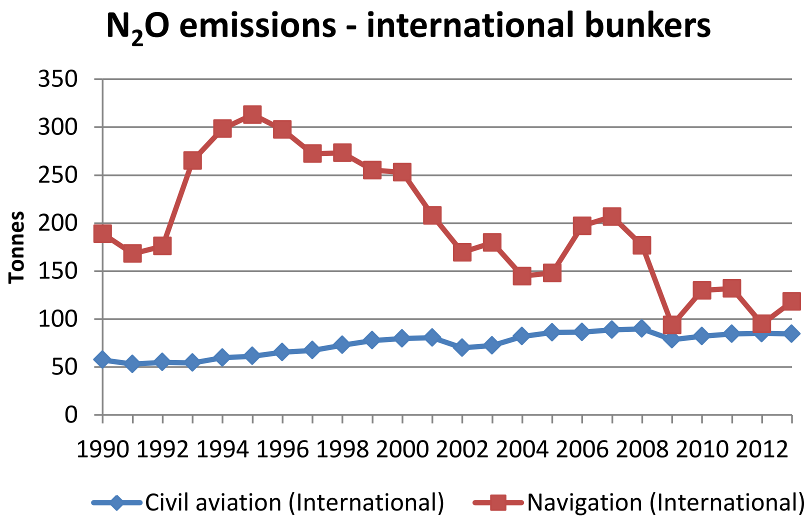


Figure 3.3.32 CO_2, CH_4 and N_2O emissions for international transport 1990-2013.

3.3.2 Methodological issues

The description of methodologies and references for the transport part of the Danish inventory is given in two sections: one for road transport and one for the other mobile sources.

Methodology and references for Road Transport

For road transport, the detailed methodology is used to make annual estimates of the Danish emissions, as described in the EMEP/EEA Air Pollutant Emission Inventory Guidebook (EMEP/EEA, 2013). The actual calculations are made with a model developed by DCE, using the European COPERT IV model methodology explained by EMEP/EEA (2013). In COPERT, fuel consumption and emission simulations can be made for operationally hot engines, taking into account gradually stricter emission standards and emission degradation due to catalyst wear. Furthermore, the emission effects of cold-start and evaporation are simulated.

Vehicle fleet and mileage data

Corresponding to the COPERT IV fleet classification, all present and future vehicles in the Danish fleet are grouped into vehicle classes, sub-classes and layers. The layer classification is a further division of vehicle sub-classes into groups of vehicles with the same average fuel consumption and emission behaviour, according to EU emission legislation levels. Table 3.3.4 gives an overview of the different model classes and sub-classes, and the layer level with implementation years are shown in Annex 3.B.1.

Table 3.3.4 Model vehicle classes and sub-classes and trip speeds.

			Trip speed [km pr h]		
Vehicle classes	Fuel type	Engine size/weight	Urban	Rural	Highway
PC	Gasoline	< 1.4 l.	40	70	100
PC	Gasoline	1.4 – 2 l.	40	70	100
PC	Gasoline	> 2 l.	40	70	100
PC	Diesel	< 2 l.	40	70	100
PC	Diesel	> 2 l.	40	70	100
PC	LPG		40	70	100
PC	2-stroke		40	70	100
LDV	Gasoline		40	65	80
LDV	Diesel		40	65	80
LDV	LPG		40	65	80
Trucks	Gasoline		35	60	80
Trucks	Diesel	Rigid 3,5 - 7,5t	35	60	80
Trucks	Diesel	Rigid 7,5 - 12t	35	60	80
Trucks	Diesel	Rigid 12 - 14 t	35	60	80
Trucks	Diesel	Rigid 14 - 20t	35	60	80
Trucks	Diesel	Rigid 20 - 26t	35	60	80
Trucks	Diesel	Rigid 26 - 28t	35	60	80
Trucks	Diesel	Rigid 28 - 32t	35	60	80
Trucks	Diesel	Rigid >32t	35	60	80
Trucks	Diesel	TT/AT 14 - 20t	35	60	80
Trucks	Diesel	TT/AT 20 - 28t	35	60	80
Trucks	Diesel	TT/AT 28 - 34t	35	60	80
Trucks	Diesel	TT/AT 34 - 40t	35	60	80
Trucks	Diesel	TT/AT 40 - 50t	35	60	80
Trucks	Diesel	TT/AT 50 - 60t	35	60	80
Trucks	Diesel	TT/AT >60t	35	60	80
Urban buses	Gasoline		30	50	70
Urban buses	Diesel	< 15 tonnes	30	50	70
Urban buses	Diesel	15-18 tonnes	30	50	70
Urban buses	Diesel	> 18 tonnes	30	50	70
Coaches	Gasoline		35	60	80
Coaches	Diesel	< 15 tonnes	35	60	80
Coaches	Diesel	15-18 tonnes	35	60	80
Coaches	Diesel	> 18 tonnes	35	60	80
Mopeds	Gasoline		30	30	-
Motorcycles	Gasoline	2 stroke	40	70	100
Motorcycles	Gasoline	< 250 cc.	40	70	100
Motorcycles	Gasoline	250 – 750 cc.	40	70	100
Motorcycles	Gasoline	> 750 cc.	40	70	100

Fleet and annual mileage data are provided by DTU Transport for the vehicle categories present in COPERT IV (Jensen, 2014). DTU Transport use data from the Danish vehicle register kept by Statistics Denmark. The vehicle register data consist of vehicle type (passenger cars, vans, trucks, buses, mopeds, motorcycles), fuel type, vehicle weight, gross vehicle weight, engine size (passenger cars registered from 2005+), Euro class (trucks and buses registered from 1997+), NEDC type approval fuel efficiency value (passenger cars registered from 1997+) and vehicle first registration year.

In order to establish engine size data for passenger cars registered before 2005, a weight class-engine size transformation key is used examined by Cowi (2008) for new Danish cars from 1998. For the years before 1998, data for 1998 is used, and for the years 1999-2004 a linear interpolation between 1998 and 2005 weight class-engine size relations is used. For trucks, truck driver registration notes gathered by Statistics Denmark are used to split the fleet figures of ordinary trucks into number of solo trucks and truck-trailer combinations. Further the registration notes make it possible to assume the average total vehicle weight of the truck trailer combination. For articulated trucks also, the registration notes make it possible to assume the average total vehicle weight of the full articulated truck.

Danish mileage data comes from the Danish Road Directorate based on the Danish vehicle inspection program. Total mileage per year and vehicle category are derived for the years 1985-2012, together with a more detailed mileage matrix examined for the year 2008 (based on detailed vehicle inspection data analysis). The detailed mileage matrix contains annual mileage per vehicle subcategory for new vehicles and for every vintage back in time, which detemines the yearly mileage reduction percentages as a function of vehicle age. In a first step, the detailed mileage matrix is combined with corresponding fleet numbers in order to estimate intermediate total mileages for each year on a detailed fleet level. Next, each year's detailed (intermediate) mileage figures are scaled according to the difference between true and intermediate total mileage per vehicle subcategory.

DTU Transport (Jensen, 2014) also provides information of the mileage split between urban, rural and highway driving based on traffic monitoring data. The respective average speeds come from The Danish Road Directorate (e.g. Winther & Ekman, 1998). Additional data for the moped fleet and motorcycle fleet disaggregation is given by The National Motorcycle Association (Markamp, 2013).

In addition data from a survey made by the Danish Road Directorate (Hansen, 2010) has given information of the total mileage driven by foreign trucks on Danish roads in 2009. This mileage contribution has been added to the total mileage for Danish trucks on Danish roads, for trucks > 16 tonnes of gross vehicle weight. The data has been further processed by DTU Transport; by using appropriate assumptions the mileage have been backcasted to 1985 and forecasted to 2013.

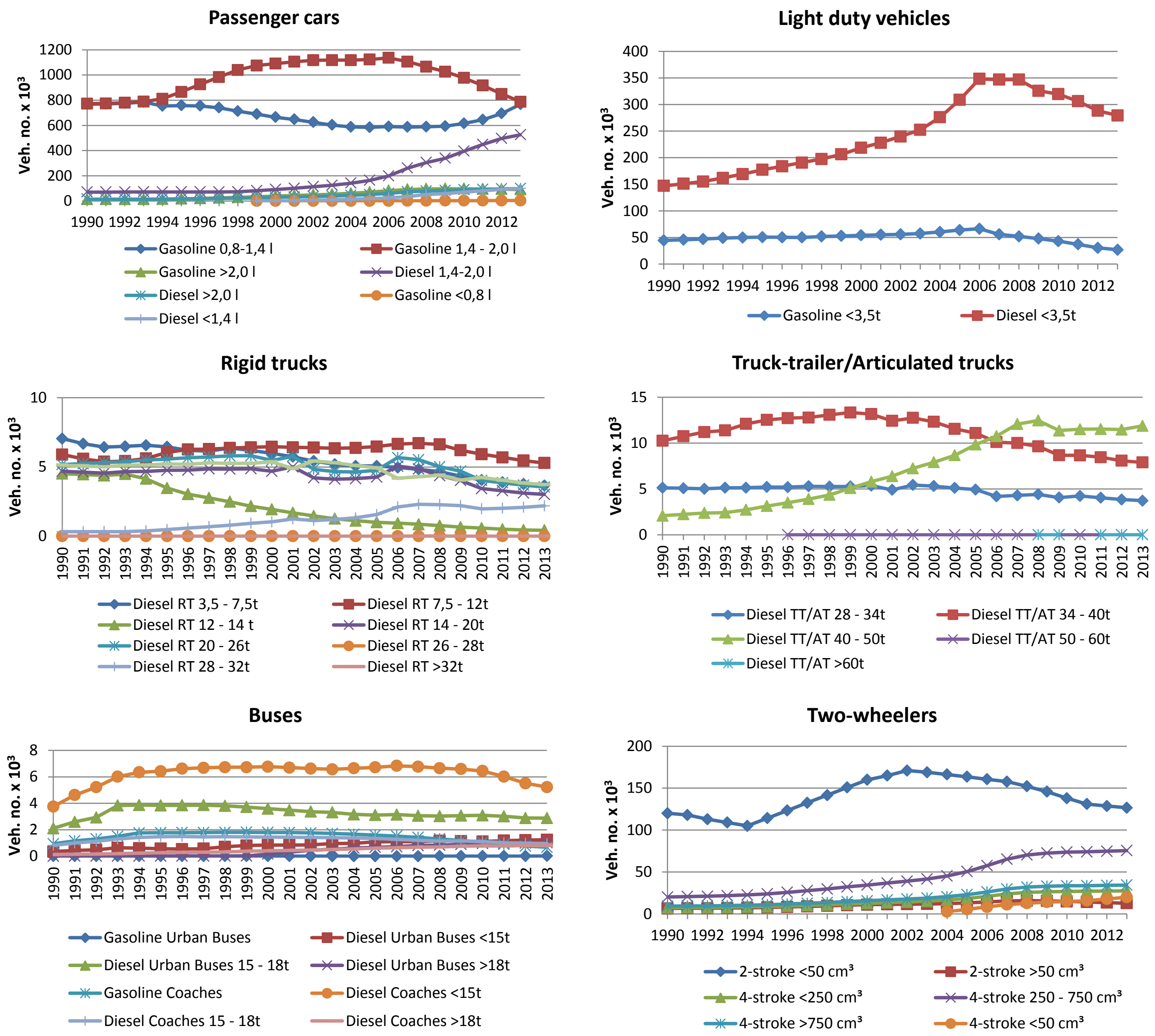


Figure 3.3.33 Number of vehicles in sub-classes in 1990-2013.

For passenger cars, the engine size differentiation is less certain for the years before 2005. The increase in the total number of passenger cars is mostly due to a growth in the number of diesel cars between 1.4 and 2 litres (from the 2000's up to now). Until 2005, there has been a decrease in the number of gasoline cars with an engine size between 0.8 and 1.4 litres. These cars, however, have also increased in numbers during the later years, while the number of 1.4-2 litres gasoline cars has decreased. Since the late 1990's small cars (< 0.8 l gasoline and <1.4 l. diesel) has slowly begun to penetrate the fleet.

There has been a considerable growth in the number of diesel light-duty vehicles from 1985 to 2006; the number of vehicles has, however, decreased somewhat after 2006.

For the truck-trailer and articulated truck combinations there is a tendency towards the use of increasingly larger trucks throughout the time period. The decline in fleet numbers for many of the truck categories in 2007/2008 and until 2009 is caused by the impact of the global financial crisis and the reflagging of Danish commercial trucks to companies based in the neighbouring countries.

The number of urban buses has been almost constant between 1985 and 2011. The sudden change in the level of coach numbers from 1994 to 1995 is due to uncertain fleet data.

The reason for the significant growth in the number of mopeds from 1994 to 2002 is the introduction of the so-called Moped 45 vehicle type. From 2004 onwards there is a gradual switch from 2-stroke to 4-stroke in new sales for this vehicle category. For motorcycles, the number of vehicles has grown in general throughout the entire 1985-2013 period. The increase is, however, most visible from the mid-1990s and onwards.

The vehicle numbers are summed up in EU emission layers for each year (Figure 3.3.34) by using the correspondence between layers and first year of registration:

$$N_{j,y} = \sum_{i=FYear(j)}^{LYear(j)} N_{i,y} \quad (1)$$

Where N = number of vehicles, j = layer, y = year, i = first year of registration.

Weighted annual mileages pr layer are calculated as the sum of all mileage driven pr first registration year divided by the total number of vehicles in the specific layer.

$$M_{j,y} = \frac{\sum_{i=FYear(j)}^{LYear(j)} N_{i,y} \cdot M_{i,y}}{\sum_{i=FYear(j)}^{LYear(j)} N_{i,y}} \quad (2)$$

Since 2006 economical incitements have been given to private vehicle owners to buy Euro 5 diesel passenger cars and vans in order to bring down the particulate emissions from diesel vehicles. The estimated sales between 2006 and 2010 have been examined by the Danish EPA and are included in the fleet data behind the Danish inventory (Winther, 2011).

For heavy duty trucks, there is a slight deviation from the strict correspondence between EU emission layers and first registration year.

In this case, specific Euro class information for most of the vehicles from 2001 onwards is incorporated into the fleet and mileage data model developed by Jensen (2014). For inventory years before 2001, and for vehicles with no Euro information the normal correspondence between layers and first year of registration is used.

Vehicle numbers and weighted annual mileages per layer are shown in Annex 3.B.1 and 3.B.2 for 1990-2013. The trends in vehicle numbers per layer are also shown in Figure 3.3.34. The latter figure shows how vehicles complying with the gradually stricter EU emission levels (EURO I, II, III, IV, V etc.) have been introduced into the Danish motor fleet.

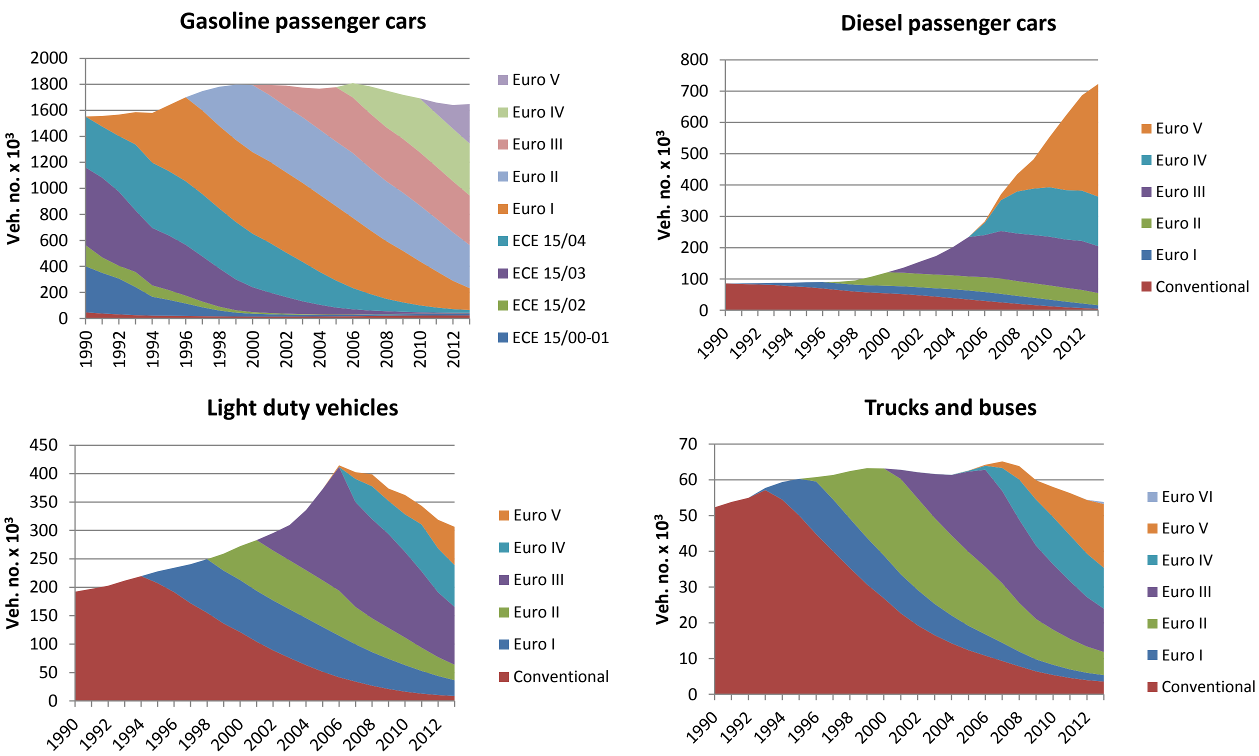


Figure 3.3.34 Layer distribution of vehicle numbers pr vehicle type in 1990-2013.

Emission legislation

The EU 443/2009 regulation sets new emission performance standards for new passenger cars as part of the Community's integrated approach to reduce CO_2 emissions from light-duty vehicles. Some key elements of the adopted text are as follows:

- **Limit value curve:** the fleet average to be achieved by all cars registered in the EU is 130 gram CO_2 per kilometre (g per km). A so-called limit value curve implies that heavier cars are allowed higher emissions than lighter cars while preserving the overall fleet average.
- **Further reduction:** a further reduction of 10 g CO_2 per km, or equivalent if technically necessary, will be delivered by other technological improvements and by an increased use of sustainable biofuels.
- **Phasing-in of requirements:** in 2012, 65 % of each manufacturer's newly registered cars must comply on average with the limit value curve set by the legislation. This will rise to 75 % in 2013, 80 % in 2014, and 100 % from 2015 onwards.
- **Lower penalty payments for small excess emissions until 2018:** if the average CO_2 emissions of a manufacturer's fleet exceed its limit value in any year from 2012, the manufacturer has to pay an excess emissions premium for each car registered. This premium amounts to €5 for the first g per km of exceedance, €15 for the second g per km, €25 for the third g per km, and €95 for each subsequent g per km. From 2019, already the first g per km of exceedance will cost €95.
- **Long-term target:** a target of 95g CO_2 per km is specified for the year 2020.
- **Eco-innovations:** because the test procedure used for vehicle type approval is outdated, certain innovative technologies cannot demonstrate their CO_2 reducing effects under the type approval test. As an interim procedure until the test procedure is reviewed by 2014, manufacturers can be granted a maximum of 7g per km of emission credits on average

for their fleet if they equip vehicles with innovative technologies, based on independently verified data.

The EU 510/2011 regulation sets new emission performance standards for new light commercial vehicles (vans). Some key elements of the regulation are as follows:

- **Target dates:** the EU fleet average of 175 g CO_2 per km will be phased in between 2014 and 2017. In 2014 an average of 70 %of each manufacturer's newly registered vans must comply with the limit value curve set by the legislation. This proportion will rise to 75 % in 2015, 80 % in 2016, and 100% from 2017 onwards.
- **Limit value curve:** emissions limits are set according to the mass of vehicle, using a limit value curve. The curve is set in such a way that a fleet average of 175 grams of CO_2 per kilometre is achieved. A so-called limit value curve of 100 % implies that heavier vans are allowed higher emissions than lighter vans while preserving the overall fleet average. Only the fleet average is regulated, so manufacturers will still be able to make vehicles with emissions above the limit value curve provided these are balanced by other vehicles which are below the curve.
- **Vehicles affected:** the vehicles affected by the legislation are vans, which account for around 12 % of the market for light-duty vehicles. This includes vehicles used to carry goods weighing up to 3.5t (vans and car-derived vans, known as N1) and which weigh less than 2610 kg when empty.
- **Long-term target:** a target of 147g CO_2 per km is specified for the year 2020.
- **Excess emissions premium for small excess emissions until 2018:** if the average CO_2 emissions of a manufacturer's fleet exceed its limit value in any year from 2014, the manufacturer has to pay an excess emissions premium for each van registered. This premium amounts to €5 for the first g per km of exceedance, €15 for the second g per km, €25 for the third g per km, and €95 for each subsequent g per km. From 2019, the first g per km of exceedance will cost €95. This value is equivalent to the premium for passenger cars.
- **Super-credits:** vehicles with extremely low emissions (below 50g per km) will be given additional incentives whereby each low-emitting van will be counted as 3.5 vehicles in 2014 and 2015, 2.5 in 2016 and 1.5 vehicles in 2017.
- **Eco-innovations:** because the test procedure used for vehicle type approval is outdated, certain innovative technologies cannot demonstrate their CO_2 reducing effects under the type approval test. As an interim procedure until the test procedure is reviewed by 2014, manufacturers can be granted a maximum of 7g per km of emission credits on average for their fleet if they equip vehicles with innovative technologies, based on independently verified data.
- **Other flexibilities:** manufacturers may group together to form a pool and act jointly in meeting the specific emissions targets. Independent manufacturers who sell fewer than 22,000 vehicles per year can also apply to the Commission for an individual target instead.

For Euro 1-6 passenger cars and light duty trucks, the chassis dynamometer test cycle used in the EU for measuring fuel is the NEDC (New European Driving Cycle), see Nørgaard and Hansen (2004). The test cycle is also used also for emissions testing. The NEDC cycle consists of two parts, the first part being a 4-time repetition (driving length: 4 km) of the ECE test cycle. The latter test cycle is the so-called urban driving cycle4 (average speed: 19 km pr h). The second part of the test is the run-through of the EUDC (Extra Urban Driving Cycle) test driving segment, simulating the fuel consumption under rural and highway driving conditions. The driving length of EUDC is seven km at an average speed of 63 km pr h. More information regarding the fuel measurement procedure can be found in the EU-directive 80/1268/-EØF.

For NO_X, VOC (NMVOC + CH_4), CO and PM, the emissions from road transport vehicles have to comply with the different EU directives listed in Table 3.3.5. The emission directives distinguish between three vehicle classes according to vehicle reference mass[5]: Passenger cars and light duty trucks (<1305 kg), light duty trucks (1305-1760 kg) and light duty trucks (>1760 kg).The specific emission limits are shown in Annex 3.B.3.

[4] For Euro 3 and on, the emission approval test procedure was slightly changed. The 40 s engine warm up phase before start of the urban driving cycle was removed.
[5] Reference mass: net vehicle weight + mass of fuel and other liquids + 100 kg.

Table 3.3.5 Overview of the existing EU emission directives for road transport vehicles.

Vehicle category	Emission layer	EU directive	First reg. date
Passenger cars (gasoline)	PRE ECE	-	-
	ECE 15/00-01	70/220 - 74/290	1972[a]
	ECE 15/02	77/102	1981[b]
	ECE 15/03	78/665	1982[c]
	ECE 15/04	83/351	1987[d]
	Euro I	91/441	1.10.1990[e]
	Euro II	94/12	1.1.1997
	Euro III	98/69	1.1.2001
	Euro IV	98/69	1.1.2006
	Euro V	715/2007(692/2008)	1.1.2011
	Euro VI	715/2007(692/2008)	1.9.2015
	Euro VIc	459/2012	1.9.2018
Passenger cars (diesel and LPG)	Conventional	-	-
	ECE 15/04	83/351	1987[d]
	Euro I	91/441	1.10.1990[e]
	Euro II	94/12	1.1.1997
	Euro III	98/69	1.1.2001
	Euro IV	98/69	1.1.2006
	Euro V	715/2007(692/2008)	1.1.2011
	Euro VI	715/2007(692/2008)	1.9.2015
	Euro VIc	459/2012	1.9.2018
Light duty trucks (gasoline and diesel)	Conventional	-	-
	ECE 15/00-01	70/220 - 74/290	1972[a]
	ECE 15/02	77/102	1981[b]
	ECE 15/03	78/665	1982[c]
	ECE 15/04	83/351	1987[d]
	Euro I	93/59	1.10.1994
	Euro II	96/69	1.10.1998
	Euro III	98/69	1.1.2002
	Euro IV	98/69	1.1.2007
	Euro V	715/2007	1.1.2012
	Euro VI	715/2007	1.9.2016
	Euro VIc	459/2012	1.9.2019
Heavy duty vehicles	Euro 0	88/77	1.10.1990
	Euro I	91/542	1.10.1993
	Euro II	91/542	1.10.1996
	Euro III	1999/96	1.10.2001
	Euro IV	1999/96	1.10.2006
	Euro V	1999/96	1.10.2009
	Euro VI	595/2009	1.10.2013
Mopeds	Conventional	-	-
	Euro I	97/24	2000
	Euro II	2002/51	2004
	Euro III	2002/51	2014[f]
	Euro IV	168/2013	2017
	Euro V	168/2013	2021
Motor cycles	Conventional	Conventional	0
	Euro I	97/24	2000

Continued…

	Euro II	2002/51	2004
	Euro III	2002/51	2007
	Euro IV	168/2013	2017
	Euro V	168/2013	2021

a,b,c,d: Expert judgement suggest that Danish vehicles enter into the traffic before EU directive first registration dates. The effective inventory starting years are a: 1970; b: 1979; c: 1981; d: 1986.e: The directive came into force in Denmark in 1991 (EU starting year: 1993).

In practice, the emissions from vehicles in traffic are different from the legislation limit values and, therefore, the latter figures are considered to be too inaccurate for total emission calculations. A major constraint is that the emission approval test conditions reflect only to a small degree the large variety of emission influencing factors in the real traffic situation, such as cumulated mileage driven, engine and exhaust after treatment maintenance levels and driving behaviour.

Therefore, in order to represent the Danish fleet and to support average national emission estimates, emission factors must be chosen which derive from numerous emissions measurements, using a broad range of real world driving patterns and a sufficient number of test vehicles. It is similar important to have separate fuel consumption and emission data for cold-start emission calculations and gasoline evaporation (hydrocarbons).

For heavy-duty vehicles (trucks and buses), the emission limits are given in g per kWh and the measurements are carried out for engines in a test bench, using the EU ESC (European Stationary Cycle) and ETC (European Transient Cycle) test cycles, depending on the Euro norm and exhaust gas after-treatment system installed. A description of the test cycles is given by Nørgaard and Hansen (2004). Measurement results in g per kWh from emission approval tests cannot be directly used for inventory work. Instead, emission factors used for national estimates must be transformed into g per km, and derived from a sufficient number of measurements which represent the different vehicle size classes, Euro engine levels and real world variations in driving behaviour.

Fuel consumption and emission factors

The fuel consumption and emission factors used in the Danish inventory come from the COPERT IV (version 11) model. The source for these data is various European measurement programmes. In general the COPERT data are transformed into trip-speed dependent fuel consumption and emission factors for all vehicle categories and layers by using trip speeds as shown in Table 3.3.8. The factors are listed in Annex 2.B.4.

Adjustment for fuel efficient vehicles

In the Danish fleet and mileage database, the type approval fuel efficiency value based on the NEDC driving cycle (TA_{NEDC}) is registered for each single car. Further, a modified fuel efficiency value (TA_{inuse}) is calculated using TA_{NEDC}, vehicle weight and engine size as input parameters. The TA_{inuse} value better reflects the fuel consumption associated with the NEDC driving cycle under real ("inuse") traffic conditions (Emisia, 2012).

From 2006 up to last historical year represented by fleet data, the average CO_2 emission factor (by fleet number) is calculated for each year's new sold cars, based on the registered TA_{NEDC} values. Using the average CO_2 emission factor for the last historical year as starting point, the average emission factor for each year's new sold cars are linearly reduced, until the emission factor reaches 95 g CO_2 per km in 2020.

From 2006 up to last historical year, the average CO_2 emission factor (by fleet number) is also calculated for each year's new sold cars, and for each fuel type/engine size combination, based on TA_{NEDC} and TA_{inuse}.

The linear reduction of the average emission factor for each year's new sold cars is then used to reduce the CO_2 emission factors for new sold cars based on TA_{inuse}, between last historical year and 2020, for each of the fuel type/engine size fleet segments.

Subsequently for each layer and inventory year, CO_2 emission factors are calculated based on TA_{inuse} and weighted by total mileage. On the same time corresponding layer specific CO_2 factors from COPERT IV are set up valid for Euro 4+ vehicles in the COPERT model. The COPERT IV CO_2 factors are derived from fuel consumption factors assessed by the developers of COPERT IV (Emisia, 2012) to represent the COPERT test vehicles under the NEDC driving cycle in real world traffic ($TA_{COPERT\ IV,inuse}$).

In a final step the ratio between the layer specific CO_2 emission factors for the Danish fleet and the COPERT Euro IV vehicles under TA_{inuse} are used to scale the trip speed dependent fuel consumption factors provided by COPERT IV for Euro 4 layers onwards.

Adjustment for EGR, SCR and filter retrofits

In COPERT IV updated emission factors have recently been made available for Euro V heavy duty vehicles using EGR and SCR exhaust emission after-treatment systems, respectively. The estimated new sales of Euro V diesel trucks equipped with EGR and SCR during the 2006-2010 time periods has been examined by Hjelgaard and Winther (2011). These inventory fleet data are used in the Danish inventory to calculate weighted emission factors for Euro V trucks in different size categories.

During the 2000's urban environmental zones have been established in Danish cities in order to bring down the particulate emissions from diesel fuelled heavy duty vehicles. Driving in these environmental zones prescribe the use of diesel particulate filters. The Danish EPA has provided the estimated number of Euro I-III urban buses and Euro II-III trucks and tourist buses which have been retrofitted with filters during the 2000's. These retrofit data are included in the Danish inventory by assuming that particulate emissions are lowered by 80 % compared with the emissions from the same Euro technology with no filter installed (Winther, 2011).

For all vehicle categories/technology levels not represented by measurements, the emission factors are produced by using reduction factors. The latter factors are determined by assessing the EU emission limits and the relevant emission approval test conditions, for each vehicle type and Euro class.

Deterioration factors

For three-way catalyst cars the emissions of NO_X, NMVOC and CO gradually increase due to catalyst wear and are, therefore, modified as a function of total mileage by the so-called deterioration factors. Even though the emission curves may be serrated for the individual vehicles, on average, the emissions from catalyst cars stabilise after a given cut-off mileage is reached due to OBD (On Board Diagnostics) and the Danish inspection and maintenance programme.

For each year, the deterioration factors are calculated per first registration year by using deterioration coefficients and cut-off mileages, as given in EMEP/EEA (2013), for the corresponding layer. The deterioration coefficients are given for the two driving cycles: ”Urban Driving Cycle” (UDF) and ”Extra Urban Driving Cycle” (EUDF: urban and rural), with trip speeds of 19 and 63 km per hour, respectively.

Firstly, the deterioration factors are calculated for the corresponding trip speeds of 19 and 63 km per hour in each case determined by the total cumulated mileage less than or exceeding the cut-off mileage. The Formulas 3 and 4 show the calculations for the ”Urban Driving Cycle”:

$$UDF = U_A \cdot MTC + U_B \text{, MTC} < U_{MAX} \quad (3)$$

$$UDF = U_A \cdot U_{MAX} + U_B \text{, MTC} >= U_{MAX} \quad (4)$$

where UDF is the urban deterioration factor, U_A and U_B the urban deterioration coefficients, MTC = total cumulated mileage and U_{MAX} urban cut-off mileage.

In the case of trip speeds below 19 km per hour the deterioration factor, DF, equals UDF, whereas for trip speeds exceeding 63 km per hour, DF=EUDF. For trip speeds between 19 and 63 km per hour the deterioration factor, DF, is found as an interpolation between UDF and EUDF. Secondly, the deterioration factors, one for each of the three road types, are aggregated into layers by taking into account vehicle numbers and annual mileage levels per first registration year:

$$DF_{j,y} = \frac{\sum_{i=FYear(j)}^{LYear(j)} DF_{i,y} \cdot N_{i,y} \cdot M_{i,y}}{\sum_{i=FYear(j)}^{LYear(j)} DF_{i,y} \cdot N_{i,y}} \quad (5)$$

where DF is the deterioration factor.

For N_2O and NH_3, COPERT IV takes into account deterioration as a linear function of mileage for gasoline fuelled EURO 1-4 passenger cars and light duty vehicles. The level of emission deterioration also relies on the content of sulphur in the fuel. The deterioration coefficients are given in EMEP/EEA (2013), for the corresponding layer. A cut-off mileage of 250 000 km is behind the calculation of the modified emission factors, and for the Danish situation the low sulphur level interval is assumed to be most representative.

Emissions and fuel consumption for hot engines

Emissions and fuel consumption results for operationally hot engines are calculated for each year and for layer and road type. The procedure is to combine fuel consumption and emission factors (and deterioration factors for catalyst vehicles), number of vehicles, annual mileage levels and the relevant road-type shares given in Table 3.3.7. For non-catalyst vehicles this yields:

$$E_{j,k,y} = EF_{j,k,y} \cdot S_k \cdot N_{j,y} \cdot M_{j,y} \quad (6)$$

Here E = fuel consumption/emission, EF = fuel consumption/emission factor, S = road type share and k = road type.

For catalyst vehicles the calculation becomes:

$$E_{j,k,y} = DF_{j,k,y} \cdot EF_{j,k,y} \cdot S_k \cdot N_{j,y} \cdot M_{j,y} \quad (7)$$

Extra emissions and fuel consumption for cold engines

Extra emissions of NO_X, VOC, CH_4, CO, PM, N_2O, NH_3 and fuel consumption from cold start are simulated separately. For SO_2 and CO_2, the extra emissions are derived from the cold start fuel consumption results.

Each trip is associated with a certain cold-start emission level and is assumed to take place under urban driving conditions. The number of trips is distributed evenly across the months. First, cold emission factors are calculated as the hot emission factor times the cold:hot emission ratio. Secondly, the extra emission factor during cold start is found by subtracting the hot emission factor from the cold emission factor. Finally, this extra factor is applied on the fraction of the total mileage driven with a cold engine (the β-factor) for all vehicles in the specific layer.

The cold:hot ratios depend on the average trip length and the monthly ambient temperature distribution. The Danish temperatures for 2013 are given in Cappelen et al. (2014). For previous years, temperature data are taken from similar reports available from The Danish Meteorological Institute (www.dmi.dk). The cold:hot ratios are equivalent for gasoline fuelled conventional passenger cars and vans and for diesel passenger cars and vans, respectively, see EMEP/EEA (2013). For conventional gasoline and all diesel vehicles the extra emissions become:

$$CE_{j,y} = \beta \cdot N_{j,y} \cdot M_{j,y} \cdot EF_{U,j,y} \cdot (CEr - 1) \quad (8)$$

Where CE is the cold extra emissions, β = cold driven fraction, CEr = Cold:Hot ratio.

For catalyst cars, the cold:hot ratio is also trip speed dependent. The ratio is, however, unaffected by catalyst wear. The Euro I cold:hot ratio is used for all future catalyst technologies. However, in order to comply with gradually stricter emission standards, the catalyst light-off temperature must be reached in even shorter periods of time for future EURO standards. Correspondingly, the β-factor for gasoline vehicles is reduced step-wise for Euro II vehicles and their successors.

For catalyst vehicles the cold extra emissions are found from:

$$CE_{j,y} = \beta_{red} \cdot \beta_{EUROI} \cdot N_{j,y} \cdot M_{j,y} \cdot EF_{U,j,y} \cdot (CEr_{EUROI} - 1) \quad (9)$$

where β_{red} = the β reduction factor.

For CH_4, specific emission factors for cold driven vehicles are included in COPERT IV. The β and β_{red} factors for VOC are used to calculate the cold driven fraction for each relevant vehicle layer. The NMVOC emissions during cold start are found as the difference between the calculated results for VOC and CH_4.

For N_2O and NH_3, specific cold start emission factors are also proposed by COPERT IV. For catalyst vehicles, however, just like in the case of hot emission factors, the emission factors for cold start are functions of cumulated mileage (emission deterioration). The level of emission deterioration also relies on the content of sulphur in the fuel. The deterioration coefficients are given in EMEP/EEA (2013), for the corresponding layer. For cold start, the cut-off mileage and sulphur level interval for hot engines are used, as described in the deterioration factors paragraph.

Evaporative emissions from gasoline vehicles

For each year, evaporative emissions of hydrocarbons are simulated in the forecast model as hot and warm running losses, hot and warm soak loss and diurnal emissions. The calculation approach is the same as in COPERT III. All emission types depend on RVP (Reid Vapour Pressure) and ambient temperature. The emission factors are shown in EMEP/EEA (2013).

Running loss emissions originate from vapour generated in the fuel tank while the vehicle is running. The distinction between hot and warm running loss emissions depends on engine temperature. In the model, hot and warm running losses occur for hot and cold engines, respectively. The emissions are calculated as annual mileage (broken down into cold and hot mileage totals using the β-factor) times the respective emission factors. For vehicles equipped with evaporation control (catalyst cars), the emission factors are only one tenth of the uncontrolled factors used for conventional gasoline vehicles.

$$R_{j,y} = N_{j,y} \cdot M_{j,y} \cdot ((1-\beta) \cdot HR + \beta \cdot WR) \qquad (10)$$

where R is running loss emissions and HR and WR are the hot and warm running loss emission factors, respectively.

In the model, hot and warm soak emissions for carburettor vehicles also occur for hot and cold engines, respectively. These emissions are calculated as number of trips (broken down into cold and hot trip numbers using the β-factor) times respective emission factors:

$$S_{j,y}{}^{C} = N_{j,y} \cdot \frac{M_{j,y}}{l_{trip}} \cdot ((1-\beta) \cdot HS + \beta \cdot WS) \qquad (11)$$

where S^C is the soak emission, l_{trip} = the average trip length, and HS and WS are the hot and warm soak emission factors, respectively. Since all catalyst vehicles are assumed to be carbon canister controlled, no soak emissions are estimated for this vehicle type. Average maximum and minimum temperatures pr month are used in combination with diurnal emission factors to estimate the diurnal emissions from uncontrolled vehicles $E^d(U)$:

$$E_{j,y}{}^{d}(U) = 365 \cdot N_{j,y} \cdot e^{d}(U) \qquad (12)$$

Each year's total is the sum of each layer's running loss, soak loss and diurnal emissions.

Fuel consumption balance

The calculated fuel consumption in COPERT IV must equal the statistical fuel sale totals according to the UNFCCC and UNECE emissions reporting format. The statistical fuel sales for road transport are derived from the Danish Energy Agency data (see DEA, 2014). The DEA data are further processed for gasoline in order to account for e.g. non road and recreational craft fuel consumption, which are not directly stated in the statistics, please refer to paragraph 3.3.3 for further information regarding the transformation of DEA fuel data.

The standard approach to achieve a fuel balance in annual emission inventories is to multiply the annual mileage with a fuel balance factor derived as the ratio between simulated and statistical fuel figures for gasoline and diesel, respectively. This method is also used in the present model.

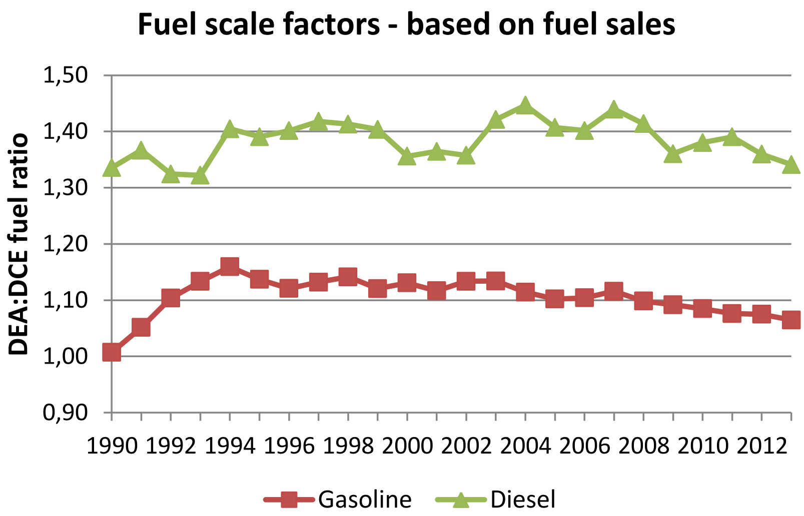


Figure 3.3.35 DEA:DCE Fuel ratios (mileage adjustment factors) based on DEA fuel sales data and DCE fuel consumption estimates.

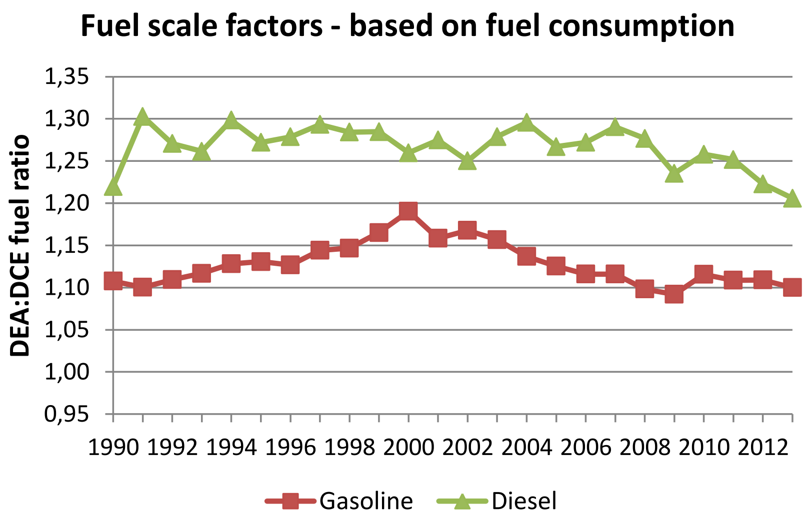


Figure 3.3.36 DEA:DCE Fuel ratios (mileage adjustment factors) based on DEA fuel consumption data and DCE fuel consumption estimates.

In Figure 3.3.35 and Figure 3.3.36 the COPERT IV:DEA gasoline and diesel fuel consumption ratios are shown for fuel sales and fuel consumption from 1990-2012. The data behind the figures are also listed in Annex 3.B.8. The fuel consumption figures are related to the traffic on Danish roads.

Per fuel type, all mileage numbers are equally scaled in order to obtain fuel equilibrium, and hence the mileage factors used are the reciprocal values of the COPERT IV:DEA fuel consumption: fuel sales ratio.

The reasons for the differences between DEA sales figures and bottom-up fuel estimates are mostly due to a combination of the uncertainties related to COPERT IV fuel consumption factors, allocation of vehicle numbers in sub-categories, annual mileage, trip speeds and mileage splits for urban, rural and highway driving conditions.

The final fuel consumption and emission factors per vehicle type are shown in Annex 3.B.7 for 1990-2013. The total fuel consumption and emissions are shown in Annex 3.B.8, per vehicle category and as grand totals, for 1990-2013 (and CRF format in Annex 3.B.16). In Annex 3.B.15, fuel consumption and emission factors as well as total emissions are given in CollectER format for 1990 and 2013.

In the following Figures 3.3.37 - 3.3.40, the fuel and km related emission factors for CO_2 (km related only), CH_4 and N_2O are shown per vehicle type for the Danish road transport (from 1990-2013).

For CO_2 the neat gasoline/diesel emission factors shown in Table 3.3.8 are country specific values, and come from the DEA. In 2006 and 2008, respectively, bio ethanol and biodiesel became available from a limited number of gas filling stations in Denmark, and today bio ethanol and biodiesel is added to all fuel commercially available. Following the IPCC guideline definitions, bio ethanol is regarded as CO_2 neutral for the transport sector as such. The sulphur content for bio ethanol/biodiesel is assumed to be zero, and hence, the aggregated CO_2 (and SO_2) factors for gasoline/diesel have been adjusted, on the basis of the energy content of neat gasoline/diesel and bio ethanol/biodiesel, respectively, in the available fuels.

At present, the Danish road transport fuels only have low biofuel (BF) shares (Table 3.3.8), and hence, no thermal efficiency changes are expected for the fuels. Consequently, the energy based fuel consumption factors (MJ/km) derived from COPERT IV are used also in this case.

As a function of the current ethanol/biodiesel energy percentage, $BF\%_E$, (Table 4.3) the average fuel related CO_2 emission factors, $emf_{CO2,E}(BF\%)$ become:

$$EF_{CO_2,E}(BF\%) = EF_{CO_2,E}(BF0) \cdot (100 - BF\%_E) \quad (13)$$

Where:

$EF_{CO2,E}(BF\%)$ = average fuel related CO_2 emission factor (g MJ^{-1}) for current BF%

$EF_{CO2,E}(BF0)$ = fuel related CO_2 emission factor (g MJ^{-1}) for fossil fuels

The kilometre based average CO_2 emission factor is subsequently calculated as the product of the fuel related CO_2 emission factor from equation 3 and the energy based fuel consumption factor, $FC_{CO2,E}(BF0)$, derived from COPERT IV:

$$EF_{CO_2,km}(BF\%) = EF_{CO_2,E}(BF\%) \cdot FC_E(BF0) \quad (14)$$

A literature review carried out in the Danish research project REBECA revealed no significant changes in emission factors between neat gasoline and E5 gasoline-ethanol blends for the combustion related emission components; NO_x, CO and VOC (Winther et al., 2012). Hence, due to the current low ethanol content in today's road transport gasoline, no modifications of the neat gasoline based COPERT emission factors are made in the inventories in order to account for ethanol usage.

REBECa results published by Winther (2009) have shown that the emission impact of using diesel-biodiesel blends is very small at low biodiesel blend ratios. Consequently no bio fuel emission factor adjustments are needed for diesel vehicles as well. However, adjustment of the emission factors for diesel vehicles will be made if the biodiesel content of road transport diesel fuel increases to a more significant level in the future.

The fuel related CO_2 emission factors for neat gasoline/diesel, bio ethanol/biodiesel, and aggregated CO_2 factors are shown in Table 3.3.6.

Table 3.3.6 Fuel-specific CO_2 emission factors and biofuel shares for road transport in Denmark.

	Emission factors (g/MJ)								
Fuel type	1990-2005	2006	2007	2008	2009	2010	2011	2012	2013
Neat gasoline	73	73	73	73	73	73	73	73	73
Neat diesel	74	74	74	74	74	74	74	74	74
LPG	63.1	63.1	63.1	63.1	63.1	63.1	63.1	63.1	63.1
Bio ethanol	0	0	0	0	0	0	0	0	0
Biodiesel	0	0	0	0	0	0	0	0	0
Gasoline, average	73	72.9	72.8	72.8	72.8	71.7	70.7	70.6	70.4
Diesel, average	74	74	74	74	73.9	74	71.5	69.4	69.2
	Biofuel share (BF%) of Danish road transport fuels								
	1990-2005	2006	2007	2008	2009	2010	2011	2012	2013
	0	0.09	0.14	0.13	0.21	0.69	3.40	5.30	5.50

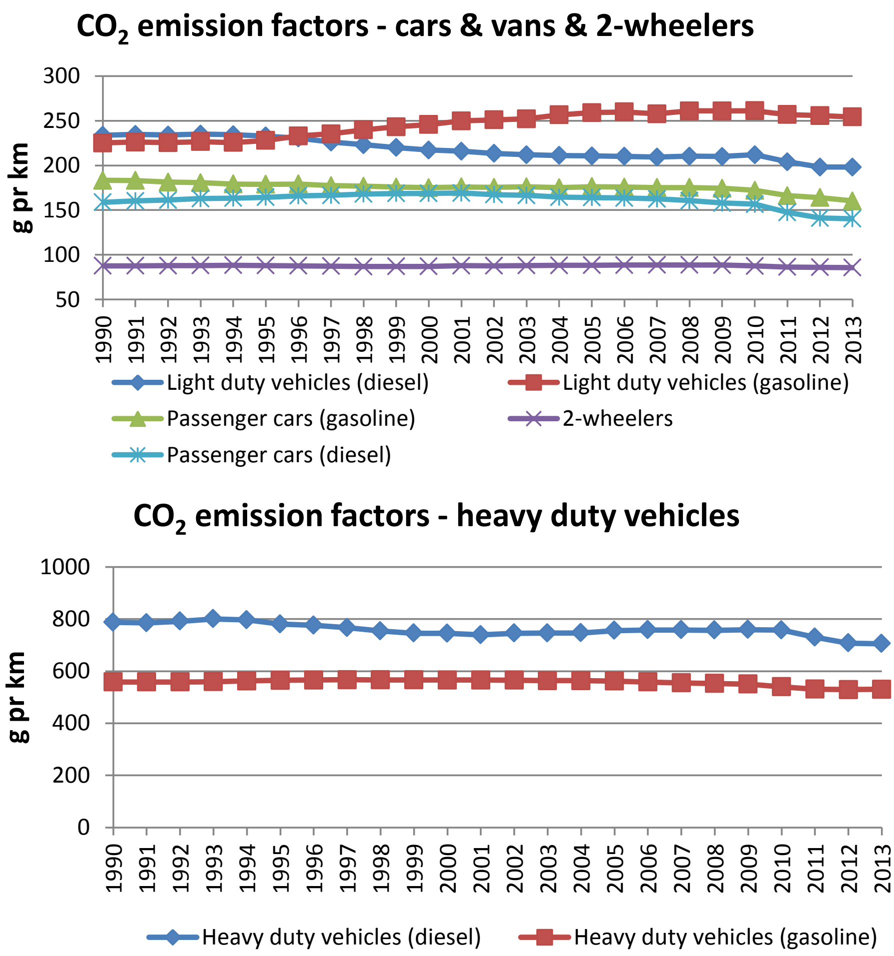


Figure 3.3.37 Km related CO_2 emission factors per vehicle type for Danish road transport (1990-2013).

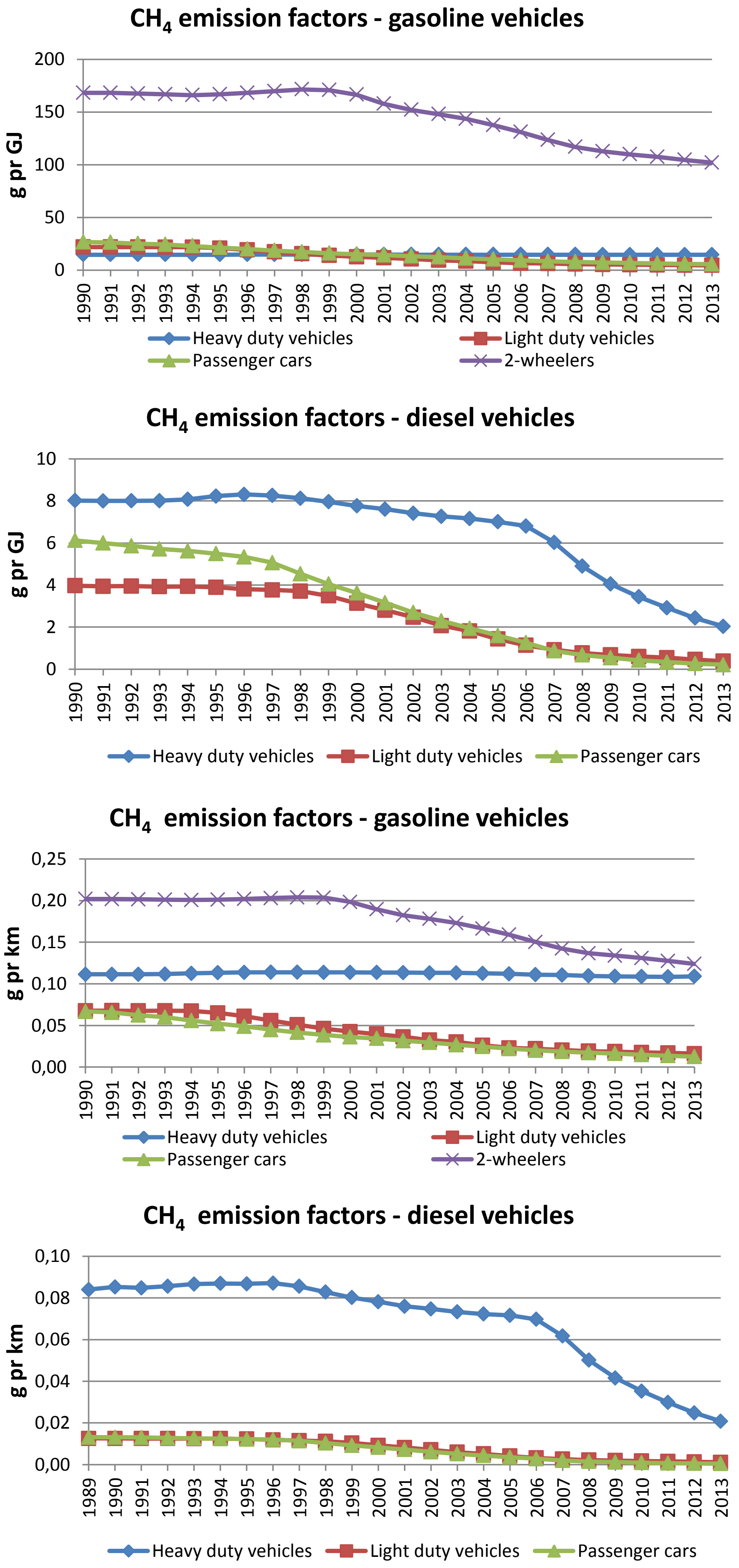


Figure 3.3.38 Fuel and km related CH_4 emission factors per vehicle type for Danish road transport (1990-2013).

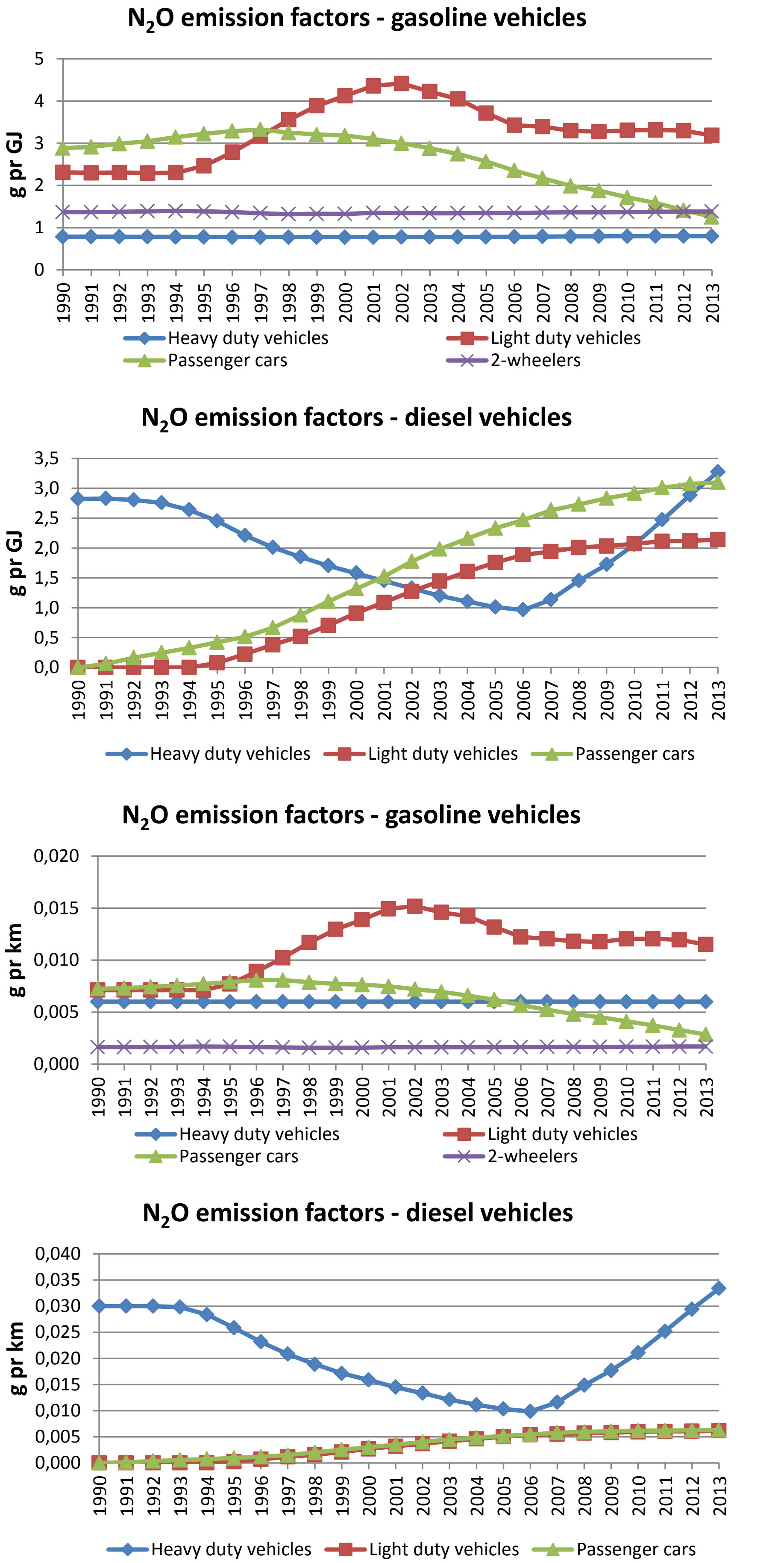


Figure 3.3.39 Fuel and km related N_2O emission factors per vehicle type for Danish road transport (1990-2013).

Methodologies and references for other mobile sources

Other mobile sources are divided into several sub-sectors: sea transport, fishery, air traffic, railways, military, and working machinery and equipment in the sectors agriculture, forestry, industry and residential. The emission calculations are made using the detailed method as described in the EMEP/EEA air pollutant emission inventory guidebook (EMEP/EEA, 2013) for air traffic, off-road working machinery and equipment, and ferries, while for the remaining sectors the simple method is used.

3.3.3 Activity data

Air traffic

The activity data for air traffic consists of air traffic statistics provided by the Danish Transport Authority and Copenhagen Airport. Fuel statistics for jet fuel consumption and aviation gasoline are obtained from the Danish energy statistics (DEA, 2014).

For 2001 onwards, per flight records are provided by the Danish Transport Authority as data codes for aircraft type, and origin and destination airports (city-pairs).

Subsequently the aircraft types are separated by DCE into larger aircraft using jet fuel (jet engines, turbo props, helicopters) and small aircraft types with piston engines using aviation gasoline. This is done by using different aircraft dictionaries, internet look-ups and by communication with the Danish Transport Authority. Each of the larger aircraft type is then matched with a representative type for which fuel consumption and emission data are available from the EMEP/EEA databank. Relevant for this selection is aircraft maximum take off mass, engine types, and number of engines. A more thorough explanation is given in Winther (2001a, b).

Annex 3.B.10 shows the correspondence table between the actual aircraft type codes and representative aircraft types behind the Danish inventory. Annex 3.B.10 also show the number of LTO's per representative aircraft type for domestic and international flights starting from Copenhagen Airport and other airports, respectively[6], in a time series from 2001-2013. The airport split is necessary to make due to the differences in LTO emission factors (c.f. section 3.3.4).

The same type of LTO activity data for the flights for Greenland and the Faroe Islands are shown in Annex 3.B.10 also, further detailed into an origin-destination airport matrix and having flight distances attached. This level of detail satisfies the demand from UNFCCC to provide precise documentation for the part of the inventory for the Kingdom of Denmark being outside the Danish mainland.

The ideal flying distance (great circle distance) between the city-pairs is calculated by DCE in a separate database. The calculation algorithm uses a global latitude/altitude coordinate table for airports. In cases when airport coordinates are not present in the DCE database, these are looked up on the internet and entered into the database accordingly.

[6] Excluding flights for Greenland and the Faroe Islands. These flights are separately listed in Annex 3.B.10.

For inventory years prior to 2001, detailed LTO/aircraft type statistics are obtained from Copenhagen Airport (for this airport only), while information of total take-off numbers for other Danish airports is provided by the Danish Transport Authority. The assignment of representative aircraft types for Copenhagen Airport is done as described above. For the remaining Danish airports representative aircraft types are not directly assigned. Instead appropriate average assumptions are made relating to the fuel consumption and emission data part.

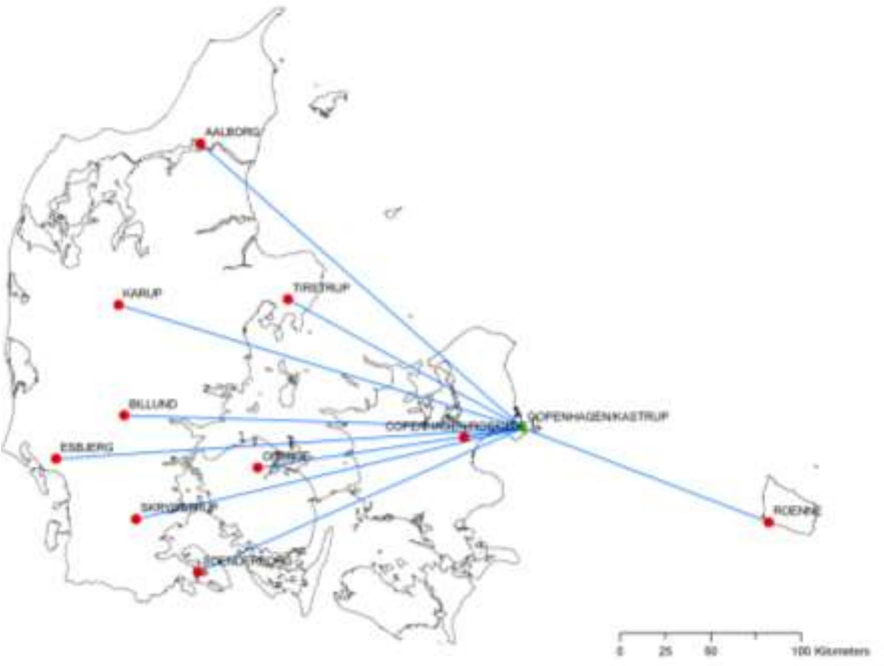
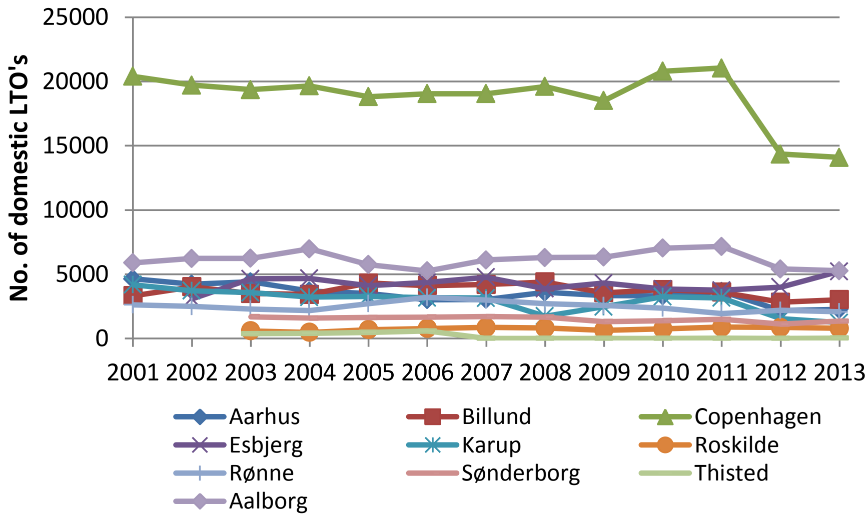


Figure 3.3.40 Most frequent domestic flying routes for large aircraft in Denmark.

Copenhagen Airport is the starting or end point for most of the domestic aviation made by large aircraft in Denmark (Figure 3.3.40; routes to Greenland/Faroe Islands are not shown). Even though many domestic flights not touching Copenhagen Airport are also reported in the flight statistics kept by the Danish Transport Authority, these flights, however, are predominantly made with small piston engine aircraft using aviation gasoline. Hence, the consumption of jet fuel by flights not using Copenhagen is merely marginal.



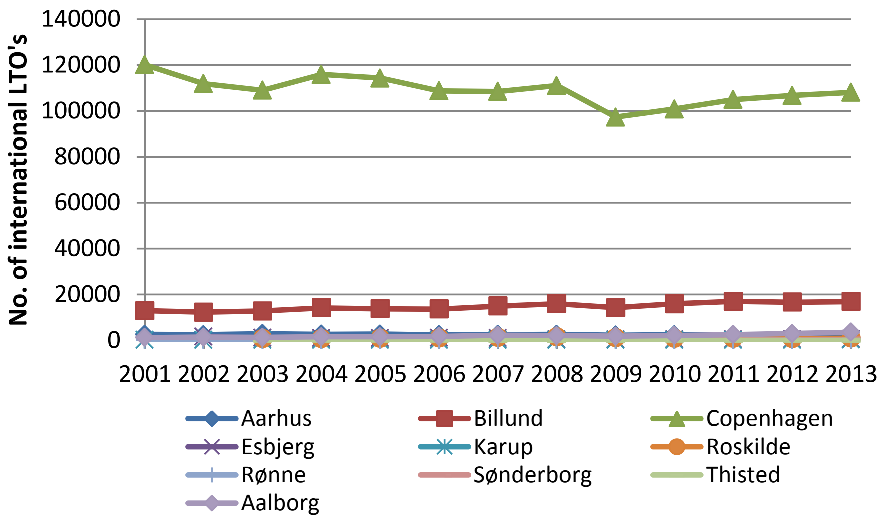


Figure 3.3.41 No. of LTO's for the most important airports in Denmark 2001-2013.

Figure 3.3.41 shows the number of domestic and international LTO's for Danish airports[7], in a time series from 2001-2013.

Non-road working machinery and equipment

Non-road working machinery and equipment are used in agriculture, forestry and industry, for household/gardening purposes and in inland waterways (recreational craft). Information on the number of different types of machines, their respective load factors, engine sizes and annual working hours has been provided by Winther et al. (2006) for the years until 2004. For later inventory years, supplementary stock data are annually provided by the Association of Danish Agricultural Machinery Dealers and the Association of Producers and Distributors of Fork Lifts in Denmark. The stock development from 1990-2013 for the most important types of machinery are shown in Figures 3.3.42 - 3.3.49. The stock data are also listed in Annex 3.B.11, together with figures for load factors, engine sizes and annual working hours. As regards stock data for the remaining machinery types, please refer to (Winther et al., 2006).

It is important to note that from key experts in the field of industrial non road activities a significant decrease in the activities is assumed for 2009 due

[7] Flights for Greenland and the Faroe Islands are included under domestic in the figure.

to the global financial crisis. This reduction is in the order of 25 % for 2009 for industrial non road in general (pers. comm. Per Stjernqvist, Volvo Construction Equipment 2010). For fork lifts, 5 % and 20 % reductions are assumed for 2008 and 2009, respectively (pers. comm. Peter H. Møller, Rocla A/S).

For agriculture, the total number of agricultural tractors and harvesters per year are shown in the Figures 3.3.42 - 3.3.43, respectively. The figures clearly show a decrease in the number of small machines, these being replaced by machines in the large engine-size ranges.

The tractor and harvester developments towards fewer vehicles and larger engines, shown in Figure 3.3.44, are very clear. From 1990 to 2013, tractor and harvester numbers decrease by around 22 % and 42 %, respectively, whereas the average increase in engine size for tractors is 35 % and 169 % for harvesters, in the same time period.

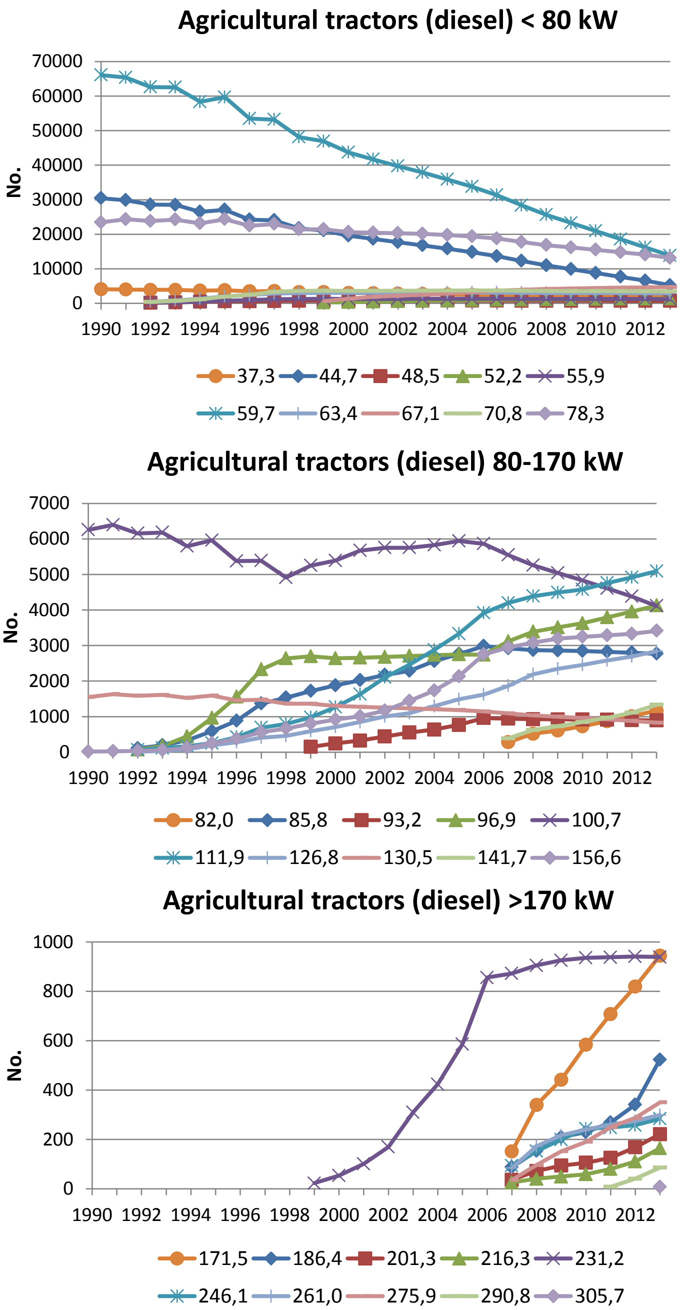


Figure 3.3.42 Total numbers in kW classes for tractors from 1990 to 2013.

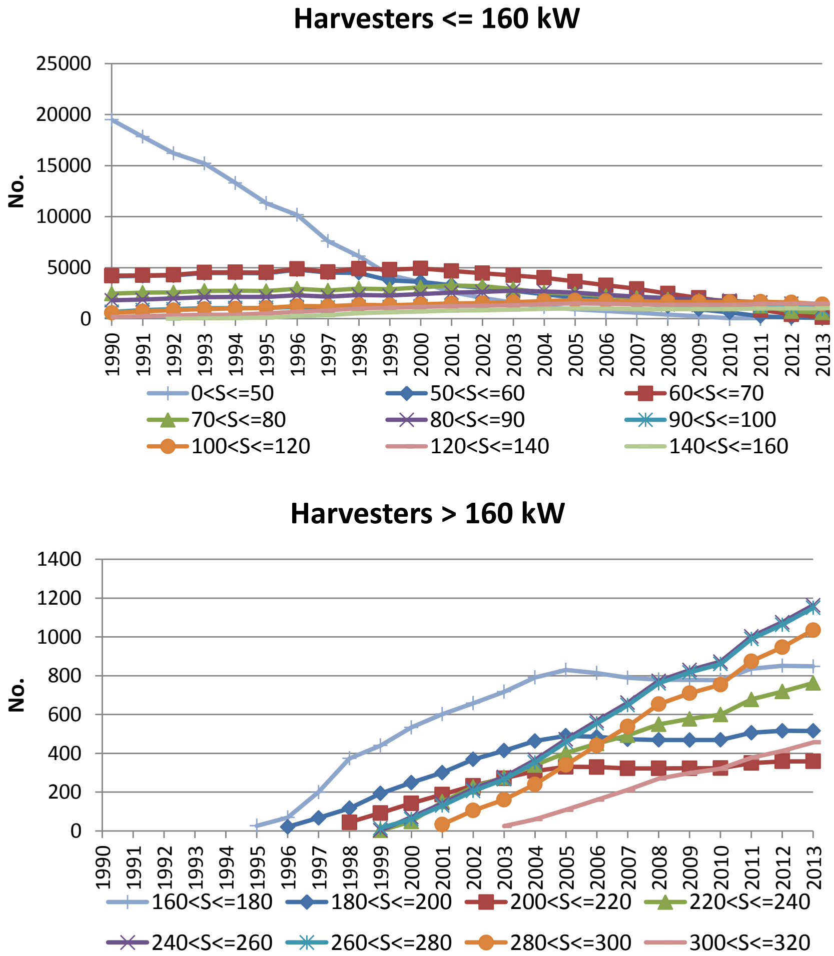


Figure 3.3.43 Total numbers in kW classes for harvesters from 1990 to 2013.

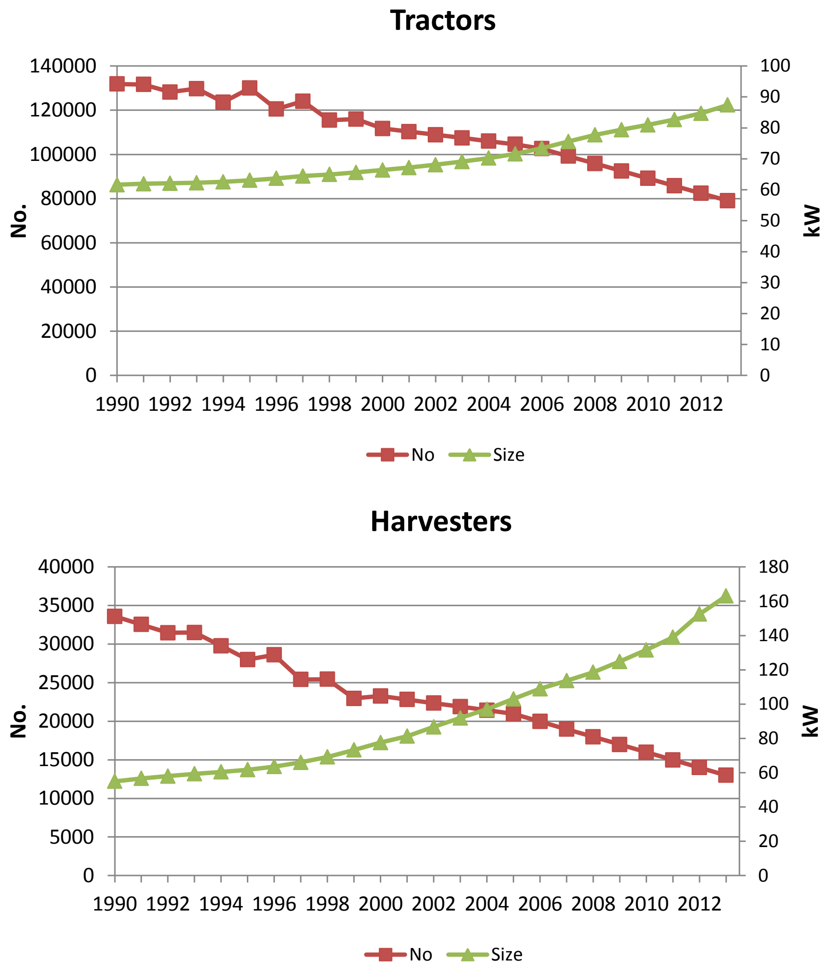


Figure 3.3.44 Total numbers and average engine size for tractors and harvesters (1990 to 2013).

The most important machinery types for industrial use are different types of construction machinery and fork lifts. The Figures 3.3.45 and 3.3.46 show the 1990-2013 stock development for specific types of construction machinery and diesel fork lifts. For most of the machinery types there is an increase in machinery numbers from 1990 onwards, due to increased construction activities. It is assumed that track type excavators/wheel type loaders (0-5 tonnes), and telescopic loaders first enter into use in 1991 and 1995, respectively.

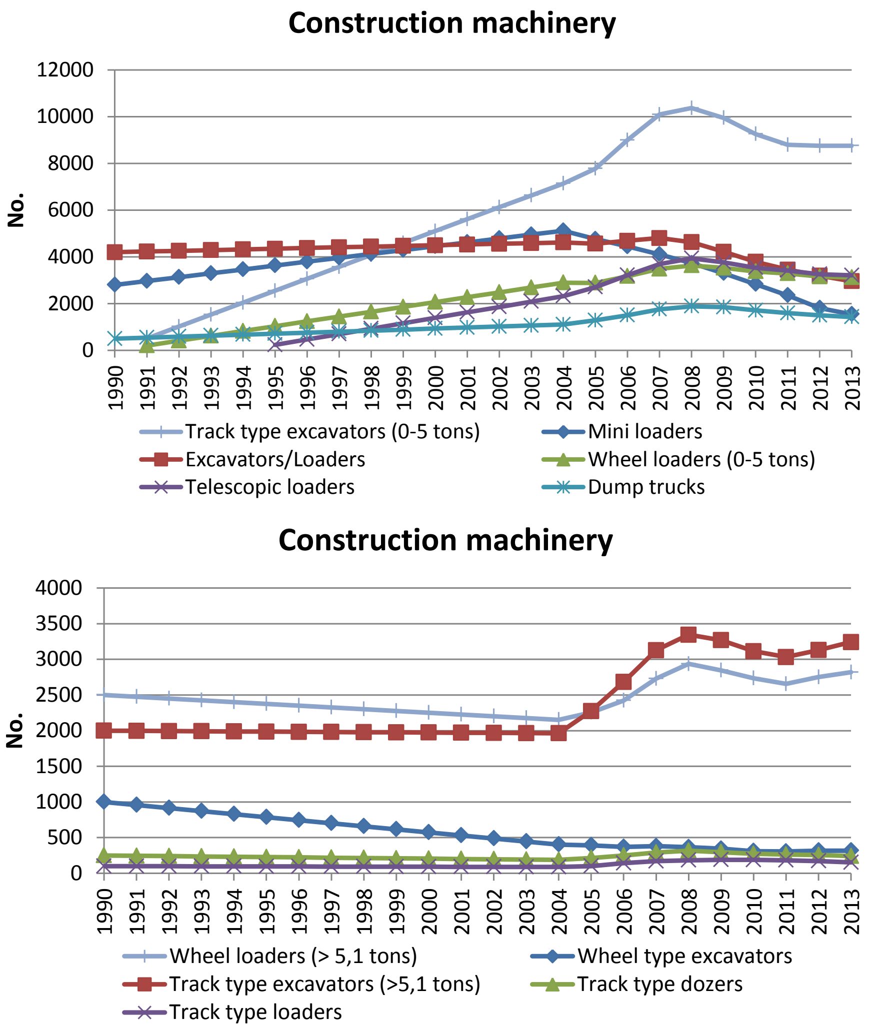


Figure 3.3.45 1990-2013 stock development for specific types of construction machinery.

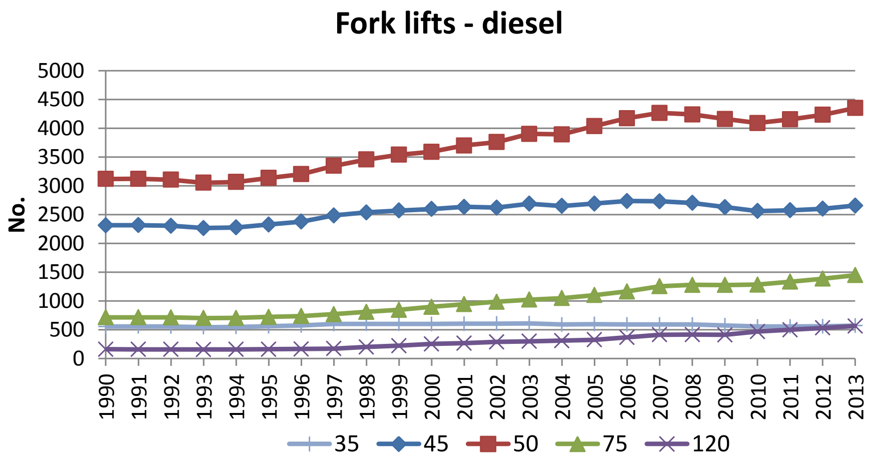


Figure 3.3.46 Total numbers of diesel fork lifts in kW classes from 1990 to 2013.

The emission level shares for tractors, harvesters, construction machinery and diesel fork lifts are shown in Figure 3.3.47, and present an overview of the penetration of the different pre-Euro engine classes, and engine stages complying with the gradually stricter EU stage I and II emission limits. The average lifetimes of 30, 25, 20 and 10 years for tractors, harvesters, fork lifts and construction machinery, respectively, influence the individual engine technology turn-over speeds.

The EU emission directive Stage I and II implementation years relate to engine size, and for all four machinery groups the emission level shares for the specific size segments will differ slightly from the picture shown in Figure 3.3.47. Due to scarce data for construction machinery, the emission level penetration rates are assumed to be linear and the general technology turnover pattern is as shown in Figure 3.3.47.

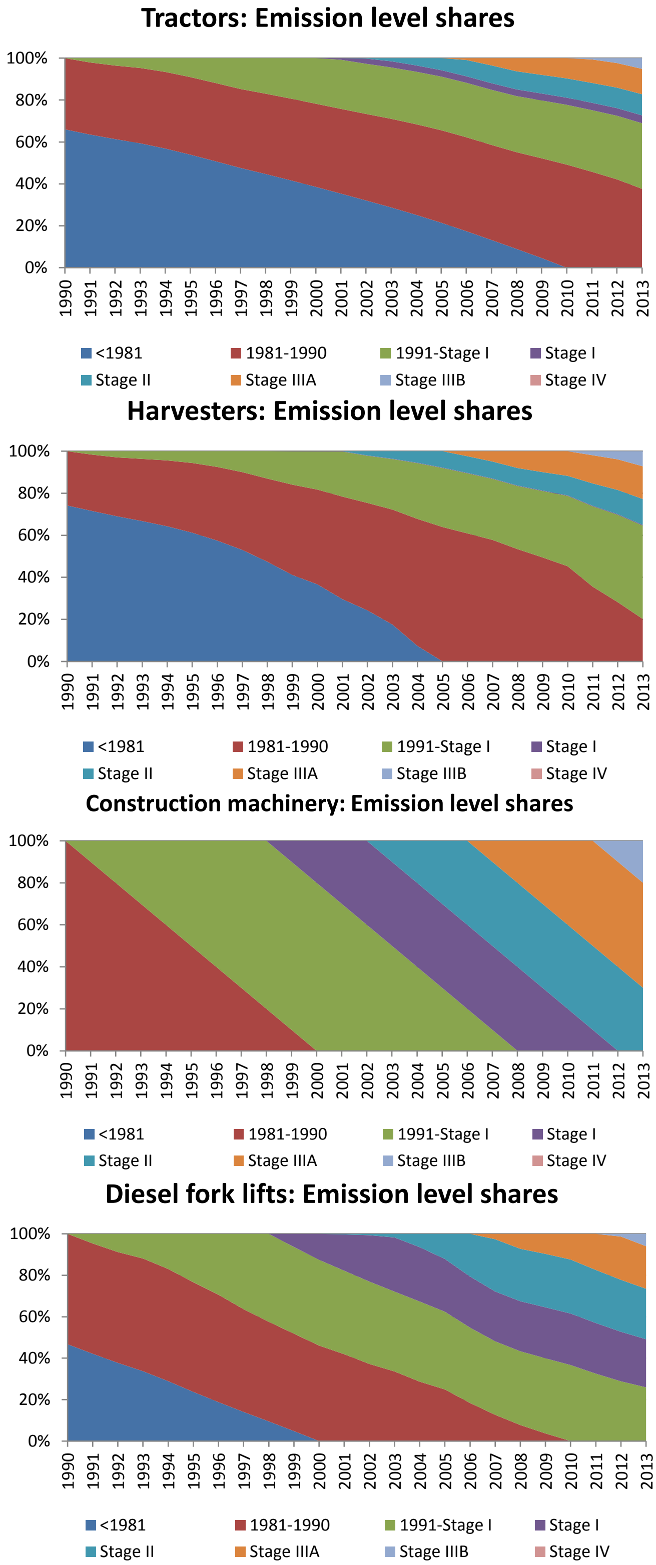


Figure 3.3.47 Emission level shares for tractors, harvesters, construction machinery and diesel fork lifts (1990 to 2013).

The 1990-2013 stock development for the most important household and gardening machinery types is shown in Figure 3.3.48.

For lawn movers and cultivators, the machinery stock remains approximately the same for all years. The stock figures for chain saws, shrub clearers, trimmers and hedge cutters increase from 1990 until 2004, and for riders this increase continues also after 2004. The yearly stock increases, in most cases, become larger after 2000. The lifetimes for gasoline machinery are short and, therefore, there new emission levels (not shown) penetrate rapidly.

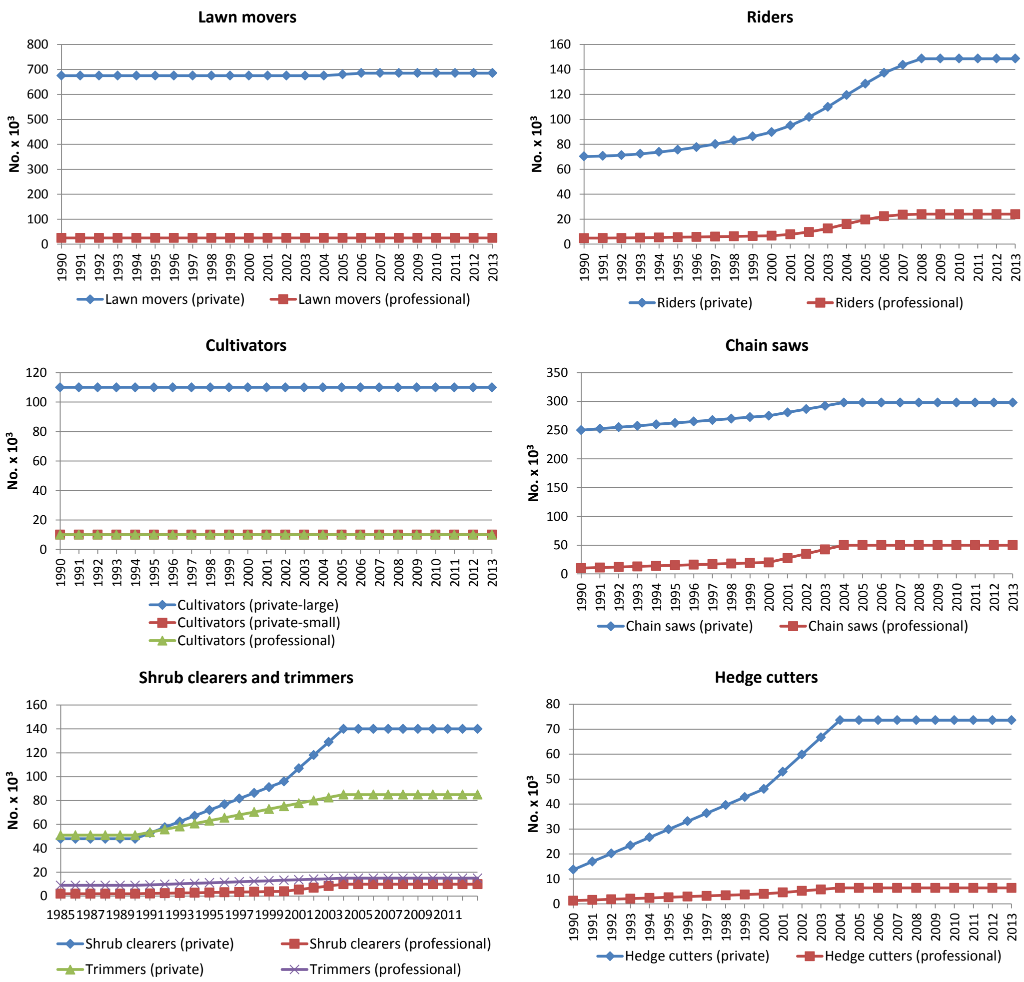


Figure 3.3.48 Stock development 1990-2013 for the most important household and gardening machinery types.

Figure 3.3.49 shows the development in numbers of different recreational craft from 1990-2013. The 2004 stock data for recreational craft are repeated for 2005+, since no new fleet information has been obtained.

For diesel boats, increases in stock and engine size are expected during the whole period, except for the number of motor boats (< 27 ft.) and the engine sizes for sailing boats (<26 ft.), where the figures remain unchanged. A decrease in the total stock of sailing boats (<26 ft.) by 21 % and increases in the total stock of yawls/cabin boats and other boats (<20 ft.) by around 25 % are expected. Due to a lack of information specific to Denmark, the shifting rate from 2-stroke to 4-stroke gasoline engines is based on a German non-road study (IFEU, 2004).

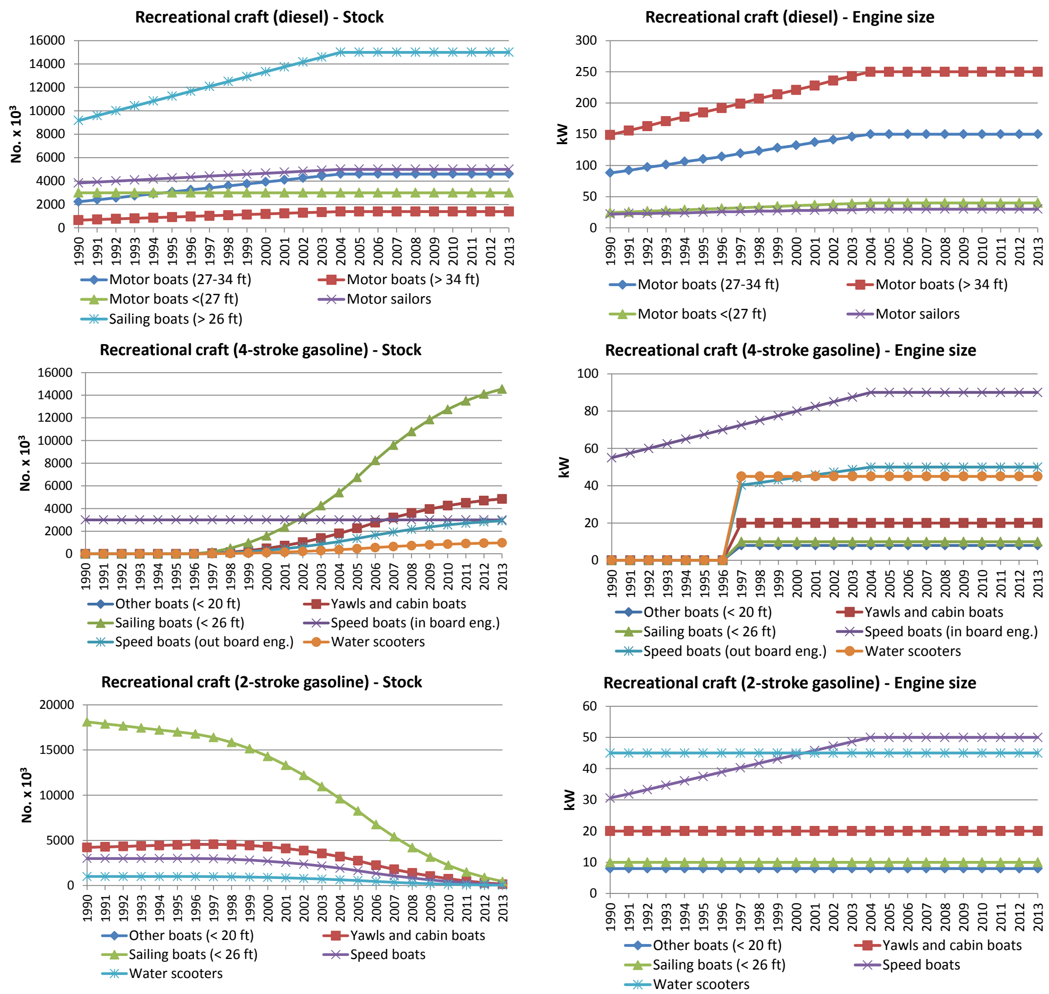


Figure 3.3.49 1990-2013 Stock and engine size development for recreational craft.

National sea transport

A detailed methodology is used to estimate the fuel consumption figures for national sea transport, based on fleet activity estimates for regional ferries, local ferries and other national sea transport (Winther, 2008).

Table 3.3.7 lists the most important domestic ferry routes in Denmark in the period 1990-2013. For these ferry routes and the years 1990-2005, the following detailed traffic and technical data have been gathered by Winther (2008): Ferry name, year of service, engine size (MCR), engine type, fuel type, average load factor, auxiliary engine size and sailing time (single trip).

For 2006-2013, the above mentioned traffic and technical data for specific ferries have been provided by Kristensen (2014) in the case of Mols-Linien (Sjællands Odde-Ebeltoft, Sjællands Odde-Århus, Kalundborg-Århus), by Jørgensen (2014) for Færgen A/S (Køge-Rønne, Tårs-Spodsbjerg). For Esbjerg/Hanst-holm/Hirtshals-Torshavn traffic and technical data have been provided by Dávastovu (2010).

Table 3.3.7 Domestic ferry routes comprised in the Danish inventory.

Ferry service	Service period
Esbjerg-Torshavn	1990-1995, 2009+
Halsskov-Knudshoved	1990-1999
Hanstholm-Torshavn	1991-1992, 1999+
Hirtshals-Torshavn	2010
Hundested-Grenaa	1990-1996
Kalundborg-Juelsminde	1990-1996
Kalundborg-Samsø	1990+
Kalundborg-Århus	1990+
Korsør-Nyborg, DSB	1990-1997
Korsør-Nyborg, Vognmandsruten	1990-1999
København-Rønne	1990-2004
Køge-Rønne	2004+
Sjællands Odde-Ebeltoft	1990+
Sjællands Odde-Århus	1999+
Tårs-Spodsbjerg	1990+

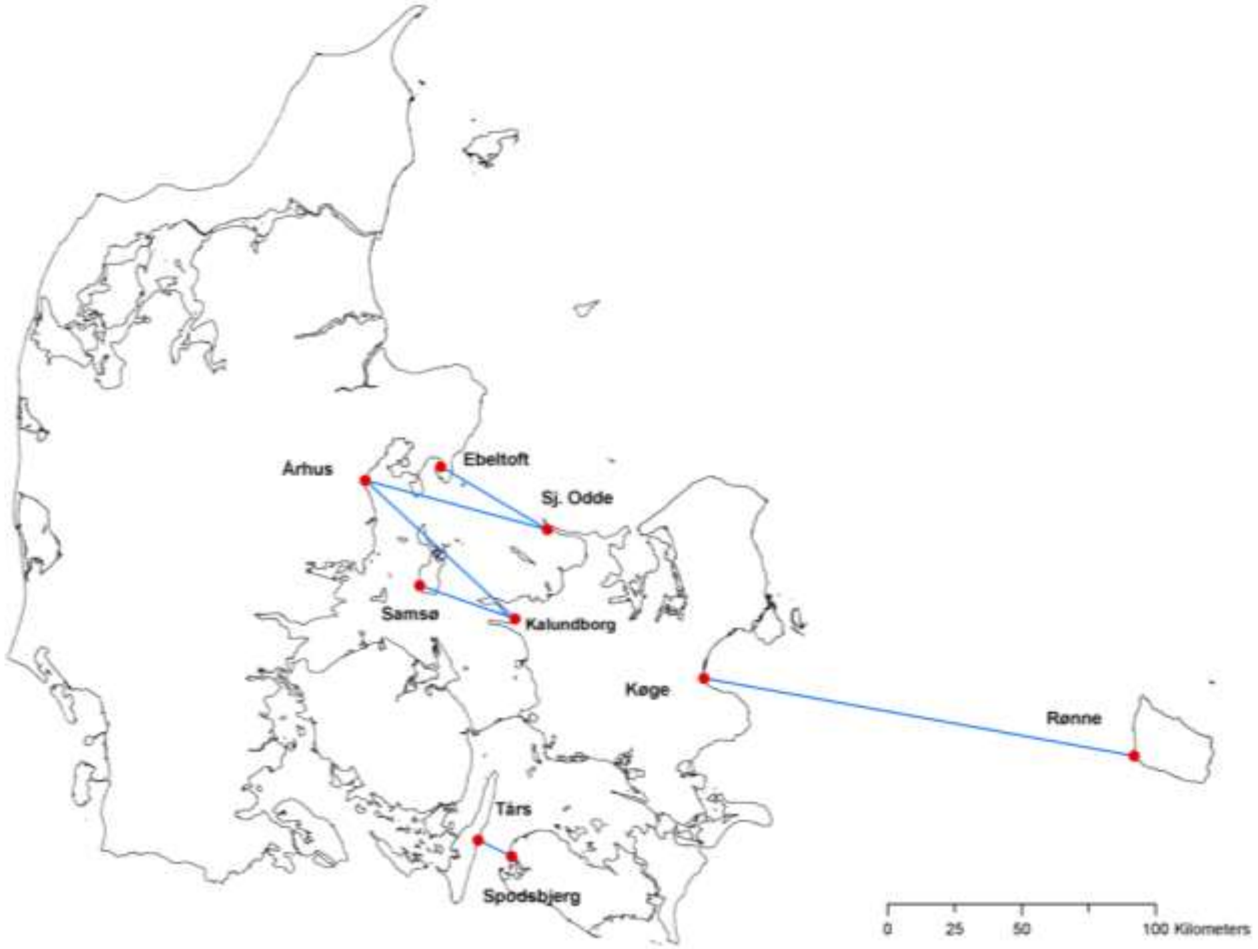
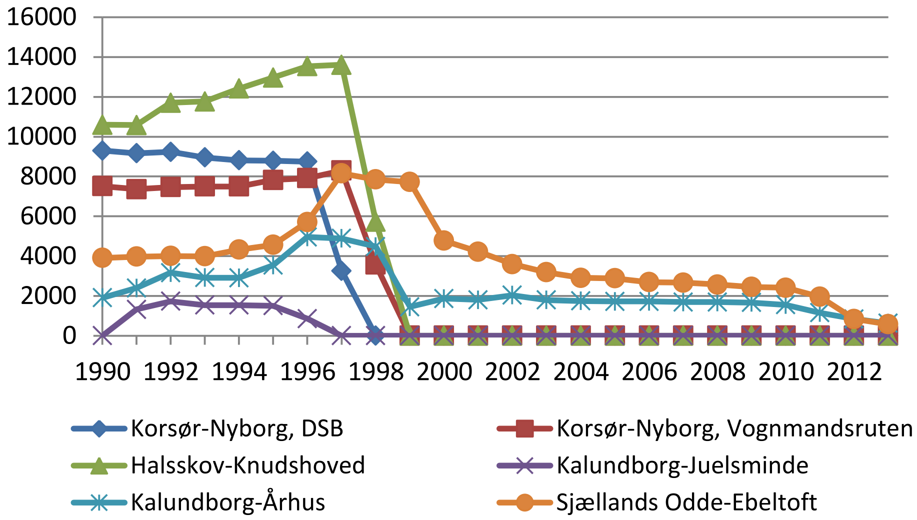


Figure 3.3.50 Domestic regional ferry routes in Denmark (2013).

The number of round trips per ferry route from 1990 to 2013 is provided by Statistics Denmark (2014), see Figure 3.3.51 (Esbjerg/Hanstholm/Hirtshals-Torshavn not shown). The traffic data are also listed in Annex 3.B.12, together with different ferry specific technical and operational data.

For each ferry, Annex 3.B.12 lists the relevant information as regards ferry route, name, year of service, engine size (MCR), engine type, fuel type, average load factor, auxiliary engine size and sailing time (single trip).



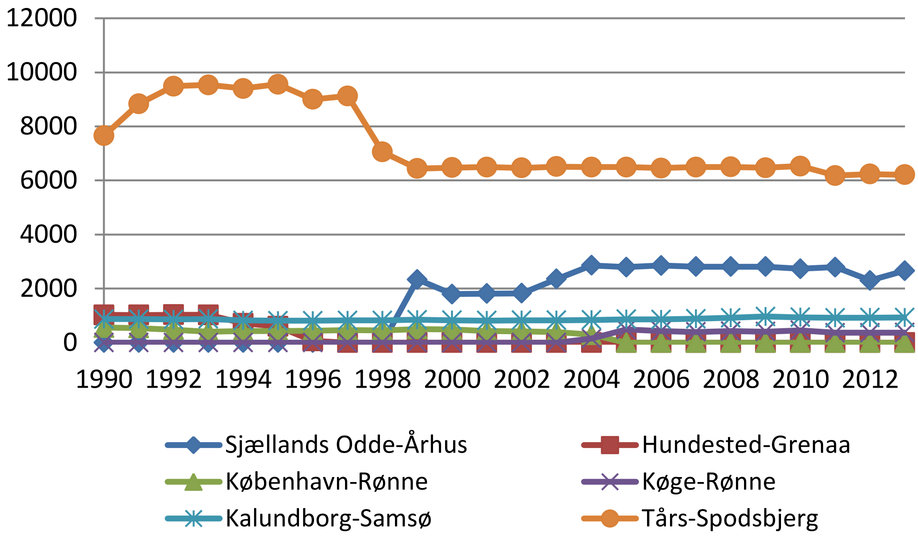


Figure 3.3.51 No. of round trips for the most important ferry routes in Denmark 1990-2013.

It is seen from Table 3.3.7 (and Figure 3.3.51) that several ferry routes were closed in the time period from 1996-1998, mainly due to the opening of the Great Belt Bridge (connecting Zealand and Funen) in 1997. Hundested-Grenaa and Kalundborg-Juelsminde was closed in 1996, Korsør-Nyborg (DSB) closed in 1997, and Halsskov-Knudshoved and Korsør-Nyborg (Vognmandsruten) was closed in 1998. The ferry line København-Rønne was replaced by Køge-Rønne in 2004 and from 1999 a new ferry connection was opened between Sjællands Odde and Århus.

For the local ferries, a bottom-up estimate of fuel consumption for 1996 has been taken from the Danish work in Wismann (2001). The latter project calculated fuel consumption and emissions for all sea transport in Danish waters in 1995/1996 and 1999/2000. In order to cover the entire 1990-2013 inventory period, the fuel figure for 1996 has been adjusted according to the developments in local ferry route traffic shown in Annex 3.B.12.

Fuel sold for freight transport by Royal Arctic Line between Aalborg (Denmark) and Greenland and by Eim Skip - East route between Aarhus (Denmark) and Torshavn (Faroe Islands) are included under other national sea transport in the Danish inventories. In both cases all fuel is being bought in Denmark (Rasmussen, 2014 and Thorarensen, 2014).

For the remaining part of the traffic between two Danish ports, other national sea transport, bottom-up estimates for fuel consumption have been calculated for the years 1995 and 1999 by Wismann (2007). These fuel consumption estimates are used as activity data for the inventory years until 1995 and 1999 onwards. Interpolated figures are used for the inventory years 1996-1998.

The calculations use the database set up for Denmark in the Wismann (2001) study, with actual traffic data from the Lloyd's LMIS database (not including ferries). The database was split into three vessel types: bulk carriers, container ships, and general cargo ships; and five size classes: 0-1000, 1000-3000, 3000-10000, 10000-20000 and >20000 DTW. The calculations assume that bulk carriers and container ships use heavy fuel oil, and that general cargo ships use gas oil. For further information regarding activity data for local ferries and other national sea transport, please refer to Winther (2008).

The fleet activity data for regional ferries, and the fleet activity based fuel consumption estimates for local ferries and other national sea transport replace the fuel based activity data which originated directly from the DEA statistics.

Other sectors

The activity data for military, railways, international sea transport and fishery consists of fuel consumption information from DEA (2014). For international sea transport, the basis is fuel sold in Danish ports for vessels with a foreign destination, as prescribed by the IPCC guidelines.

However, it must be noted that fuel sold for sailing activities between Denmark and Greenland/Faroe Islands are reported as international in the DEA energy statistics. Hence, for inventory purposes in order to follow the IPCC guidelines the bottom-up fuel estimates for the ferry routes Esbjerg/Hanstholm-Torshavn, and fuel reports from Royal Arctic Line and Eim Skip is being subtracted from the fuel sales figures for international sea transport prior to inventory fuel input.

For fisheries, the calculation methodology described by Winther (2008) remains fuel based. However, the input fuel data differ from the fuel sales figures previously used. The changes are the result of further data processing of the DEA reported gas oil sales for national sea transport and fisheries, prior to inventory input. For years when the fleet activity estimates of fuel consumption for national sea transport (not including trips to Greenland/Faroe Islands) are smaller than DEA reported fuel sold for national sea transport, fuel is added to fisheries in the inventory. In the opposite case, fuel is being subtracted from the original DEA fisheries fuel sales figure in order to make up the final fuel consumption input for fisheries in the inventories.

The updated fuel consumption time series for national sea transport lead, in turn, to changes in the energy statistics for fisheries (gas oil) and industry (heavy fuel oil), so the national energy balance can remain unchanged.

For all sectors, fuel consumption figures are given in Annex 3.B.15 for the years 1990 and 2013 in CollectER format.

Emission legislation

For other modes of transport and non road machinery, the engines have to comply with the emission legislation limits agreed by the EU and different UN organisations in terms of NO_x, CO, VOC and TSP emissions and fuel sulphur content. In terms of greenhouse gases, the emission legislation requirements for VOC influence the emissions of CH_4, the latter emission component forming a part of total VOC. Only for ships legislative limits for specific fuel consumption have been internationally agreed in order to reduce the emissions of CO_2.

For non-road working machinery and equipment, and recreational craft and railway locomotives/motor cars, the emission directives list specific emission limit values (g per kWh) for CO, VOC, NO_x (or VOC + NO_x) and TSP, depending on engine size (kW for diesel, ccm for gasoline) and date of implementation (referring to engine market date).

For diesel, the directives 97/68 and 2004/26 (Table 3.3.8) relate to non-road machinery other than agricultural and forestry tractors and the directives have different implementation dates for machinery operating under transient and constant loads. The latter directive also comprises emission limits for railway machinery (Table 3.3.12). For tractors the relevant directives are 2000/25 and 2005/13 (Table 3.3.8). For gasoline, the directive 2002/88 distinguishes between hand-held (SH) and not hand-held (NS) types of machinery (Table 3.3.9).

For engine type approval, the emissions (and fuel consumption) are measured using various test cycles (ISO 8178). Each test cycle consists of a number of measurement points for specific engine loads during constant operation. The specific test cycle used depends on the machinery type in question and the test cycles are described in more details in the directives.

Table 3.3.8 Overview of EU emission directives relevant for diesel fuelled non-road machinery.

Stage/ Engine size [kW]	CO	VOC	NO_X	$VOC+NO_X$	PM	Diesel machinery			Tractors	
	[g pr kWh]						Implement. date		EU	Implement.
						EU Directive	Transient	Constant	directive	date
Stage I										
37<=P<75	6.5	1.3	9.2	-	0.85	97/68	1/4 1999	-	2000/25	1/7 2001
Stage II										
130<=P<560	3.5	1	6	-	0.2	97/68	1/1 2002	1/1 2007	2000/25	1/7 2002
75<=P<130	5	1	6	-	0.3		1/1 2003	1/1 2007		1/7 2003
37<=P<75	5	1.3	7	-	0.4		1/1 2004	1/1 2007		1/1 2004
18<=P<37	5.5	1.5	8	-	0.8		1/1 2001	1/1 2007		1/1 2002
Stage IIIA										
130<=P<560	3.5	-	-	4	0.2	2004/26	1/1 2006	1/1 2011	2005/13	1/1 2006
75<=P<130	5	-	-	4	0.3		1/1 2007	1/1 2011		1/1 2007
37<=P<75	5	-	-	4.7	0.4		1/1 2008	1/1 2012		1/1 2008
19<=P<37	5.5	-	-	7.5	0.6		1/1 2007	1/1 2011		1/1 2007
Stage IIIB										
130<=P<560	3.5	0.19	2	-	0.025	2004/26	1/1 2011	-	2005/13	1/1 2011
75<=P<130	5	0.19	3.3	-	0.025		1/1 2012	-		1/1 2012
56<=P<75	5	0.19	3.3	-	0.025		1/1 2012	-		1/1 2012
37<=P<56	5	-	-	4.7	0.025		1/1 2013	-		1/1 2013
Stage IV										
130<=P<560	3.5	0.19	0.4	-	0.025	2004/26	1/1 2014		2005/13	1/1 2014
56<=P<130	5	0.19	0.4	-	0.025		1/10 2014			1/10 2014

Table 3.3.9 Overview of the EU Emission Directive 2002/88 for gasoline fuelled non-road machinery.

	Category	Engine size [ccm]	CO [g pr kWh]	HC [g pr kWh]	NO_X [g pr kWh]	$HC+NO_X$ [g pr kWh]	Implementation date
	Stage I						
Hand held	SH1	S<20	805	295	5.36	-	1/2 2005
	SH2	20=<S<50	805	241	5.36	-	1/2 2005
	SH3	50=<S	603	161	5.36	-	1/2 2005
Not hand held	SN3	100=<S<225	519	-	-	16.1	1/2 2005
	SN4	225=<S	519	-	-	13.4	1/2 2005
	Stage II						
Hand held	SH1	S<20	805	-	-	50	1/2 2008
	SH2	20=<S<50	805	-	-	50	1/2 2008
	SH3	50=<S	603	-	-	72	1/2 2009
Not hand held	SN1	S<66	610	-	-	50	1/2 2005
	SN2	66=<S<100	610	-	-	40	1/2 2005
	SN3	100=<S<225	610	-	-	16.1	1/2 2008
	SN4	225=<S	610	-	-	12.1	1/2 2007

For recreational craft, Directive 2003/44 comprises the Stage 1 emission legislation limits for diesel engines, and for 2-stroke and 4-stroke gasoline engines, respectively. The CO and VOC emission limits depend on engine size (kW) and the inserted parameters presented in the calculation formulas in Table 3.3.10. For NO_X, a constant limit value is given for each of the three engine types. For TSP, the constant emission limit regards diesel engines only.

In Table 3.3.11 the Stage II emission limits are shown for recreational craft. CO and HC+NOx limits are provided for gasoline engines depending on the rated engine power and the engine type (stern-drive vs. outboard) while CO, HC+NOx, and particulate emission limits are defined for Compression Ignition (CI) engines depending on the rated engine power and the swept volume.

Table 3.3.10 Overview of the EU Emission Directive 2003/44 for recreational craft.

Engine type	Impl. date	$CO=A+B/P^n$			$HC=A+B/P^n$			NO_X	TSP
		A	B	n	A	B	n		
2-stroke gasoline	1/1 2007	150.0	600.0	1.0	30.0	100.0	0.75	10.0	-
4-stroke gasoline	1/1 2006	150.0	600.0	1.0	6.0	50.0	0.75	15.0	-
Diesel	1/1 2006	5.0	0.0	0	1.5	2.0	0.5	9.8	1.0

Table 3.3.11 Overview of the EU Emission Directive 2013/53 for recreational craft.

Diesel engines					
Swept Volume, SV l/cyl.	Rated Engine Power, P_N kW	Impl. Date	CO g/kWh	$HC + NO_x$ g/kWh	PM g/kWh
SV < 0.9	P_N < 37				
	37 <= P_N < 75 (*)	18/1 2017	5	4.7	0.30
	75 <= P_N < 3 700	18/1 2017	5	5.8	0.15
0.9 <= SV < 1.2	P_N < 3 700	18/1 2017	5	5.8	0.14
1.2 <= SV < 2.5		18/1 2017	5	5.8	0.12
2.5 <= SV < 3.5		18/1 2017	5	5.8	0.12
3.5 <= SV < 7.0		18/1 2017	5	5.8	0.11
Gasoline engines					
Engine type	Rated Engine Power, P_N kW		CO g/kWh	$HC + NO_x$ g/kWh	PM g/kWh
Stern-drive and inboard engines	P_N <= 373	18/1 2017	75	5	-
	373 <= P_N <= 485	18/1 2017	350	16	-
	P_N > 485	18/1 2017	350	22	-
Outboard engines and PWC engines (**)	P_N <= 4.3	18/1 2017	500 – (5.0 x P_N)	15.7 + ($50/PN^{0.9}$)	-
	4.3 <= P_N <= 40	18/1 2017	500 – (5.0 x P_N)	15.7 + ($50/PN^{0.9}$)	-
	P_N > 40	18/1 2017	300		-

(*) Alternatively, this engine segment shall not exceed a PM limit of 0.2 g/kWh and a combined $HC + NO_x$ limit of 5.8 g/kWh
(**) Small and medium size manufacturers making outboard engines <= 15 kW have until 18/1 2020 to comply

Table 3.3.12 Overview of the EU Emission Directive 2004/26 for railway locomotives and motorcars.

	Engine size [kW]		CO [g pr kWh]	HC [g pr kWh]	NO_x [g pr kWh]	HC+NOX [g pr kWh]	PM [g pr kWh]	Implement. date
Locomotives	Stage IIIA							
	130<=P<560	RL A	3.5	-	-	4	0.2	1/1 2007
	560<P	RH A	3.5	0.5	6	-	0.2	1/1 2009
	2000<=P and piston displacement >= 5 l/cyl.	RH A	3.5	0.4	7.4	-	0.2	1/1 2009
	Stage IIIB	RB	3.5	-	-	4	0.025	1/1 2012
Motor cars	Stage IIIA							
	130<P	RC A	3.5	-	-	4	0.2	1/1 2006
	Stage IIIB							
	130<P	RC B	3.5	0.19	2	-	0.025	1/1 2012

Aircraft engine emissions of NO_x, CO, VOC and smoke are regulated by ICAO (International Civil Aviation Organization). The engine emission certification standards are contained in Annex 16 — Environmental Protection, Volume II — Aircraft Engine Emissions to the Convention on International Civil Aviation (ICAO Annex 16, 2008, plus amendments). The emission standards relate to the total emissions (in grams) from the so-called LTO (Landing and Take Off) cycle divided by the rated engine thrust (kN). The ICAO LTO cycle contains the idealised aircraft movements below 3000 ft (915 m) during approach, landing, airport taxiing, take off and climb out.

For smoke all aircraft engines manufactured from 1 January 1983 have to meet the emission limits agreed by ICAO. For NO_x, CO, VOC The emission legislation is relevant for aircraft engines with a rated engine thrust larger than 26.7 kN. In the case of CO and VOC, the ICAO regulations apply for engines manufactured from 1 January 1983.

For NO_x, the emission regulations fall in five categories

a) For engines of a type or model for which the date of manufacture of the first individual production model was before 1 January 1996, and for which the production date of the individual engine was before 1 January 2000.
b) For engines of a type or model for which the date of manufacture of the first individual production model is on or after 1 January 1996, or for individual engines with a production date on or after 1 January 2000.
c) For engines of a type or model for which the date of manufacture of the first individual production model is on or after 1 January 2004.
d) For engines of a type or model for which the date of manufacture of the first individual production model is on or after 1 January 2008, or for individual engines with a production date on or after 1 January 2013.
e) For engines of a type or model for which the date of manufacture of the first individual production model is on or after 1 January 2014.

The regulations published by ICAO are given in the form of the total quantity of pollutants (D_p) emitted in the LTO cycle divided by the maximum sea level thrust (F_{oo}) and plotted against engine pressure ratio at maximum sea level thrust.

The limit values for NO_x are given by the formulae in Table 3.3.13.

Table 3.3.13 Current certification limits for NO_x for turbo jet and turbo fan engines.

	Engines first produced before 1.1.1996 & for engines manufactured before 1.1.2000	Engines first produced on or after 1.1.1996 & for engines manufactured on or after 1.1.2000	Engines for which the date of manufacture of the first individual production model was on or after 1 January 2004	Engines first produced on or after 1.1.2047 & for engines manufactured on or after 1.1.2013	Engines for which the date of manufacture of the first individual production model was on or after 1.1.2014
Applies to engines >26.7 kN	$Dp/F_{oo} = 40 + 2\pi_{oo}$	$Dp/F_{oo} = 32 + 1.6\pi_{oo}$			
Engines of pressure ratio less than 30					
Thrust more than 89 kN			$Dp/F_{oo} = 19 + 1.6\pi_{oo}$	$Dp/F_{oo} = 16.72 + 1.4080\pi_{oo}$	$7.88 + 1.4080\pi_{oo}$
Thrust between 26.7 kN and not more than 89 kN			$Dp/F_{oo} = 37.572 + 1.6\pi_{oo} - 0.208F_{oo}$	$Dp/F_{oo} = 38.54862 + (1.6823\pi_{oo}) – (0.2453F_{oo}) – (0.00308\pi_{oo}F_{oo})$	$Dp/F_{oo} = 40.052 + 1.5681\pi_{oo} - 0.3615F_{oo} - 0.0018\ \pi_{oo} \times F_{oo}$
Engines of pressure ratio more than 30 and less than 62.5 (104.7)					
Thrust more than 89 kN			$Dp/F_{oo} = 7+2.0\pi_{oo}$	$Dp/F_{oo} = -1.04+ (2.0*\pi_{oo})$	
Thrust between 26.7 kN and not more than 89 kN			$Dp/F_{oo} = 42.71 +1.4286\pi_{oo} -0.4013F_{oo} +0.00642\pi_{oo}F_{oo}$	$Dp/F_{oo} = 46.1600 + (1.4286\pi_{oo}) – (0.5303F_{oo}) – (0.00642\pi_{oo}F_{oo})$	
Engines with pressure ratio 62.5 or more					
Engines with pressure ratio 82.6 or more			$Dp/F_{oo} = 32+1.6\pi_{oo}$	$Dp/F_{oo} = 32+1.6\pi_{oo}$	
Engines of pressure ratio more than 30 and less than (104.7)					
Thrust more than 89 kN					$Dp/F_{oo} = -9.88 + 2.0\pi_{oo}$
Thrust between 26.7 kN and not more than 89 kN					$Dp/F_{oo} = 41.9435 + 1.505\pi_{oo} - 0.5823F_{oo} + 0.005562\pi_{oo} \times F_{oo}$
Engines with pressure ratio 104.7 or more					$Dp/F_{oo} = 32 + 1.6\pi_{oo}$

Source: International Standards and Recommended Practices, Environmental Protection, ICAO Annex 16 Volume II 3rd edition July 2008, plus amendments: Amendment 7 (17 November 2011), Amendment 8 (July 2014),

where:

D_p = the sum of emissions in the LTO cycle in g.

F_{oo} = thrust at sea level take-off (100 %).

π_{oo} = pressure ratio at sea level take-off thrust point (100 %).

The equivalent limits for HC and CO are D_p/F_{oo} = 19.6 for HC and D_p/F_{oo} = 118 for CO (ICAO Annex 16 Vol. II paragraph 2.2.2). Smoke is limited to a regulatory smoke number = 83 $(F_{oo})^{-0.274}$ or a value of 50, whichever is the lower.

A further description of the technical definitions in relation to engine certification as well as actual engine exhaust emission measurement data can be found in the ICAO Engine Exhaust Emission Database. The latter database is accessible from http://www.caa.co.uk, hosted by the UK Civil Aviation Authority.

Marpol 73/78 Annex VI agreed by IMO (International Maritime Organisation) concerns the control of NO_x emissions (Regulation 13 plus amendments) and SO_x and particulate emissions (Regulation 14 plus amendments) from ships(DNV, 2009). Recently the so called Energy Efficiency Design Index (EEDI) fuel efficiency regulations for new built ships was included in Chapter 4 of Annex VI in the Marpol convention for the purpose of controlling the CO_2 emissions from ships (Lloyd's Register, 2012).

The baseline NO_x emission regulation of Annex VI apply for diesel engines with a power output higher than 130 kW, which are installed on a ship constructed on or after 1 January 2000 and diesel engines with a power output higher than 130 kW which undergo major conversion on or after 1 January 2000.

The baseline NO_x emission limits for ship engines in relation to their rated engine speed (n) given in RPM (Revolutions Pr Minute) are the following:

- 17 g pr kWh, n < 130 RPM
- 45 x n-0.2 g pr kWh, 130 ≤ n < 2000 RPM
- 9.8 g pr kWh, n ≥ 2000 RPM

The further amendment of Annex VI Regulation 13 contains a three tiered approach in order to strengthen the emission standards for NO_x. The three tier approach comprises the following:

- Tier I: Diesel engines (> 130 kW) installed on a ship constructed on or after 1 January 2000 and prior to 1 January 2011 (initial regulation).
- Tier II: Diesel engines (> 130 kW) installed on a ship constructed on or after 1 January 2011.
- Tier III[8]: Diesel engines (> 130 kW) installed on a ship constructed on or after 1 January 2016.

The three tier NO_x emission limit functions are shown in Table 3.3.14.

Table 3.3.14 Tier I-III NO_x emission limits for ship engines in MARPOL Annex VI.

	NO_x limit	RPM (n)
Tier I	17 g pr kWh	n < 130
	45 · n-0.2 g pr kWh	130 ≤ n < 2000
	9,8 g pr kWh	n ≥ 2000
Tier II	14.4 g pr kWh	n < 130
	44 · n-0.23 g pr kWh	130 ≤ n < 2000
	7.7 g pr kWh	n ≥ 2000
Tier III	3.4 g pr kWh	n < 130
	9 · n-0.2 g pr kWh	130 ≤ n < 2000
	2 g pr kWh	n ≥ 2000

Further, the NO_x Tier I limits are to be applied for existing engines with a power output higher than 5000 kW and a displacement per cylinder at or above 90 litres, installed on a ship constructed on or after 1 January 1990 but prior to 1 January 2000.

In relation to the sulphur content in heavy fuel and marine gas oil used by ship engines, Table 3.3.15 shows the EU and IMO (Regulation 14 plus amendments) legislation in force for SECA (Sulfur Emission Control Area) areas and outside SECA's.

[8] For ships operating in a designated Emission Control Area. Outside a designated Emission Control Area, Tier II limits apply.

Table 3.3.15 Current legislation in relation to marine fuel quality.

Legislation		Heavy fuel oil		Gas oil	
		S- %	Implement. date (day/month/year)	S- %	Implement. date (day/month/year)
EU-directive 93/12		None		0.2[1]	01.10.1994
EU-directive 1999/32		None		0.2	01.01.2000
EU-directive 2005/33[2]	SECA - Baltic sea	1.5	11.08.2006	0.1	01.01.2008
	SECA - North sea	1.5	11.08.2007	0.1	01.01.2008
	Outside SECA's	None		0.1	01.01.2008
MARPOL Annex VI	SECA – Baltic sea	1.5	19.05.2006		
	SECA – North sea	1.5	21.11.2007		
	Outside SECA	4.5	19.05.2006		
MARPOL Annex VI amendments	SECA's	1	01.03.2010		
	SECA's	0.1	01.01.2015		
	Outside SECA's	3.5	01.01.2012		
	Outside SECA's	0.5	01.01.2020[3]		

[1] Sulphur content limit for fuel sold inside EU.

[2] From 1.1.2010 fuel with a sulphur content higher than 0.1 % must not be used in EU ports for ships at berth exceeding two hours

[3] Subject to a feasibility review to be completed no later than 2018. If the conclusion of such a review becomes negative the effective date would default 1 January 2025.

In Marpol 83/78 Annex VI (Chapter 4) the EEDI fuel efficiency regulations are mandatory from 1st January 2013 for new built ships larger than 400 GT.

EEDI is a design index value that expresses how much CO_2 is produced per work done (g CO_2/tonnes.nm). At present the IMO EEDI scheme comprises the following ship types; bulk carriers, gas carriers, tankers, container ships, general cargo ships, refrigerated and combination cargo carriers.

The EEDI percentage reductions that need to be achieved for new built ships relative to existing ships, are shown in Table 3.3.16 stratified according to ship type and dead weight tonnes (DWT) in the temporal phases (new built year in brackets); 0 (2013-14), 1 (2015-19), 2 (2020-24) and 3 (2025+).

Table 3.3.16 EEDI percentage reductions for new built ships relative to existing ships.

Ship type	Size	Phase 0 1-Jan-2013 to 31-Dec-2014	Phase 1 1-Jan-2015 to 31-Dec-2019	Phase 2 1-Jan-2020 to 31-Dec-2024	Phase 3 1-Jan-2025 onwards
Bulk carrier	20,000 DWT and above	0	10	20	30
	10,000 – 20,000 DWT	n/a	0-10*	0-20*	0-30*
Gas carrier	10,000 DWT and above	0	10	20	30
	2,000 – 10,000 DWT	n/a	0-10*	0-20*	0-30*
Tanker	20,000 DWT and above	0	10	20	30
	4,000 – 20,000 DWT	n/a	0-10*	0-20*	0-30*
Container ship	15,000 DWT and above	0	10	20	30
	10,000 – 15,000 DWT	n/a	0-10*	0-20*	0-30*
General cargo ship	15,000 DWT and above	0	10	15	30
	3,000 – 15,000 DWT	n/a	0-10*	0-15*	0-30*
Refrigerated cargo carrier	5,000 DWT and above	0	10	15	30
	3,000 – 5,000 DWT	n/a	0-10*	0-15*	0-30*
Combination carrier	20,000 DWT and above	0	10	20	30
	4,000 – 20,000 DWT	n/a	0-10*	0-20*	0-30*

It is envisaged that also Ro-ro cargo, ro-ro passenger and cruise passenger ships will be included in the EEDI scheme in the near future.

For non road machinery, the EU directive 2003/17/EC gives a limit value of 10 ppm sulphur in diesel (from 2011).

Emission factors

The CO_2 emission factors are country-specific and come from the DEA. The N_2O emission factors are taken from the EMEP/EEA guidebook (EMEP/EEA, 2013).

For military ground material, aggregated CH_4 emission factors for gasoline and diesel are derived from the road traffic emission simulations. The CH_4 emission factors for railways are derived from specific Danish VOC measurements from the Danish State Railways (Delvig, 2014) and a NMVOC/CH_4 split, based on expert judgement.

For agriculture, forestry, industry, household gardening and recreational craft, the VOC emission factors are derived from various European measurement programmes; see IFEU (2004, 1999) and Winther et al. (2006). The NMVOC/CH_4 split is taken from IFEU (1999).

For national sea transport and fisheries, the VOC emission factors come from Trafikministeriet (2010). Specifically for the ferries used by Mols Linjen new VOC emission factors are provided by Kristensen (2008), originating from measurement results by Hansen et al. (2004), Wismann (1999) and PHP (1996). Kristensen (2013) has provided complimentary emission factor data for new ferries.

For ship engines VOC/CH_4 splits are taken from EMEP/EEA (2013), and all emission factors are shown in Annex 3.B.13.

The source for aviation (jet fuel) CH_4 emission factors is the EMEP/EEA guidebook (EMEP/EEA, 2013). For a number of different representative aircraft types, the EMEP/EEA guidebook comprises fuel flow and NO_x, CO and VOC emission indices for the four LTO modes and distance based emission factors for cruise. VOC/CH_4 splits for aviation are taken from EMEP/EEA (2013).

The CH_4 emission factors for domestic aviation come from the EMEP/EEA (2013). For a number of different representative aircraft types, the EMEP/EEA guidebook comprises fuel flow and NO_x, CO and VOC emission indices for the four LTO modes and distance based emission factors for cruise.

For all sectors, emission factors for the years 1990 and 2013 are given in CollectER format in Annex 3.B.15.

Table 3.3.17 shows the aggregated emission factors for CO_2, CH_4 and N_2O in 2013 used to calculate the emissions from other mobile sources in Denmark.

Table 3.3.17 Fuel-specific emission factors for CO_2, CH_4 and N_2O for other mobile sources in Denmark

			Emission factors[9]		
			CH_4	CO_2	N_2O
SNAP ID	Category	Fuel type	g pr GJ	g pr GJ	g pr GJ
080100	Military	AvGas	21,90	73,00	2,00
080100	Military	Diesel	0,94	74,00	2,97
080100	Military	Gasoline	7,03	73,00	1,30
080100	Military	Jet fuel	2,65	72,00	2,30
080200	Railways	Diesel	1,89	74,00	2,04
080300	Recreational craft	Diesel	3,40	74,00	2,97
080300	Recreational craft	Gasoline	22,96	73,00	1,58
080402	National sea traffic	Diesel	1,81	74,00	4,68
080402	National sea traffic	Residual oil	1,96	78,00	4,89
080403	Fishing	Diesel	1,79	74,00	4,68
080404	International sea traffic	Diesel	1,80	74,00	4,68
080404	International sea traffic	Residual oil	1,98	78,00	4,89
080501	Air traffic, Dom. < 3000 ft.	AvGas	21,90	73,00	2,00
080501	Air traffic, Dom. < 3000 ft.	Jet fuel	1,06	72,00	9,32
080502	Air traffic, Int. < 3000 ft.	AvGas	21,90	73,00	2,00
080502	Air traffic, Int. < 3000 ft.	Jet fuel	1,09	72,00	5,63
080503	Air traffic, Dom. > 3000 ft.	Jet fuel	0,00	72,00	2,30
080504	Air traffic, Int. > 3000 ft.	Jet fuel	0,00	72,00	2,30
080600	Agriculture	Diesel	1,18	74,00	3,20
080600	Agriculture	Gasoline	150,56	73,00	1,70
080700	Forestry	Diesel	0,67	74,00	3,22
080700	Forestry	Gasoline	240,84	73,00	0,46
080800	Industry	Diesel	1,32	74,00	3,11
080800	Industry	Gasoline	60,50	73,00	1,49
080800	Industry	LPG	7,69	63,10	3,50
080900	Household and gardening	Gasoline	49,71	73,00	1,26
081100	Commercial and institutional	Gasoline	73,80	73,00	1,13
080501	Air traffic, Dom. < 3000 ft.	AvGas	21,90	73,00	2,00
080501	Air traffic, Dom. < 3000 ft.	Jet fuel	1,39	72,00	5,69
080502	Air traffic, Int. < 3000 ft.	AvGas	21,90	73,00	2,00
080502	Air traffic, Int. < 3000 ft.	Jet fuel	1,17	72,00	3,64
080503	Air traffic, Dom. > 3000 ft.	Jet fuel	0,00	72,00	2,30
080504	Air traffic, Int. > 3000 ft.	Jet fuel	0,00	72,00	2,30
080100	Military	AvGas	21,90	73,00	2,00
080100	Military	Diesel	0,94	74,00	2,97

Factors for deterioration, transient loads and gasoline evaporation for non road machinery

The emission effects of engine wear are taken into account for diesel and gasoline engines by using the so-called deterioration factors. For diesel engines alone, transient factors are used in the calculations, to account for the emission changes caused by varying engine loads. The evaporative emissions of NMVOC are estimated for gasoline fuelling and tank evaporation. The factors for deterioration, transient loads and gasoline evaporation are taken from IFEU (2004, 1999, 2014), and are shown in Annex 3.B.10. For more details regarding the use of these factors, please refer to paragraph 3.3.4 or Winther et al. (2006).

[9] References. CO_2: Country-specific. N_2O: EMEP/EEA. CH_4: Railways: DSB/DCE; Agriculture/Forestry/Industry/Household-Gardening: IFEU; National sea traffic/Fishing/International sea traffic: Trafikministeriet/EMEP/EEA; domestic and international aviation: EMEP/EEA.

3.3.4 Calculation method

Air traffic

For aviation, the domestic and international estimates are made separately for landing and take-off (LTOs < 3000 ft), and cruising (> 3000 ft).

By using the LTO mode specific fuel flow and emission indices from EMEP/EEA (2013), the fuel consumption and emission factors for the full LTO cycle can be estimated for each of the representative aircraft types used in the Danish inventory.

The fuel consumption for one LTO cycle is calculated according to the following sum formula:

$$FC^{a}_{LTO} = \sum_{m=1}^{4} t_m \cdot ff_{a,m} \qquad (15)$$

Where FC = fuel consumption (kg), m = LTO mode (approach/landing, taxiing, take off, climb out), t = times in mode (s), ff = fuel flow (kg per s), a = representative aircraft type.

The emissions for one LTO cycle are estimated as follows:

$$E^{a}_{LTO} = \sum_{m=1}^{4} FC_{a,m} \cdot EI_{a,m} \qquad (16)$$

Due to lack of specific airport data, for approach/descent, take off and climb out, standardised times-in-modes of 4, 0.7 and 2.2 minutes are used as defined by ICAO (ICAO, 1995), whereas for taxiing the appropriate time interval is 13 minutes in Copenhagen Airport and 5 minutes in other airports present in the Danish inventory.

For each representative aircraft type, the calculated fuel consumption and emission factors per LTO are shown in Annex 3.B.10 for Copenhagen Airport and other airports.

The calculations for cruise use the distance specific fuel consumption and emissions given by EMEP/EEA (2013) per representative aircraft type. Data interpolations or extrapolations are made – in each case determined by the great circle distance between the origin and the destination airports.

If the great circle distance, y, is smaller than the maximum distance for which fuel consumption and emission data are given in the EMEP/EEA data bank the fuel consumption or emission E (y) becomes:

$$E(y) = E_{x_i} + \frac{(y - x_i)}{x_{i+1} - x_i} \cdot (E_{x_{i+1}} - E_{x_i}) \qquad y<x_{max},\ i = 0,1,2\ldots max-1 \qquad (17)$$

In (15) x_i and x_{max} denominate the separate distances and the maximum distance, respectively, with known fuel consumption and emissions. If the flight distance y exceeds x_{max} the maximum figures for fuel consumption and emissions must be extrapolated and the equation then becomes:

$$E(y) = E_{x_{max}} + \frac{(y - x_{max})}{x_{max} - x_{max-1}} \cdot (E_{x_{max}} - E_{x_{max-1}}) \qquad y>x_{max} \qquad (18)$$

Total results are summed up and categorised according to each flight's destination airport code in order to distinguish between domestic and international flights.

Annex 3.B.10 shows the average fuel consumption and emission factors per representative aircraft type for cruise flying, as well as total distance flown, for 2013[10]. The factors are split between Copenhagen Airport and other airports and distinguish between domestic and international flights.

Specifically for flights between Denmark and Greenland or the Faroe Islands, for each representative aircraft type, the flight distances are directly shown in Annex 3.B.10, which go into the cruise calculation expressions 17 and 18.

The overall fuel precision in the model is 0.92 in 2013, derived as the fuel ratio between model estimates and statistical sales. The fuel difference is accounted for by adjusting cruising fuel consumption and emissions in the model according to domestic and international cruising fuel shares.

For inventory years before 2001, the calculation procedure is to estimate each year's fuel consumption and emissions for LTO based on LTO/aircraft type statistics from Copenhagen Airport, and total take off numbers for other airports provided by the Danish Transport Authority. Due to lack of aircraft type specific LTO data, fuel consumption and emission factors derived for domestic LTO's in Copenhagen Airport is used for all LTO's in other airports. In a next step, the total fuel consumption for cruise (true cruise fuel consumption) is found year by year as the statistical fuel consumption total minus the calculated fuel consumption for LTO.

For each inventory year, intermediate cruise fuel consumption figures split into four parts (Copenhagen/Other airports; domestic/international) are found as proportional values between part specific LTO fuel consumption values estimated as described previously, and part specific cruise:LTO fuel consumption ratios for 1998. In the latter ratio, the cruise fuel contribution is taken from a Danish city-pair emission inventory in 1998 (Winther, 2001a), whereas the LTO fuel consumption is the 1998 figures estimated as explained above.

Each inventory year's true cruise fuel consumption is finally split into four parts by using the intermediate cruise fuel consumption values as a distribution key. As emission factor input data for cruise, aggregated fuel related emission factors are derived from the present model and the first historical year 2001.

Non-road working machinery and recreational craft

Prior to adjustments for deterioration effects and transient engine operations, the fuel consumption and emissions in year X, for a given machinery type, engine size and engine age, are calculated as:

$$E_{Basis}(X)_{i,j,k} = N_{i,j,k} \cdot HRS_{i,j,k} \cdot P \cdot LF_i \cdot EF_{y,z} \qquad (19)$$

where E_{Basis} = fuel consumption/emissions in the basic situation, N = number of engines, HRS = annual working hours, P = average rated engine size

[10] Excluding flights for Greenland and the Faroe Islands.

in kW, LF = load factor, EF = fuel consumption/emission factor in g pr kWh, i = machinery type, j = engine size, k = engine age, y = engine-size class and z = emission level. The basic fuel consumption and emission factors are shown in Annex 3.B.11.

The deterioration factor for a given machinery type, engine size and engine age in year X depends on the engine-size class (only for gasoline), y, and the emission level, z. The deterioration factors for diesel and gasoline 2-stroke engines are found from:

$$DF_{i,j,k}(X) = \frac{K_{i,j,k}}{LT_i} \cdot DF_{y,z} \qquad (20)$$

where DF = deterioration factor, K = engine age, LT = lifetime, i = machinery type, j = engine size, k = engine age, y = engine-size class and z = emission level.

For gasoline 4-stroke engines the deterioration factors are calculated as:

$$DF_{i,j,k}(X) = \sqrt{\frac{K_{i,j,k}}{LT_i}} \cdot DF_{y,z} \qquad (21)$$

The deterioration factors inserted in (20) and (21) are shown in Annex 3.B.11. No deterioration is assumed for fuel consumption (all fuel types) or for LPG engine emissions and, hence, DF = 1 in these situations.

The transient factor for any given machinery type, engine size and engine age in year X, relies only on emission level and load factor, and is denominated as:

$$TF_{i,j,k}(X) = TF_z \qquad (22)$$

Where i = machinery type, j = engine size, k = engine age and z = emission level.

The transient factors inserted in (20) are shown in Annex 3.B.11. No transient corrections are made for gasoline and LPG engines and, hence, TF_z = 1 for these fuel types.

The final calculation of fuel consumption and emissions in year X for a given machinery type, engine size and engine age, is the product of the expressions 17-20:

$$E(X)_{i,j,k} = E_{Basis}(X)_{i,j,k} \cdot TF(X)_{i,j,k} \cdot (1 + DF(X)_{i,j,k}) \qquad (23)$$

The evaporative hydrocarbon emissions from fuelling are calculated as:

$$E_{Evap,\,fueling,i} = FC_i \cdot EF_{Evap,\,fueling} \qquad (24)$$

Where $E_{Evap,fueling}$, = hydrocarbon emissions from fuelling, i = machinery type, FC = fuel consumption in kg, $EF_{Evap,fueling}$ = emission factor in g NMVOC pr kg fuel.

For tank evaporation, the hydrocarbon emissions are found from:

$$E_{Evap,\tan k,i} = N_i \cdot EF_{Evap,\tan k,i} \quad (25)$$

Where $E_{Evap,tank,i}$ = hydrocarbon emissions from tank evaporation, N = number of engines, i = machinery type and $EF_{Evap,fueling}$ = emission factor in g NMVOC pr year.

Ferries, other national sea transport and fisheries

The fuel consumption and emissions in year X, for regional ferries are calculated as:

$$E(X) = \sum_i N_i \cdot T_i \cdot S_{i,j} \cdot P_i \cdot LF_j \cdot EF_{k,l,y} \quad (26)$$

Where E = fuel consumption/emissions, N = number of round trips, T = sailing time pr round trip in hours, S = ferry share of ferry service round trips, P = engine size in kW, LF = engine load factor, EF = fuel consumption/emission factor in g pr kWh, i = ferry service, j = ferry, k = fuel type, l = engine type, y = engine year.

For the remaining navigation categories, the emissions are calculated using a simplified approach:

$$E(X) = \sum_i EC_{i,k} EF_{k,l,y} \quad (27)$$

Where E = fuel consumption/emissions, EC = energy consumption, EF = fuel consumption/emission factor in g per kg fuel, i = category (local ferries, other national sea, fishery, international sea), k = fuel type, l = engine type, y = average engine year.

The emission factor inserted in (27) is found as an average of the emission factors representing the engine ages which are comprised by the average lifetime in a given calculation year, X:

$$EF_{k,l,y} = \frac{\sum_{year=X}^{year=X-LT} EF_{k,l}}{LT_{k,l}} \quad (28)$$

Other sectors

For military and railways, the emissions are estimated with the simple method using fuel-related emission factors and fuel consumption from the DEA:

$$E = FC \cdot EF \quad (29)$$

where E = emission, FC = fuel consumption and EF = emission factor. The calculated emissions for other mobile sources are shown in CollectER format in Annex 3.B.16 for the years 1990 and 2013 and as time series 1990-2013 in Annex 3.B.15 (CRF format).

Fuel balance between DEA statistics and inventory estimates

Following convention rules, the DEA statistical fuel sales figures are the basis for the full Danish inventory. However, in some cases for mobile sources the DEA statistical sectors do not fully match the inventory sectors. This is the case for non road machinery, where relevant DEA statistical sectors also include fuel consumed by stationary sources.

In other situations, fuel consumption figures estimated by DCE from specific bottom-up calculations are regarded as more reliable than DEA reported sales. This is the case for national sea transport.

In the following the transferral of fuel consumption data from DEA statistics into inventory relevant categories is explained for national sea transport and fisheries, non road machinery and recreational craft, and road transport. A full list of all fuel consumption data, DEA figures as well as intermediate fuel consumption data, and final inventory input figures is shown in Annex 3.B.14.

National sea transport and fisheries

For national sea transport in Denmark, the fuel consumption estimates obtained by DCE (see 3.3.3 Activity data – national sea transport) are regarded as much more accurate than the DEA fuel sales data, since the large fluctuations in reported fuel sales cannot be explained by the actual development in the traffic between different national ports. As a consequence, the new bottom-up estimates replace the previous fuel based figures for national sea transport.

There are different potential reasons for the differences between estimated fuel consumption and reported sales for national sea transport in Denmark. According to the DEA, the latter fuel differences are most likely explained by inaccurate costumer specifications made by the oil suppliers. This inaccuracy can be caused by a sector misallocation in the sales statistics between national sea transport and fisheries for gas oil, and between national sea transport and industry for heavy fuel oil (Peter Dal, DEA, personal communication, 2007). Further, fuel sold for vessels sailing between Denmark and Greenland/Faroe Islands are reported as international in the DEA statistics, and this fuel categorisation is different from the IPCC guideline definitions (see following paragraph “Bunkers”).

Following this, for fisheries and industry the updated fuel consumption time series for national sea transport lead, in turn, to changes in the fuel activity data for fisheries (gas oil), industry (heavy fuel oil) and international sea transport, so the national energy balance can remain unchanged.

For fisheries, fuel investigations made prior to the initiation of the work made by Winther (2008) have actually pointed out a certain area of inaccuracy in the DEA statistics. No engines installed in fishing vessels use heavy fuel oil, even though a certain amount of heavy fuel oil is listed in the DEA numbers for some statistical years (H. Amdissen, Danish Fishermen's Association, personal communication, 2006). Hence, for fisheries small amounts of fuel oil are transferred to national sea transport, and in addition small amounts of gasoline and diesel are transferred to recreational craft.

Non road machinery and recreational craft

For diesel and LPG, the non-road fuel consumption estimated by DCE is partly covered by the fuel consumption amounts in the following DEA sectors: agriculture and forestry, market gardening, and building and construction. The remaining quantity of non-road diesel and LPG is taken from the DEA industry sector.

For gasoline, the DEA residential sector, together with the DEA sectors mentioned for diesel and LPG, contribute to the non-road fuel consumption total. In addition, a certain amount of fuel from road transport is needed to reach the fuel consumption goal.

The amount of diesel and LPG in DEA industry not being used by non-road machinery is included in the sectors, “Combustion in manufacturing industry” (0301) and “Non-industrial combustion plants” (0203) in the Danish emission inventory.

For recreational craft, the calculated fuel consumption totals for diesel and gasoline are subsequently subtracted from the DEA fishery sector. For gasoline, the DEA reported fuel consumption for fisheries is far too small to fill the fuel gap, and hence the missing fuel amount is taken from the DEA road transport sector.

Bunkers

The distinction between domestic and international emissions from aviation and navigation should be in accordance with the Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories. For the national emission inventory, this, in principle, means that fuel sold (and associated emissions) for flights/sea transportation starting from a seaport/airport in the Kingdom of Denmark, with destinations inside or outside the Kingdom of Denmark, are regarded as domestic or international, respectively.

Aviation

As prescribed by the IPCC guidelines, for aviation, the fuel consumption and emissions associated with flights inside the Kingdom of Denmark are counted as domestic.

This report includes flights from airports in Denmark and associated jet fuel sales. Hence, the flights between airports in Denmark and flights from Denmark to Greenland and the Faroe Islands are classified as domestic and flights from Danish airports with destinations outside the Kingdom of Denmark are classified as international flights.

In Greenland and in the Faroe Islands, the jet fuel sold is treated as domestic. This decision becomes reasonable when considering that almost no fuel is bunkered in Greenland/the Faroe Islands by flights other than those going to Denmark.

Navigation

In DEA statistics, the domestic fuel total consists of fuel sold to Danish ferries and other ships sailing between two Danish ports. The DEA international fuel total consists of the fuel sold in Denmark to international ferries, international warships, other ships with foreign destinations, transport to Greenland and the Faroe Islands, tank vessels and foreign fishing boats.

In order to follow the IPCC guidelines the bottom-up fuel estimates for the ferry routes between Denmark and the Faroe Islands, and freight transport between Denmark and Greenland/Faroe Islands are being subtracted from the fuel sales figures for international sea transport prior to inventory fuel input.

In Greenland, all marine fuel sales are treated as domestic. In the Faroe Islands, fuel sold in Faroese ports for Faroese fishing vessels and other Faroese ships is treated as domestic. The fuel sold to Faroese ships bunkering outside Faroese waters and the fuel sold to foreign ships in Faroese ports or outside Faroese waters is classified as international (Lastein and Winther, 2003).

Conclusively, the domestic/international fuel split (and associated emissions) for navigation is not determined with the same precision as for aviation. It is considered, however, that the potential of incorrectly allocated fuel quantities is only a small part of the total fuel sold for navigational purposes in the Kingdom of Denmark.

3.3.5 Uncertainties and time series consistency

Uncertainty estimates for greenhouse gases on Tier 1 and Tier 2 levels, are made for road transport and other mobile sources using the guidelines formulated in the Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories (IPCC, 2000). For road transport, railways and fisheries, these guidelines provide uncertainty factors for activity data that are used in the Danish situation. For other sectors, the factors reflect specific national knowledge (Winther et al., 2006 and Winther, 2008). These sectors are (SNAP categories): Inland Waterways (a part of 1A3d: Navigation), Agriculture and Forestry (parts of 1A4c: Agriculture-/forestry/fisheries), Industry (mobile part of (1A2f: Industry-other), Residential (1A4b) and National sea transport (a part of 1A3d: Navigation).

The activity data uncertainty factor for civil aviation is based on expert judgement.

The calculations for Tier 1 are shown in Annex 3.B.17 for all emission components. Please refer to Chapter 1.7 for further information regarding the calculation procedure for Tier 2 uncertainty calculations.

Table 3.3.18 Tier 1 Uncertainties for activity data, emission factors and total emissions in 2013 and as a trend.

Category	Activity data %	CO_2 %	CH_4 %	N_2O %
Road transport	2	5	40	50
Military	2	5	100	1000
Railways	2	5	100	1000
Navigation (small boats)	41	5	100	1000
Navigation (large vessels)	11	5	100	1000
Fisheries	2	5	100	1000
Agriculture	24	5	100	1000
Forestry	30	5	100	1000
Industry (mobile)	41	5	100	1000
Residential	35	5	100	1000
Commercial/Institutional	35	5	100	1000
Civil aviation	10	5	100	1000
Overall uncertainty in 2013		5.3	32.7	143.9
Trend uncertainty		5.8	7.1	67.7

Table 3.3.19 Tier 2 Uncertainty factors for activity data and emission factors in 2013.

Category	Activity data %	CO_2 %	CH_4 %	N_2O %
Road transport	2	5	40	500
Military	2	5	100	1000
Railways	2	5	100	1000
Pleasure craft	41	5	100	1000
Regional ferries	20	5	100	1000
Local ferries	20	5	100	1000
Fisheries	2	5	100	1000
Greenland & Faroe Islands	20	5	100	1000
Other national sea transport	20	5	100	1000
Civil aviation	10	5	100	1000
Agriculture	24	5	100	1000
Forestry	30	5	100	1000
Industry	41	5	100	1000
Household and gardening	35	5	100	1000
Commercial and institutional	35	5	100	1000

Table 3.3.20 Tier 2 Uncertainty estimates for CO_2, CH_4, N_2O and CO_2-eq. in 2013.

		1990			2013			1990-2013		
		Median	Uncertainty (%)		Median	Uncertainty (%)		Median	Uncertainty (%)	
		Emission	Lower (-)	Upper (+)	Emission	Lower (-)	Upper (+)	Emission	Lower (-)	Upper (+)
CO_2	ktonnes	13643	5	5	14993	5	5	10	11	11
CH_4	tonnes	2930	27	37	930	26	39	-68	30	42
N_2O	Tonnes	694	46	202	750	42	170	9	259	559
CO_2 eq.	Ktonnes	13948	5	6	15268	5	6	9	12	14

As regards time series consistency, background flight data cannot be made available on a city-pair level prior to 2000. However, aided by LTO/aircraft statistics for these years and the use of proper assumptions, a good level of consistency is, in any case, obtained for this part of the transport inventory.

The time series of emissions for mobile machinery in the agriculture, forestry, industry, household and gardening (residential) and inland waterways (part of navigation) sectors are less certain than time series for other sectors, since DEA statistical figures do not explicitly provide fuel consumption information for working equipment and machinery.

3.3.6 Quality assurance/quality control (QA/QC)

The intention is to publish every second year a sector report for road transport and other mobile sources. The last sector report prepared concerned the 2010 inventory (Winther, 2012).

The QA/QC descriptions of the Danish emission inventories for transport follow the general QA/QC description for DCE in Section 1.6, based on the prescriptions given in the IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories (IPCC, 2000). A general QA/QC plan for the Danish greenhouse gas inventory has been elaborated by Nielsen et al. (2012).

An overview diagram of the Danish emission inventory system is presented in Figure 1.2 (Data storage and processing levels), and the exact definitions of Critical Control Points (CCP) and Points of Measurements (PM) are given in Section 1.6. The status for the PMs relevant for the mobile sector are given in the following text and the result of this investigation indicates a need for future QA/QC activities in order to fulfil the QA/QC requirements from the IPCC GPG.

Data storage level 1

Data Storage level 1	3.Completeness	DS.1.3.1	Documentation showing that all possible national data sources are included by setting down the reasoning behind the selection of datasets.

The following external data sources are used in the mobile part of the Danish emission inventories for activity data and supplementary information:

- Danish Energy Agency: Official Danish energy statistics.
- National sea transport (Royal Arctic Line, Eim Skip): Annual fuel consumption data.
- DTU Transport: Road traffic vehicle fleet and mileage data.
- Civil Aviation Agency of Denmark: Flight statistics.
- Non-road machinery: Information from statistical sources, research organisations, different professional organisations and machinery manufacturers.
- Ferries (Statistics Denmark): Data for annual return trips for Danish ferry routes.
- Ferries (Danish Ferry Historical Society): Detailed technical and operational data for specific ferries.
- Ferries (Mols Linjen, Bornholmstrafikken, Langelandstrafikken, Smyril Line): Detailed technical and operational data for specific ferries.
- Danish Meteorological Institute (DMI): Temperature data.
- The National Motorcycle Association: 2-wheeler data.

The emission factors come from various sources:

- Danish Energy Agency: CO_2 emission factors and lower heating values (all fuel types).
- COPERT IV: Road transport (all exhaust components, except CO_2, SO_2).
- Danish State Railways: Diesel locomotives (NO_X, VOC, CO and TSP).
- EMEP/EEA guidebook: Civil aviation and supplementary.
- Non road machinery: References given in NERI reports.
- National sea transport and fisheries: TEMA2010 (NO_X, VOC, CO and TSP) and MAN Diesel (sfc, NO_X).

Table 3.3.21 to follow contains Id, File/Directory/Report name, Description, Reference and Contacts. As regards File/Directory/Report name, this field refers to a file name for Id when all external data (time series for the existing inventory) are stored in one file. In other cases, a computer directory name is given when the external data used are stored in several files, e.g. each file contains one inventory year's external data or each file contains time series of external data for sub-categories of machinery. A third situation occurs when the external data are published in publicly available reports; here the aim is to obtain electronic copies for internal archiving.

Table 3.3.21 Overview table of external data and contact persons for transport.

Id no	File/-Directory/-Report name	Description	Activity data or emission factor	Reference	Contacts	Data agreement
T1	Transport energy[1]	Dataset for all transport energy use	Activity data	The Danish Energy Agency (DEA)	Jane Rusbjerg	Yes
T2	Fleet and mileage data[1]	Road transport fleet and mileage data	Activity data	DTU Transport	Thomas Jensen	Yes
T3	Flight statistics[2]	Data records for all flights	Activity data	Danish Transport Authority	Maria Dunbar	Yes
T4	Non road machinery[2]	Stock and operational data for non-road machinery	Activity data	Non road Documentation report		No
T5	Emissions from ships[3]	Data for ferry traffic	Activity data	Statistics Denmark	Bo Henry Eriksen	No
T6	Emissions from ships[3]	Technical and operational data for Danish ferries	Activity data	Navigation emission documentation report	Hans Otto Kristensen	No
T7	Temperature data[3]	Monthly average of daily max/min temperatures	Other data	Danish Meteorological Institute	Danish Meteorological Institute	No
T8	Fleet and mileage data[1]	Stock data for mopeds and motorcycles	Activity data	The National Motorcycle Association	Henrik Markamp	No
T9	CO_2 emission factors[1]	DEA CO_2 emission factors (all fuel types)	Emission factor	The Danish Energy Agency (DEA)	Jane Rusbjerg	No
T10	COPERT IV emission factors[3]	Road transport emission factors	Emission factor	Laboratory of applied thermodynamics Aristotle University Thessaloniki	Leonidas Ntziachristos	No
T11	Railways emission factors[1]	Emission factors for diesel locomotives	Emission factor	Danish State Railways	Per Delvig	Yes
T12	EMEP/EEA guidebook[3]	Emission factors for navigation, civil aviation and supplementary	Emission factor	European Environment Agency	European Environment Agency	No
T13	Non road emission factors[3]	Emission factors for agriculture, forestry, industry and household/gardening	Emission factor	Non road Documentation report		No
T14	Emissions from ships[3]	Emission factors for national sea transport and fisheries	Emission factor	Navigation emission documentation report		No

[1)] File name; [2)] Directory in the DCE data library structure; [3)] Reports available on the internet.

Danish Energy Agency (energy statistics)

The official Danish energy statistics are provided by the Danish Energy Agency (DEA) and are regarded as complete on a national level. For most transport sectors, the DEA subsector classifications fit the SNAP classifications used by DCE.

For non-road machinery, this is however not the case, since DEA do not distinguish between mobile and stationary fuel consumption in the subsectors relevant for non-road mobile fuel consumption.

Here, DCE calculates a bottom-up non-road fuel consumption estimate and for diesel (land based machinery only) and LPG, the residual fuel quantities are allocated to stationary consumption. For gasoline (land-based machinery) the relevant fuel consumption quantities for the DEA are smaller than the DCE estimates, and the amount of fuel consumption missing is subtracted from the DEA road transport total to account for all fuel sold. For recreational craft, no specific DEA category exists and, in this case, the gasoline and diesel fuel consumption is taken from road transport and fisheries, respectively.

In the case of Danish national sea transport, fuel consumption estimates are obtained by DCE (Winther, 2008), since they are regarded as much more accurate than the DEA fuel sales data. For the latter source, the large fluctuations in reported fuel sales cannot be explained by the actual development in the traffic between different national ports.

In order to maintain the national energy balance, the updated fuel consumption time series for national sea transport lead, in turn, to changes in the fuel activity data for fisheries (gas oil) and industry (heavy fuel oil).

The DCE fuel modifications, thus, give DEA-SNAP differences for road transport, national sea transport and fisheries.

A special note must be made for the DEA civil aviation statistical figures. The domestic/international fuel consumption division derives from bottom-up fuel consumption calculations made by DCE.

DTU Transport

Figures for fleet numbers and mileage data are provided by DTU Transport on behalf of the Danish Ministry of Transport. Following the data deliverance contract between DCE and the Danish Ministry of Transport, it is a basic task for DTU Transport to possess comprehensive information on Danish road traffic. The fleet figures are based on data from the Car Register, kept by Statistics Denmark and are, therefore, regarded as very precise. Annual mileage information is obtained by DTU Transport from the Danish Vehicle Inspection and Maintenance Programme.

Danish Transport Authority (Civil Aviation Agency of Denmark)

The Danish Transport Authority monitors all aircraft movements in Danish airspace and, in this connection, possesses data records for all take-offs and landings at Danish airports. The dataset from 2001 onwards, among others consisting of aircraft type and origin and destination airports for all flights leaving major Danish airports, are, therefore, regarded as very complete. For inventory years before 2001, the most accurate data contain Transport Authority total movements from major Danish airports and detailed aircraft type distributions for aircraft using Copenhagen Airport, provided by the airport itself.

Non-road machinery (stock and operational data)

A great deal of new stock and operational data for non road machinery was obtained in a research project carried out by Winther et al. (2006) for the 2004 inventory. The source for the agricultural machinery stock of tractors and harvesters is Statistics Denmark. Sales figures for tractors, harvesters and construction machinery, together with operational data and supplementary information, are obtained from The Association of Danish Agricultural Machinery Dealers. IFAG (The Association of Producers and Distributors of Fork Lifts in Denmark) provides fork-lift sale figures, whereas total stock numbers for gasoline equipment are obtained from machinery manufacturers with large Danish market shares, with figures validated through discussions with KVL. Stock information disaggregated into vessel types for recreational craft was obtained from the Danish Sailing Association. A certain part of the operational data comes from previous Danish non-road research projects (Dansk Teknologisk Institut, 1992 and 1993; Bak et al., 2003).

No statistical register exists for non-road machinery types and this affects the accuracy of stock and operational data. For tractors and harvesters, Statistics Denmark provide total stock data based on information from questionnaires and the registers of crop subsidy applications kept by the Ministry of Food, Agriculture and Fishery. In combination with new sales figures pr engine size from The Association of Danish Agricultural Machinery Dealers, the best available stock data are obtained. In addition, using the sources for construction machinery and fork lift sale figures are regarded as the only realistic approach for consolidated stock information for these machinery types. Use of this source-type also applies in the case of machinery types (gasoline equipment, recreational craft) where data is even scarcer.

To support the 2013 inventory, new 2013 stock data for tractors, harvesters, fork lifts and construction machinery was obtained from the same sources as in Winther et al. (2006). For non-road machinery in general, it is, however, uncertain if data in such a level can be provided annually in the future.

Ferries (Statistics Denmark)

Statistics Denmark provides information of annual return trips for all Danish ferry routes from 1990 onwards. The data are based on monthly reports from passenger and ferry shipping companies in terms of transported vehicles passengers and goods. Thus, the data from Statistics Denmark are regarded as complete. Most likely the data can be provided annually in the future.

Ferries (Danish Ferry Historical Society, DFS)

No central registration of technical and operational data for Danish ferries and ferry routes is available from official statistics. However, one valuable reference to obtain data and facts about construction and operation of Danish ferries, especially in the recent 20 - 30 years is the archives of Danish Ferry Historical Society. Pure technical data has not only been obtained from this society´s archives, but some of the knowledge has been obtained through the personal insight about ferries from some of the members of the society, which have been directly involved in the ferry business for example consultants, naval architects, marine engineers, captains and superintendents. However, until recently no documentation of the detailed DFS knowledge was established in terms of written reports or a central database system.

To make use of all the ferry specific data for the Danish inventories, DSF made a data documentation for the years 1990-2005 as a specific task of the research project carried out by Winther (2008).

Ferries (Mols Linjen, Bornholmstrafikken, Langelandstrafikken, Smyril Line)

For the years 2006+, the major Danish ferry companies are contacted each year in order to obtain ferry technical data, relating to specific ferries in service, annual share of total round trips and other technical information. The relevant annual information is given as personal communication, a method which can be repeated in the future.

National sea transport (Royal Arctic Line, Eim Skip)

For the years 2006+, the major shipping companies with frequent sailing activities between Denmark and Greenland/Faroe Islands are contacted each year in order to obtain data for fuel sold in Denmark used for these vessel activities. The relevant annual information is given as personal communication, a method which can be repeated in the future.

Danish Meteorological Institute

The monthly average max/min temperature for Denmark comes from DMI. This source is self explanatory in terms of meteorological data. Data are publicly available for each year on the internet.

The National Motorcycle Association

Road transport: 2-wheeler stock information (The National Motorcycle Association). Given that no consistent national data are available for mopeds in terms of fleet numbers and distributions according to new sales per year, The National Motorcycle Association is considered to be the professional organisation, where most expert knowledge is available. The relevant annual information is given as personal communication, a method which can be repeated in the future.

Danish Energy Agency (CO_2 emission factors and lower heating values)

The CO_2 emission factors and net calorific values (NCV) are fuel-specific constants. The country-specific values from the DEA are used for all inventory years.

COPERT IV

COPERT IV provides factors for fuel consumption and for all exhaust emission components which are included in the national inventory. For several reasons, COPERT IV is regarded as the most appropriate source of road traffic fuel consumption and emission factors. First of all, very few Danish emission measurements exist, so data are too scarce to support emission calculations on a national level. Secondly, most of the fuel consumption and emission information behind the COPERT model are derived from different large European research activities, and the formulation of fuel consumption and emission factors for all single vehicle categories has been made by a group of road traffic emission experts. A large degree of internal consistency is, therefore, achieved. Finally, the COPERT model is regularly updated with new experimental findings from European research programmes and, apart from updated fuel consumption and emission factors, the use of COPERT IV by many European countries ensures a large degree of cross-national consistency in reported emission results.

Danish State Railways

Aggregated emission factors of NO_x, VOC, CO and TSP for diesel locomotives are provided annually by the Danish State Railways. Taking into account available time resources for subsector emission calculations, the use of data from Danish State Railways is sensible. This operator accounts for around 90 % of all diesel fuel consumed by railway locomotives in Denmark and the remaining diesel fuel is used by various private railways companies. Setting up contacts with the private transport operators is considered to be a rather time consuming experience taking time away from inventory work in areas of greater emission importance.

EMEP/EEA guidebook

Fuel consumption and emission data from the EMEP/EEA guidebook is the prime and basic source for the aviation and navigation part of the Danish emission inventories. For aviation, the guidebook contains the most comprehensive list of representative aircraft types available for city-pair fuel consumption and emission calculations. The data have been evaluated specifically for detailed national inventory use by a group of experts representing civil aviation administration, air traffic management, emission modellers and inventory compilers.

In addition, the EMEP/EEA guidebook is the source of non-exhaust TSP, PM_{10}, $PM_{2.5}$ and BC emission factors for road transport, and the primary source of emission factors for some emission components – typically N_2O, NH_3 and PAH – for other mobile sources.

Non-road machinery (fuel consumption and emission factors)

The references for non-road machinery fuel consumption and emission factors are listed in Winther et al. (2006). The fuel consumption and emission data is regarded as the most comprehensive data collection on a European level, having been thoroughly evaluated by German emission measurement and non-road experts within the framework of a German non-road inventory project.

National sea transport and fisheries

Emission factors for NO_x, VOC, CO and TSP are taken from the TEMA2010 model developed for the Ministry of Transport. To a large extent the emission factors originate from the exhaust emission measurement programme carried out by Lloyd's (1995). For NO_x, additional information of emission factors in a time series going back to 1949, and PM_{10} and $PM_{2.5}$ fractions of total TSP was provided by the engine manufacturer MAN Diesel.

Specifically for the ferries used by Mols Linjen new NO_x, VOC and CO emission factors are provided by Kristensen (2008), originating from measurement results by Hansen et al. (2004), Wismann (1999) and PHP (1996). Kristensen (2013) has provided complimentary emission factor data for new ferries.

The experimental work by Lloyd's is still regarded as the most comprehensive measurement campaign with results publicly available. The additional NO_x and $PM_{10}/PM_{2.5}$ information comes from the world's largest ship engine manufacturer and data from this source is consistent with data from Lloyd's.

Consequently the data used in the Danish inventories for national sea transport is regarded as the best available for emission calculations.

Data Storage level 1	1. Accuracy	DS.1.1.1	General level of uncertainty for every dataset, including the reasoning for the specific values

The uncertainty involved in the DEA fuel consumption information (except civil aviation) and the Danish Transport Authority flight statistics is negligible, as such, and this is also true for DMI temperature data. For civil aviation, some uncertainty prevails, since the domestic fuel consumption figures originate from a division of total jet-fuel sales figures into domestic and international fuel quantities, derived from bottom-up calculations. A part of the fuel consumption uncertainties for non-road machines is due to the varying levels of stock and operational data uncertainties, as explained in DS 1.3.1.

As regards emission factors, the CO_2 factors (and NCVs) from the DEA are considered to be very precise, since they relate only to fuel. For the remaining emission factor sources, the SO_2 (based on fuel sulphur content), NO_X, NMVOC, CH_4, CO, TSP, PM_{10} and $PM_{2.5}$ emission factors are less accurate. Though many measurements have been made, the experimental data rely on the individual measurement and combustion conditions. The uncertainties for N_2O and NH_3 emission factors increase even further due to the small number of measurements available. For heavy metals and PAH, experimental data are so scarce that uncertainty becomes very high.

A special note, however, must be made for energy. The uncertainties due to the subsequent treatment of DEA data for road transport, national sea transport, fisheries and the non-road relevant sectors, explained in DS 1.3.1, trigger some uncertainties in the fuel consumption figures for these sectors. This point is, though, more relevant for QA/QC description for data processing, Level 1.

Data Storage level 1	2.Comparability	DS.1.2.1	Comparability of the emission factors/calculation parameters with data from international guidelines, and evaluation of major discrepancies.

Work has been carried out to compare Danish figures with corresponding data from other countries in order to evaluate discrepancies. The comparisons have been made on a CRF level, mostly for implied emission factors (Fauser et al., 2007, 2013).

Data Storage level 1	4.Consistency	DS.1.4.1	The origin of external data has to be archived with proper reference.

It is ensured that the original files from external data sources are archived internally at DCE. Subsequent raw data processing is carried out either in the DCE database models or in spreadsheets (data processing level 1).

Data Storage level 1	6.Robustness	DS.1.6.1	Explicit agreements between the external institution holding the data and DCE about the condition of delivery

For transport, DCE has made formal agreements with regard to external data deliverance with (Table 3.3.21 external data source Id's in brackets): DEA (T1), the Danish Transport Authority (T3), Danish State Railways (T9) and DTU Transport (T2).

Data Storage level 1	7. Transparency	DS.1.7.1	Listing of all archived datasets and external contacts

The listing of all archived datasets and external contact persons are given in Table 3.3.21.

Data Processing Level 1

Data Processing level 1	1. Accuracy	DP.1.1.1	Uncertainty assessment for every data source not part of DS.1.1.1 as input to Data Storage level 2 in relation to type and scale of variability.

The general uncertainties of the DEA fuel consumption information, DMI temperature data, road transport stock totals and the Danish Transport Authority flight statistics are zero. For domestic aviation fuel consumption, the uncertainty is based on own judgement. For road transport, military and railways the fuel consumption uncertainties are taken from the IPCC Good Practice Guidance manual. It is noted that for road transport, it is not possible to quantify in-depth the uncertainties (1) of stock distribution into COPERT IV-relevant vehicle subsectors and (2) of the national mileage figures, as such.

In the mobile part of the Danish emission inventories, uncertainty assessments are made at Data Processing Level 1 for non-road machinery, recreational craft and national sea transport. For these types of mobile machinery, the stock and operational data variations are assumed to be normally distributed (Winther et al., 2006; Winther, 2008). Tier 1 uncertainty calculations produce final fuel consumption uncertainties ready for Data Storage Level 2 (SNAP level 2: Inland waterways, agriculture, forestry, industry and household-gardening). The sizes of the variation intervals are given for activity data and emission factors in the present report.

For non-road machinery stock and operational data, the uncertainty figures are given in Winther et al. (2006). For navigation, the uncertainty figures are given in Winther (2008).

For emission factors, the uncertainties for mobile sources are determined as suggested in the IPCC and UNECE guidelines. The uncertainty figures are listed in Paragraph 1.1.5 for greenhouse gases, and in Winther et al. (2006) and Winther (2008, 2012) for the remaining emission components.

Data Processing level 1	1. Accuracy	DP.1.2.1	The methodologies have to follow the international guidelines suggested by UNFCCC and IPCC.

An evaluation of the methodological inventory approach has been made, which proves that the emission inventories for transport are made according to the IPCC guidelines (IPCC, 2006). Further, the Danish inventories are reviewed annually by the UNFCCC.

Data Processing level 1	1. Accuracy	DP.1.1.4	Verification of calculation results using guideline values

It has been checked that the greenhouse gas emission factors used in the Danish inventory are within margin of the IPCC guideline values.

Data Processing level 1	3.Completeness	DP.1.3.1	Identification of data gaps with regard to data sources that could improve quantitative knowledge.

No important areas can be identified.

Data Processing level 1	4.Consistency	DP.1.4.1	Documentation and reasoning of methodological changes during the time series and the qualitative assessment of the impact on time series consistency.

Se DP 1.7.5.

Data Processing level 1	5.Correctness	DP.1.5.2	Verification of calculation results using time series

Data Processing level 1	5.Correctness	DP.1.5.3	Verification of calculation results using other measures

For road transport, aviation, navigation and non-road machinery, whether all external data are correctly put into the DCE transport models is checked. This is facilitated by the use of sum queries which sum up stock data (and mileages for road transport) to input aggregation levels. However, spreadsheet or database manipulations of external data are, in some cases, included in a step prior to this check.

This is carried out in order to produce homogenous input tables for the DCE transport models (road, civil aviation, non-road machinery/recreational craft, navigation/fisheries). The sub-routines perform operations, such as the aggregation/disaggregation of data into first sales year (Examples: Fleet numbers and mileage for road transport, stock numbers for tractors, harvesters and fork lifts) or simple lists of total stock pr year (per machinery type for e.g. household equipment and for recreational craft). For civil aviation, additional databases control the allocation of representative aircraft to real aircraft types and the cruise distance between airports. A more formal description of the sub-routines will be made.

Regarding fuel data, it is checked for road transport and civil aviation that DEA totals (modified for road) match the input values in the DCE models.

For the transport modes military and railways, the DEA fuel consumption figures go directly into Data Storage Level 2. This is also the case for the railway emission factors obtained from Danish State Railways and, generally, for the emission factors, which are kept constant over the years.

The DCE model simulations of fuel consumption and emission factors for road transport, civil aviation and non-road machinery refer to Data Processing Level 1.

When DCE transport model changes are made relating to fuel consumption, it is checked that the calculated fuel consumption sums correspond to the expected fuel consumption levels in the time series. The fuel consumption check also includes a time series comparison with fuel consumption totals calculated in the previous model version. The checks are performed on a SNAP level and, if appropriate, detailed checks are made for vehicle/machinery technology splits.

As regards model changes in relation to derived emission factors (and calculated emissions), the time series of emission factors (and emissions) are compared to previous model figures. A part of this evaluation includes an assessment, if the development corresponds to the underlying assumptions given by detailed input parameters. Among other things, the latter parameters depend on emission legislation, new technology phase-in, deterioration factors, engine operational conditions/driving modes, gasoline evaporation (hydrocarbons) and cold starts. For methodological issues, please refer to Section 3.3.2.

Data Processing level 1	7.Transparency	DP.1.7.1	The calculation principle, the equations used and the assumptions made must be described

The DCE model calculation principles and basic equations are thoroughly described in the present report, together with the theoretical model reasoning and assumptions. Documentation is also given e.g. in Winther (2001a, 2008, 2012) and Winther et al. (2006). Further formal descriptions of DCE model sub routines are given in internal notes, and flow maps show the interrelations between tables and calculation queries in the models.

During model development it has been checked that all mathematical model relations give exactly the same results as independent calculations.

Data Processing level 1	7.Transparency	DP.1.7.2	Clear reference to dataset at Data Storage level 1

In the different documentation reports for transport in the Danish emission inventories, there are explicit references for the different external data used.

Data Processing level 1	7.Transparency	DP.1.7.3	A manual log to collect information about recalculations

Recalculation changes in the emission inventories are described in the NIR and IIR reports as a standard. These descriptions take into account changes in emission factors, activity data and calculation methods.

Data Storage Level 2

Data Storage level 2	5.Correctness	DS.2.5.1	Check if a correct data import to level 2 has been made

At present, a DCE software programme imports data from prepared input data tables (SNAP fuel consumption figures and emission factors) into the CollectER database.

Tables for CollectER fuel consumption and emission results are prepared by a special DCE database (NERIrep.mdb). The results relevant for mobile sources are copied into a database containing all the official inventory results for mobile sources (Data2013 NIR-UNECE.mdb). By the use of database queries, the results from this latter database are aggregated into the same formats as being used by the relevant DCE transport models in their results calculation part. The final comparison between CollectER and DCE transport model results are set up in a spreadsheet.

Data Storage Level 4

Data Storage level 4	4.Consistency	DS.4.4.3	The IEFs from the CRF are checked both regarding level and trend. The level is compared to relevant emission factors to ensure correctness. Large dips/jumps in the time series are explained

A spreadsheet "Check CRF 2013.xls" has been set up to check that the fuel consumption and emission totals from CollectER imported in Data2013 NIR-UNECE.mdb are identical to the fuel consumption and emission totals from the CRF.

3.3.7 Recalculations and improvements

The following recalculations and improvements of the emission inventories have been made since the emission reporting in 2013.

Road transport

Based on the updated version of COPERT IV version 11 launched in 2014, fuel consumption and NO_x , VOC, CO and PM emission factors for euro 5 and 6 gasoline and diesel passenger cars and light duty vehicles have been updated in the model. Updated Euro V and VI fuel consumption and NO_x, VOC, CO and PM emission factors for heavy duty vehicles have been included in the calculations also.

For N_2O and NH_3, Euro 5/6 and V/VI emission factors are also updated for passenger cars/light duty vehicles (only N_2O) and heavy duty vehicles.

Further a new Euro 6c technology class has been added for diesel passenger cars and light duty vehicles.

The amount of diesel sold for road transport reported by the Danish Energy Agency has been slightly changed in 2012.

Very small changes in mileage data has been made for the years 1985-2012 based on new information from DTU Transport.

The percentage emission change interval and year of largest percentage differences (low %; high %, year) for the different emission components are:

CO_2 (0 %; 0.2 %, 2011), CH_4 (-0.1 %; 0.4 %, 2012) and N_2O (-21.7 %; 0 %, 2006).

Navigation

Recreational craft have been regrouped in the Danish inventory. These vessels have now been removed from the navigation sector and included under Other (1A5b), the latter sector according to its sector subtitle also comprise recreational craft. Further, small amounts of LPG and kerosene previously included in the navigation sector has now been transferred to stationary sources.

The following largest percentage differences (in brackets) for domestic navigation are noted for: CO_2 (-20 %), CH_4 (-72 % and N_2O (-12 %).

Agriculture/forestry

The baseline emission factors of NOx, TSP, CO and VOC and the transient factors for fuel consumption, NOx, TSP, CO and VOC for diesel machinery has been slightly changed in the calculation model used to estimate the emissions from Danish non road mobile machinery. Further, the CH_4 fraction of VOC has been updated. The changes are made based on new emission knowledge published by IFEU (1999) for baseline emission factors and CH_4 fractions, and IFEU (2014) for transient factors.

The number of agricultural tractors has been regrouped into finer engine size intervals for all inventory years. The total number of agricultural tractors and harvesters has been updated for the years 2006-2012 based on new stock data from Statistics Denmark for the year 2013.

The following largest percentage differences (in brackets) for agriculture/forestry are noted for: The following largest percentage differences (in brackets) are noted for: CO_2 (0.5 %), CH_4 (100 % and N_2O (0.6 %).

Fisheries

Small amounts of LPG and kerosene previously included in the navigation sector has now been transferred to stationary sources.

The following largest percentage differences (in brackets) for fisheries are noted for: CO_2 (-0.8 %), CH_4 (-8.9 % and N_2O (0.1 %).

Industry

The baseline emission factors of NOx, TSP, CO and VOC and the transient factors for fuel consumption, NOx, TSP, CO and VOC for diesel machinery has been slightly changed in the calculation model used to estimate the emissions from Danish non road mobile machinery. Further, the CH_4 fraction of VOC has been updated. The changes are made based on new emission knowledge published by IFEU (1999) for baseline emission factors and CH_4 fractions, and IFEU (2014) for transient factors.

The following largest percentage differences (in brackets) for industrial non road machinery are noted for: CO_2 (0.6 %), CH_4 (14 % and N_2O (0.1 %).

Civil aviation

The model used for calculating civil aviation emissions has been updated by replacing the previous fuel consumption and emission factors for representative aircraft types (46 types) with a new and more comprehensive list of aircraft types (79 types) provided by Eurocontrol and published in the EMEP/EEA guidebook (EMEP/EEA, 2014).

The following largest percentage differences (in brackets) for civil aviation are noted for: CO_2 (32 %), CH_4 (44 % and N_2O (-8.9 %).

Other (Military and recreational craft)

Recreational craft have been regrouped in the Danish inventory. These vessels have now been removed from the navigation sector and included under Other (1A5b), the latter sector according to its sector subtitle also comprises recreational craft.

NOx, CO, VOC and TSP emission factors have been updated for diesel and gasoline boats complying with Directive 2003/44 based on reassessment of the emission factor data reported by IFEU (2004). The latter reference has all the time been the source of emission data for recreational craft in the Danish emission inventory.

The following largest percentage differences (in brackets) for military are noted for: CO_2 (108 %), CH_4 (1780 %) and N_2O (93 %).

3.3.8 Planned improvements

No planned improvements are envisaged to be made.

QA/QC

Future improvements regarding this issue are dealt with in Section 3.1.4.

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3.4 Additional information, fuel combustion

3.4.1 Reference approach, feedstocks and non-energy use of fuels

In addition to the sector specific CO_2 emission inventories (the national approach), the CO_2 emission is also estimated using the reference approach described in the IPCC Guidelines (IPCC, 2006). The reference approach is based on data for fuel production, import, export and stock change. The CO_2 emission inventory based on the reference approach is reported to the Climate Convention and used for verification of the sectoral approach.

Data for import, export and stock change used in the reference approach originate from the annual "basic data" table prepared by the Danish Energy

Agency (DEA) and published on their home page (DEA, 2014). The fraction of carbon oxidised has been assumed to be 1.00.

The applied carbon emission factors are equal to the emission factors also applied in the sectoral approach and thus include nationally referenced emission factors. This is in agreement with the 2006 IPCC Guidelines. It is however a recalculation compared to earlier years where default IPCC emission factors were applied in the reference approach.

The Climate Convention reporting tables include a comparison of the national approach and the reference approach estimates.

In the revised CRF format the consumption for non-energy purposes is subtracted in the reference approach, because non-energy use of fuels is included in other sectors (Industrial processes and Solvent use) in the Danish national approach. Three fuels are used for non-energy purposes: lubricants, bitumen and white spirit. The total consumption for non-energy purposes is relatively low – 11.6 PJ in 2013.

The CO_2 emission from oxidation of lube oil during use was 32 Gg in 2013 and this emission is reported in the sector industrial processes and product use (sector 2.D). The reported emission corresponds to 20 % of the CO_2 emission from lube oil consumption assuming full oxidation. This is in agreement with the methodology for lube oil emissions in the 2006 IPCC Guidelines (IPCC, 2006). Methodology and emission data for lube oil are shown in NIR Chapter 4.5.2.

For white spirit the CO_2 emission is indirect as the emissions occur as NMVOC emissions from the use of white spirit as a solvent. The indirect CO_2 emission from solvent use was 68 Gg in 2013. The methodology and emission data for white spirit are included in NIR Chapter 4.5.4.

The CO_2 emission from bitumen is included in sector 2.D.3, Road paving with asphalt and Asphalt roofing. The total CO_2 emissions for these sectors are 0.16 Gg. Methodology and emission data for non-energy use of bitumen are shown in NIR Chapter 4.5.6.

In the current version of the CRF, the CO_2 emission from fossil waste combustion is not included in the total CO_2 emission based on the reference approach shown in CRF Table 1.A(c). Thus, the difference between the two CO_2 emission estimates stated in CRF Table 1.A(c) is not correct. To make results comparable, the CO_2 emission from incineration of fossil waste have been added to the reference approach CO_2 emission data in CRF Table 1.A(c) and this total CO_2 emission have been compared to the results in the national approach. This corrected comparison is shown in Table 3.4.1 below.

Table 3.4.1 Corrected values for CRF Table 1.A(c).

Year	**Difference Energy consumption [%]**	CRF value in Table 1.A(c), Difference CO_2 emission [%]	CRF value in Table 1.A(b), Actual CO_2 emission from waste (non-biomass fraction), kt.	Corrected CO_2 emission based on the reference approach, kt.	CO_2 emission based on sectoral approach, kt.	**Corrected difference in CO_2 emission [%]**
1990	**0.25**	-1.27	573.46	51240	51317	**-0.15**
1991	**-0.63**	-1.89	619.53	60992	61533	**-0.88**
1992	**-0.13**	-1.73	658.50	55373	55677	**-0.55**
1993	**-0.49**	-2.13	718.17	57544	58063	**-0.89**
1994	**-0.39**	-2.03	751.56	61518	62024	**-0.82**
1995	**-0.65**	-2.27	847.53	58455	58943	**-0.83**
1996	**-0.56**	-1.96	923.24	71651	72141	**-0.68**
1997	**-0.09**	-1.64	990.49	62382	62414	**-0.05**
1998	**1.46**	-0.28	983.86	59341	58522	**1.40**
1999	**-0.62**	-2.74	1,078.12	54928	55366	**-0.79**
2000	**0.21**	-2.01	1,124.50	51489	51400	**0.17**
2001	**0.83**	-1.41	1,192.65	53448	53005	**0.84**
2002	**0.13**	-2.32	1,253.35	52753	52724	**0.06**
2003	**0.17**	-2.24	1,354.16	58012	57959	**0.09**
2004	**0.08**	-2.62	1,379.10	52312	52302	**0.02**
2005	**-0.79**	-3.58	1,398.30	48569	48922	**-0.72**
2006	**-0.55**	-3.14	1,421.76	56488	56853	**-0.64**
2007	**-0.82**	-3.64	1,470.88	51645	52068	**-0.81**
2008	**-0.02**	-3.24	1,535.85	48971	49025	**-0.11**
2009	**-1.48**	-4.54	1,455.75	46565	47255	**-1.46**
2010	**0.39**	-2.78	1,398.44	47630	47552	**0.16**
2011	**-0.87**	-4.15	1,421.81	42232	42575	**-0.81**
2012	**-1.33**	-5.11	1,380.42	37543	38110	**-1.49**
2013	**-0.46**	-4.50	1,391.41	39527	39934	**-1.02**

The comparison of the national approach and the reference approach is illustrated in Figure 3.4.1. In 2013, the fuel consumption rates in the two approaches differ by 0.46 % and the CO_2 emission differs by 1.02 %. In the period 1990-2013 both the fuel consumption and the CO_2 emission differ by less than 1.5 %.

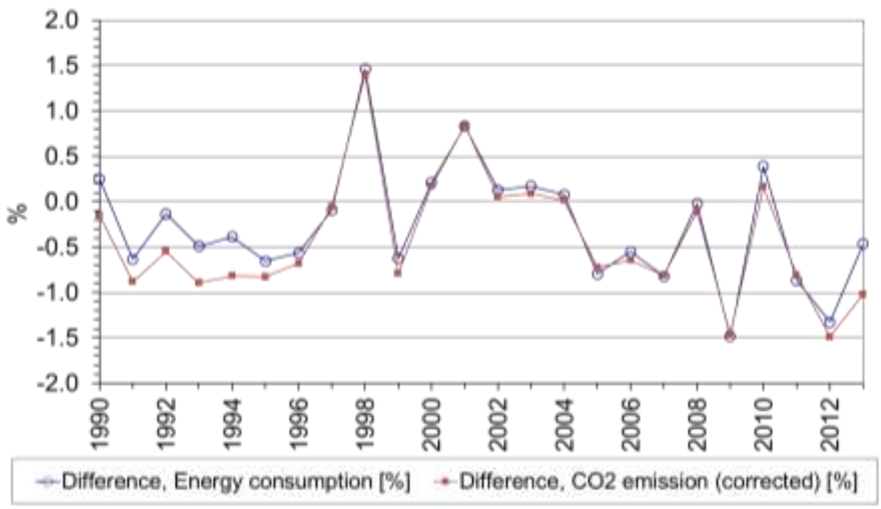

Figure 3.4.1 Comparison of the reference approach and the national approach.

The fluctuations in figure 3.4.1 follow the fluctuations of the statistical difference in the Danish energy statistics shown in Figure 3.4.2. The large differences in certain years, e.g. in 1998, 2009 and 2012 are due to high statistical differences in the Danish energy statistics in these years.

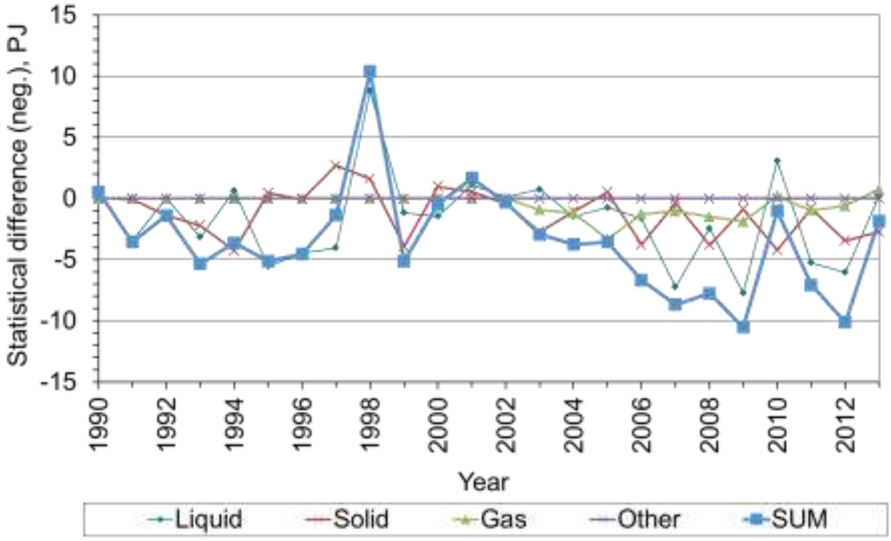

Figure 3.4.2 Statistical difference in the Danish energy statistics (DEA, 2014).

References for Chapter 3.4

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3.5 Fugitive emissions

Fugitive emissions from fuels include emissions from production, storage, refining and transport of oil and natural gas. Emissions from solid fuels are not occurring in Denmark. Most fugitive emission sources are of minor importance compared to the total Danish emissions. Fugitive and national total emissions are given in Table 3.5.1 with the fugitive emissions share of national total emission.

Table 3.5.1 National and fugitive emissions of CO_2, CH_4 N_2O and GHG in 2013, and the fugitive emissions share of national total emissions.

Compound	National emission		Fugitive emission		Fugitive/national emission	
CO_2	41 622	Gg CO_2 eqv.	238	Gg CO_2 eqv.	0.6	%
CH_4	6 906	Gg CO_2 eqv.	107	Gg CO_2 eqv.	1.6	%
N_2O	5 132	Gg CO_2 eqv.	41	Gg CO_2 eqv.	0.8	%
GHG	54 584	Gg CO_2 eqv.	387	Gg CO_2 eqv.	0.7	%

The key category analysis shows that CO_2 from offshore flaring is Approach 1 Level key category in 1990 and 2013. Further N_2O from offshore flaring is Approach 2 Level key category in 1990 and 2013 (Table 3.5.2).

Table 3.5.2 Key categories in the fugitive emission sector.

CRF table	Pollutant	Emission source	Key category identification	
			Approach 1	Approach 2
1.B.2	CO_2	Exploration, oil	-	-
1.B.2	CO_2	Production, oil	-	-
1.B.2	CO_2	Transport, oil	-	-
1.B.2	CO_2	Exploration, gas	-	-
1.B.2	CO_2	Production, gas	-	-
1.B.2	CO_2	Transport and storage, gas	-	-
1.B.2	CO_2	Distribution, gas	-	-
1.B.2	CO_2	Venting, gas	-	-
1.B.2	CO_2	Flaring, oil	-	-
1.B.2	CO_2	Flaring, gas	Level in 1990 & 2013	-
1.B.2	CH_4	Exploration, oil	-	-
1.B.2	CH_4	Production, oil	-	-
1.B.2	CH_4	Transport, oil	-	-
1.B.2	CH_4	Exploration, gas	-	-
1.B.2	CH_4	Production, gas	-	-
1.B.2	CH_4	Transport and storage, gas	-	-
1.B.2	CH_4	Distribution, gas	-	-
1.B.2	CH_4	Venting, gas	-	-
1.B.2	CH_4	Flaring, oil	-	-
1.B.2	CH_4	Flaring, gas	-	-
1.B.2	N_2O	Exploration, oil	-	-
1.B.2	N_2O	Production, oil	-	-
1.B.2	N_2O	Flaring, oil	-	-
1.B.2	N_2O	Flaring, gas	-	Level in 1990 & 2013

Calculations of fugitive emissions are based on Tier 3 methodologies. In accordance with the IPCC Good Practice Guidance (2006) emission calculations for fugitive key sources are done using higher methodological tiers than Tier 1. The applied methodologies and the level of detail for the applied emission factors in are listed in (Table 3.5.3).

Table 3.5.3 Applied methodology for fugitive emission sources.

CRF	Source	Pollutant	Method	Emission factor
1 B 2 a i	Exploration of oil	CO_2 CH_4 N_2O	Tier 3 Tier 3 Tier 3	PS CS D
1 B 2 a ii	Production of oil, Land-based activities	CO_2 CH_4	Tier 3 Tier 3	D CS, OTH (EMEP/EEA 2013)
1 B 2 a ii	Production of oil, Offshore activities	CO_2 CH_4	Tier 3 Tier 3	D D, OTH (EMEP/EEA 2013)
1 B 2 a iv	Refining/storage	CH_4	Tier 3	PS
1 B 2 b i	Exploration of gas	CO_2 CH_4 N_2O	Tier 3 Tier 3 Tier 3	PS CS D
1 B 2 b ii	Production of gas, Offshore activities	CO_2 CH_4	Tier 3 Tier 3	D D
1 B 2 b iii	Transmissions and storage	CO_2 CH_4	Tier 3 Tier 3	CS CS
1 B 2 b iv	Distribution	CO_2 CH_4	Tier 3 Tier 3	CS CS
1 B 2 c 1 ii	Venting in gas storage	CO_2 CH_4	Tier 3 Tier 3	CS D
1 B 2 c 2 i	Flaring in oil refinery	CO_2 CH_4 N_2O	Tier 3 Tier 3 Tier 3	PS * PS, CS D
1 B 2 c 2 ii	Flaring in gas storage, transmission and distribution	CO_2 CH_4 N_2O	Tier 3 Tier 3 Tier 3	PS * D D
1 B 2 c 2 iii	Flaring in oil and gas extraction	CO_2 CH_4 N_2O	Tier 3 Tier 3 Tier 3	PS ** D D

PS: plant specific. CS: country specific, D: default (IPCC, 2006), OTH: other.
* Plant specific emission factors are available from the EU ETS from 2007 and forward. For earlier years country specific emission factors are applied.
** Plant specific emission factors are available from the EU ETS from 2008 and forward. For earlier years country specific emission factors are applied.

3.5.1 Source category description

According to the IPCC sector definitions the category *fugitive emissions* is a sub-category under the main-category Energy (Sector 1). The category *fugitive emissions* (Sector 1B) is segmented into sub-categories covering emissions from solid fuels (coal mining and handling (1B1a), solid fuel transformation (1B1b) and other (1B1c)) and from oil and natural gas (oil (1B2a), natural gas (1B2b), venting and flaring (1B2c) and other (1B2d)). The sub-categories relevant for the Danish emission inventory are shortly described below according to Danish conditions:

- 1B1a: Fugitive emission from solid fuels: Coal mining is not occurring in Denmark. Therefore only emissions of particulate matter from storage and handling of coal are considered.
- 1B2a: Fugitive emissions from oil include emissions from exploration, extraction, storage, and transmission of crude oil, distribution of oil products and fugitive emissions from refining.
- 1B2b: Fugitive emissions from natural gas include emissions from exploration, extraction, transmission and distribution of natural gas.
- 1B2c: Venting and flaring include activities onshore and offshore. Flaring occur both offshore and onshore in gas treatment and storage plants and in refineries. Venting occurs in gas storage plants. Venting of gas is as-

sumed to be negligible in extraction and in refineries as controlled venting enters the gas flare system.

Activity data, emission factors and emissions are stored in the Danish emission database on SNAP sector categories (Selected Nomenclature for Air Pollution). In Table 3.5.4 the corresponding SNAP codes and IPCC sectors relevant to fugitive emissions are shown. Further, the table holds the SNAP names for the SNAP codes and the overall activity (e.g. oil and natural gas).

Table 3.5.4 List of the IPCC sectors and corresponding SNAP codes for the categories included in the Danish emission inventory model.

IPCC sectors	SNAP code	SNAP name	Fuel/source
1 B 1 a	050103*	Storage of solid fuel	Coal mining and handling
1 B 2 a i	050204	Exploration of oil	Oil
1 B 2 a ii	050201	Land-based activities	Oil
1 B 2 a ii	050202	Offshore activities	Oil
1 B 2 a iv	040101	Petroleum products processing	Oil
1 B 2 a iv	040103	Sulphur recovery plants	Oil
1 B 2 a v	050503	Service stations (including refuelling of cars)	Oil
1 B 2 b i	050304	Exploration of gas	Natural gas
1 B 2 b ii	050303	Offshore activities	Natural gas
1 B 2 b iii	050601	Transmissions and storage	Natural gas
1 B 2 b iv	050603	Distribution	Natural gas
1 B 2 c 1 ii	050699	Venting in gas storage	Venting
1 B 2 c 2 i	090203	Flaring in oil refinery	Flaring
1 B 2 c 2 ii	090206	Flaring in oil and gas extraction	Flaring
1 B 2 c 2 iii	090298	Flaring in gas storage	Flaring
1 B 2 c 2 iii	090299	Flaring in gas transmission and distribution	Flaring

*Only relevant for emissions of particulate matter from storage and handling of coal.

Table 3.5.5 summarizes the Danish fugitive emissions in 2013 (for information on other pollutants, please refer to Nielsen et. al., 2015). The methodologies, activity data and emission factors used for calculation are described in the following chapters.

Table 3.5.5 Summary of the Danish fugitive emissions 2013. P refers to point source and A to area source.

IPCC code	SNAP code	Source	Pollutant	Emission	Unit
1.B.2.a.1	050204	A	004	0,01	Mg
1.B.2.a.1	050204	A	006	3	Gg
1.B.2.a.1	050204	A	007	<0.01	Mg
1.B.2.a.2	050202	A	004	6	Mg
1.B.2.a.2	050202	A	006	<0.01	Gg
1.B.2.a.3	050201	A	004	721	Mg
1.B.2.a.3	050201	A	006	<0.01	Gg
1.B.2.a.3	050202	A	004	48	Mg
1.B.2.a.4	040101	P	004	619	Mg
1.B.2.b.1	050304	A	004	<0.01	Mg
1.B.2.b.1	050304	A	006	<0.01	Gg
1.B.2.b.1	050304	A	007	<0.01	Mg
1.B.2.b.2	050303	A	004	1788	Mg
1.B.2.b.2	050303	A	006	0,07	Gg
1.B.2.b.4	050601	A	004	16	Mg
1.B.2.b.4	050601	A	006	<0.01	Gg

1.B.2.b.5	050603	A	004	122	Mg
1.B.2.b.5	050603	A	006	<0.01	Gg
1.B.2.c.1.ii	050699	A	006	<0.01	Gg
1.B.2.c.1.ii	050699	P	004	53	Mg
1.B.2.c.1.ii	050699	P	006	<0.01	Gg
1.B.2.c.2.i	090203	P	004	5	Mg
1.B.2.c.2.i	090203	P	006	15	Gg
1.B.2.c.2.i	090203	P	007	0,1	Mg
1.B.2.c.2.ii	090206	A	004	916	Mg
1.B.2.c.2.ii	090206	A	006	218	Gg
1.B.2.c.2.ii	090206	A	007	138	Mg
1.B.2.c.2.ii	090298	P	004	0,02	Mg
1.B.2.c.2.ii	090298	P	006	2	Gg
1.B.2.c.2.ii	090298	P	007	<0.01	Mg
1.B.2.c.2.ii	090299	A	004	0,6	Mg
1.B.2.c.2.ii	090299	A	006	0,1	Gg
1.B.2.c.2.ii	090299	A	007	<0.01	Mg

3.5.2 Methodological issues

The following chapters give descriptions on the methods of calculation used in the Danish emission inventory. Further, the activity data and emission factors that form the basis for the calculations are described according to data source and values.

Test Use of EU ETS data

Reporting to the European Union Emission Trading Scheme (EU ETS) are available in the annual EU ETS reports for refineries, offshore oil and gas extraction facilities and the natural gas treatment plant, concerning fugitive emissions. EU ETS data are only included in the national emission inventory if higher tier methodologies are applied. The EU ETS data used are fully in line with the requirements in the IPCC good practice guidance and are considered the best data source on CO_2 emission factors due to the legal obligation for the relevant companies to make the accounting following the specified EU decisions. The EU ETS data are thereby a source of consistent data with low uncertainties. For further information on EU ETS please refer to Chapter 1.4.10. Unfortunately, corresponding data do not exist before the commencement of EU ETS in 2006 and therefore it is not possible to set up time series based on EU ETS. In these cases appropriate methods from the IPCC good practice guidance have been selected to ensure time series consistency. This is described in the specific sections.

Refineries:

Activity data are measured with flow meters and amounts are reported with high accuracy and the oxidation factor is set to 1. CO_2 emission factors are calculated according to the relevant Tier given in the EU Commission Decision of 18 July 2007 (EU Commission, 2007). For combustion of fuel gas, the Tier 2b methodology based on yearly density and calorific values is applied, while the activity specific Tier 3 methodology is applied for diesel. CO_2 emissions factors for flaring are calculated using the Tier 3 methodology based on the measured carbon contents of flare gas.

Offshore installations:

Activity data are measured with flow meters and amounts are reported with high accuracy (± 1.5 % for combustion and ± 7.5 – ± 17.5 % for flare). The oxidation factor is set to 1. CO_2 emission factors are calculated according to the relevant Tier given in the EU Commission Decision of 18 July 2007 (EU Commission, 2007). For combustion of fuel gas the Tier 3 methodology, which is activity specific, is applied, while the country specific Tier 2a methodology is applied for diesel. CO_2 emissions factors for flaring are calculated using the Tier 3 methodology based on the measured carbon contents of flare gas.

Fugitive emissions from oil (1B2a)

The emissions from oil derive from offshore activities, service stations and refineries. Emissions from offshore activities include emissions from exploration, production, onshore oil tanks and onshore and offshore loading of ships. In the case of service stations emissions from reloading of tankers and refuelling of vehicles are included. The emissions from refineries derive from petroleum products processing (oil refining). Emissions from flaring and venting are included in the chapters concerning flaring. The total emission can be expressed as:

$$E_{total} = E_{\mathrm{exploration}} + E_{extraction} + E_{shiploading} + E_{oil\,terminal} \qquad \text{(Eq. 3.5.1)}$$

Fugitive emissions from exploration

Fugitive emissions from exploration of oil are based on amounts and composition per exploration drilling. As calorific values and densities are not available per drilling, data from a gas test in 1992 are used.

Fugitive emissions from extraction

The methodology for calculation of emissions from extraction is based on standard emission factors from the 2006 IPCC Guidelines (IPCC, 2006).

Loading of ships

Fugitive emissions of CH_4 and NMVOC from loading of ships include the transfer of oil from storage tanks or directly from the well into ships. The activity also includes losses during transport. When oil is loaded hydrocarbon vapour will be displaced by oil and new vapour will be formed, both leading to emissions. The emissions from ships are calculated by equation 3.5.2.

$$E_{ships} = EF_{ships,onshore} \cdot L_{oil,onshore} + EF_{ships,offshore} \cdot L_{oil,ofshore} \qquad \text{(Eq. 3.5.2)}$$

where EF_{ships} is the emission factor for loading of ships offshore and onshore and L_{oil} is the amount of oil loaded.

Oil terminal

The CH_4 and NMVOC emissions from storage and handling of oil are given in the environmental reports for the raw oil terminal from DONG Oil Pipe A/S for 2013 (DONG Oil Pipe A/S, 2014). An implied emission factor is calculated for use in the reporting template on the basis of the amount of oil transported in pipelines according to equation 3.5.3.

$$IEF_{terminal} = \frac{E_{terminal}}{T_{oil}} \qquad \text{(Eq. 3.5.3)}$$

where $IEF_{terminal}$ is the implied emission factor for storage of raw oil in tanks, $E_{terminal}$ is the emission and T_{oil} is the amount of oil transported in pipelines.

Service stations

NMVOC emissions from service stations are estimated as outlined in equation 3.5.4.

$$E_{service\,stations} = \left(EF_{reloading} \cdot T_{fuel}\right) + \left(EF_{refuelling} \cdot T_{fuel}\right) \qquad \text{(Eq.3.5.4)}$$

where $EF_{reloading}$ is the emission factor for reloading of tankers to underground storage tanks at the service stations, $EF_{refuelling}$ is the emission factor for refuelling of vehicles and T_{fuel} is the amount of gasoline used for road transport.

Oil refining

When oil is processed in the refineries, part of the volatile organic compounds (VOC) is emitted to the atmosphere. The VOC emissions from the oil refinery process include non-combustion emissions from handling and storage of feedstock (raw oil), from the petroleum product processing and from handling and storage of products. When only the total VOC emission is given by a refinery the emission of CH_4 and NMVOC is estimated due to the assumption that 10 % of VOC is CH_4 and the remaining 90 % is NMVOC (Hjerrild & Rasmussen, 2014).

Both the non-combustion processes including product processing and sulphur recovery plants emit SO_2. The SO_2 emissions are calculated by the refineries and implemented in the emission inventory without further calculation.

Emissions from flaring in refineries are included under “Flaring”. Emissions related to process furnaces in refineries are included in stationary combustion with the relevant emission factors.

Fugitive emissions from gas (1B2b)

Transmission and distribution of gas

The fugitive emission from transmission, storage and distribution of natural gas is based on information from the gas companies. The transmission and distribution companies give data on the transported amount and length and material of the pipeline systems.

The fugitive losses from pipelines are only given for some companies, here among the transmission company. The available distribution data are used for the remaining companies too. Emissions are calculated from the fugitive losses from transmission and distribution pipelines due to the gas quality measured by Energinet.dk (Energinet.dk 2014c). The same approach is used for town gas, which is natural gas admixed ~ 50 % ambient air.

Calculations of emissions from distribution of town gas are based on data from the distribution companies on distribution losses. At present, there are two areas with town gas distribution and correspondingly distribution companies. Two others companies in other areas were closed in 2004 and 2006, and it have not been possible to collect data for all years in the time series. The emissions have been calculated for the years with available data and the distribution loss for the first year with data has been applied for the previous years in the time series. Data is missing for the later years (1996-2003) for one of the distribution companies. The distribution amount is assumed to decrease linearly to cero over these years, and the share (“distribution loss”/”distribution amount”) are assumed equal to the value for 1995.

Flaring

Emissions from flaring are estimated from the amount of gas flared offshore, in gas treatment/storage plants, in refineries, and in gas transmission and distribution, combined with corresponding emission factors. From 2006 data on offshore flaring is given in the reports for the European Union Greenhouse Gas Emission Trading System (EU ETS) and thereby flaring can be split to the individual production units. Before 2006 only the total flared amount is available.

3.5.3 Activity data

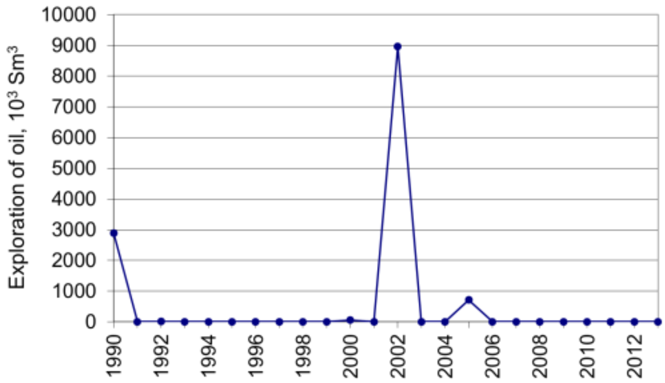
Exploration and extraction of oil and gas, and loading of ships

Activity data used in the calculations of the emissions from oil and gas exploration and production, and loading of ships onshore and offshore are shown in Table 3.5.6. Data are based on information provided by the Danish Energy Agency (Andersen 2014, DEA 2014a) and from the environmental reports from DONG Oil Pipe A/S (2014).

Table 3.5.6 Activity data for 2013.

Activity	Amounts	Data source
Extracted gas, Sm^3	1 242	Andersen, 2014
Extracted oil, Nm^3	102	Andersen, 2014
Produced gas, 10^6 Nm^3	4 704	Danish Energy Agency, 2014a
Produced oil, 10^3 m^3	10 185	Danish Energy Agency, 2014a
Oil loaded, 10^3 m^3	1 549	Danish Energy Agency, 2014a
Oil loaded, 10^3 m^3	10 500	DONG Oil Pipe A/S, 2014
Density of crude oil, tonnes/m^3	0,86	Danish Energy Agency, 2014a

Exploration of oil and gas vary between years. The largest oil amounts are seen for 1990, 2002 and 2005, while relatively large gas amounts are seen for more years of the time series. Explored amounts are shown in Figure 3.5.1.



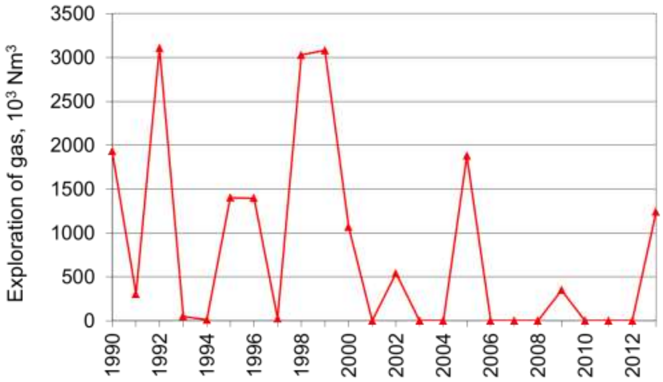


Figure 3.5.1. Exploration of oil and gas in the Danish part of the North Sea.

As seen in Figure 3.5.2 the production of oil and gas in the North Sea has generally increased in the years 1990-2004, and since 2004 the production has decreased. Five major platforms were completed in 1997-1999, which is the main reason for the great increase in the oil production in the years 1998-2000.

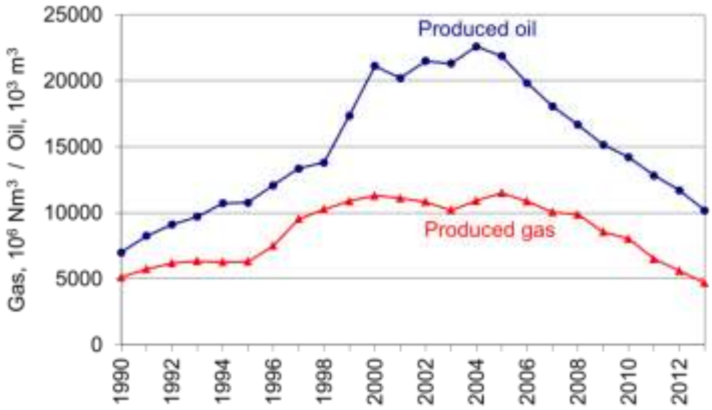


Figure 3.5.2 Production of oil and gas in the Danish part of the North Sea.

The amounts of oil loaded offshore on ships roughly follow the trend of the oil and gas production (Figure 3.5.3). In case of onshore loading of ships the trend is more smoothed.

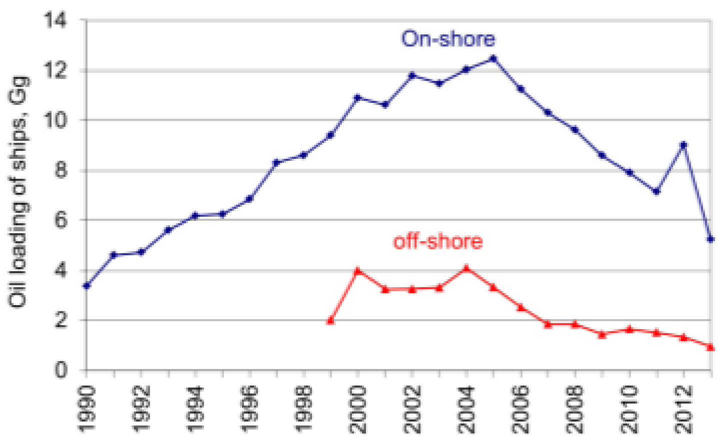


Figure 3.5.3 Onshore and offshore loading of ships.

Oil refining

Data on the amount of crude oil processed in the two Danish refineries are given by the refineries in their annual environmental report (A/S Dansk Shell, 2014 and Statoil A/S, 2014). Until 1996 a third refinery was in operation, leading to a decrease in the crude oil amount from 1996 to 1997. Data are shown in Figure 3.5.4. In 2013 the amount of crude oil being processed was 7 179 Gg.

Figure 3.5.4 Oil refineries. Processed crude oil in Danish refineries.

Service stations

The Danish Energy statistics contains data on the sale of gasoline that are the basis for estimating emissions of NMVOC from service stations. The gasoline sales show an increase from 1990-1998 and a decreasing trend since 1999 as shown in Figure 3.5.5. In 2013 the gasoline sale was 1 339 Gg.

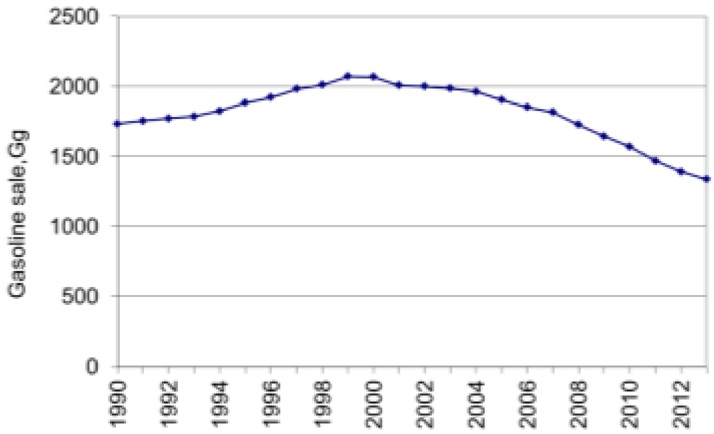


Figure 3.5.5 Gasoline sales in Denmark.

Transmission, storage and distribution of gas

The activity data used in the calculation of the emissions from natural gas are shown in Table 3.5.7. Transmission rates for 1990-1998 refer to annual environmental reports of DONG Energy. In 1999-2006 transmission rates refer to the Danish Gas Technology Centre (Karll 2002, Karll 2003, Karll 2004, Karll 2005, Oertenblad 2006, Oertenblad 2007). From 2008 onwards transmission rates refer to Energinet.dk (2014b). Transmission losses for 1991-1999 are based on annual environmental report of DONG Energy. The average for 1991-1995 is applied for 1990. From 2005 onwards transmission losses are given by Energinet.dk. The average for 2005-2010 is applied for the years 2000-2004.

Distribution rates for 1990-1998 are estimated from the Danish energy statistics. Distribution rates are assumed to equal total Danish consumption rate minus the consumption rates of sectors that receive the gas at high pressure. The following consumers are assumed to receive high pressure gas: town gas production companies, production platforms and power plants. In 1999-2006 distribution rates refer to DONG Energy/Danish Gas Technology Centre/Danish gas distribution companies (Karll 2002, Karll 2003, Karll 2004, Karll 2005, Oertenblad 2006, Oertenblad 2007). Since 2007 the distribution rates are given by the companies. Distribution rates for town gas is based on the available data from the Danish town gas distribution companies of which more are closed down today. Distribution losses for 1990-2000 are based on annual environmental report of DONG Energy. For 2000-2006 the average losses-% for the gas distribution companies are used. From 2007 data on distribution losses available from the companies are used.

Table 3.5.7 Activity data on transmission and distribution of gas for selected years of the time series. Town gas is included in distribution.

	1990	1995	2000	2005	2010	2011	2012	2013
Transmission, Mm^3 [1]	2739	4689	7079	7600	7462	6181	5365	4886
Distribution of natural gas, Mm^3 [2]	1714	3054	3181	3265	3416	2933	2728	2634
Distribution of town gas, Mm^3 [3]	35	35	34	32	22	21	24	28

1 Transmission rates for 1990-1998 refer to the annual environmental report of DONG Energy. In 1999-2006 transmission rates refer to the Danish Gas Technology Centre (Karll 2002, Karll 2003, Karll 2004, Karll 2005, Oertenblad 2006, Oertenblad 2007). From 2008 onwards transmission rates refer to Energinet.dk.

2 In 1990-98 distribution rates are estimated from the Danish energy statistics. Distribution rates are assumed to equal total Danish consumption rate minus the consumption rates of sectors that receive the gas at high pressure. The following consumers are assumed to receive high pressure gas: town gas production companies, production platforms and power plants. In 1999-2006 distribution rates refer to DONG Energy / Danish Gas Technology Centre / Danish gas distribution companies (Karll 2002, Karll 2003, Karll 2004, Karll 2005, Oertenblad 2006, Oertenblad 2007). Since 2007 the distribution rates are given by the companies.

3 The distribution of town gas is based on the available data from the Danish town gas distribution companies of which more are closed down today.

In 2013 the gas transmission rate was 4 886 Mm^3 and the distribution rate was 2 662 Mm_n^3, hereof 28 Mm_n^3 town gas (Figure 3.5.6). The variation over the time series owes mainly to variations in the winter temperature and to the variation of import/export of electricity from Norway and Sweden. The transmission rate is less than the production rate, as part of the produced natural gas is exported through the NOGAT pipeline system.

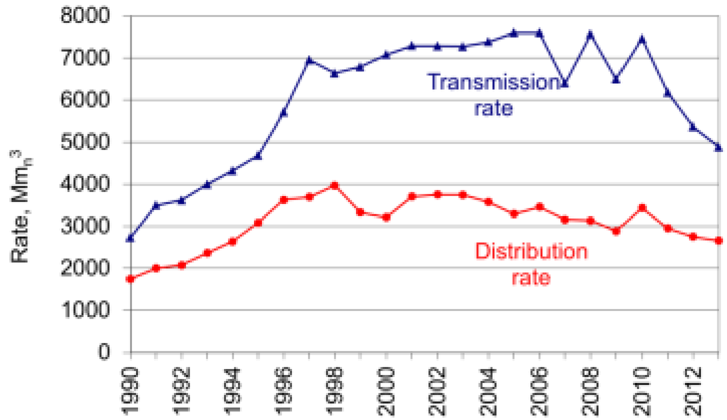


Figure 3.5.6 Rates for transmission and distribution of gas. Distribution cower both natural gas and town gas.

Data on the transmission pipelines excluding offshore pipelines and on the distribution network are given by Energinet.dk, DGC and the distribution companies concerning length and material. The length of the transmission pipelines is approximately 900 km. Because the distribution system in Denmark is relatively new most of the distribution network is made of plastic (PE). In 2013 the length of the distribution network was around 20 000 km. The major part is made of plastic (approximately 90 %) and the remaining part is made of steel. For this reason the fugitive emission is negligible under normal operating conditions as the distribution system is basically tight with no fugitive losses. However, the plastic pipes are vulnerable and therefore most of the fugitive emissions from the pipes are caused by losses due to excavation damages and construction and maintenance activities performed by the gas companies. These losses are either measured or estimated by calculation in each case by the gas companies. About 5 % of the distribution network is used for town gas. This part of the network is older and the fugitive losses are larger. The fugitive losses from this network are associated with more uncertainty as it is estimated as a percentage (15 %) of the meter differential. This assumption is based on expert judgement from one of the town gas companies (Jensen, 2008). It must be noted that two town gas distribution companies have been closed in recent years (one in 2004 and another in 2006). There are only two town gas distribution companies left, and therefore the data availability is scarce.

Venting and flaring

Venting

In Denmark there are two natural gas storage facilities. Both are obligated to make an environmental report on annual basis. Data on gas input and withdrawal are included and were 891 Mm^3 and 650 Mm^3 in 2013, respectively. Venting and flaring at the gas storage plants are included in the inventory. Venting of gas is assumed to be not occurring in extraction and in refineries as controlled venting enters the gas flare system. Venting rates in gas storage facilities are shown in Figure 3.4.8. As venting rates are not available for the years 1990-1994, the average for 1995-1998 is used.

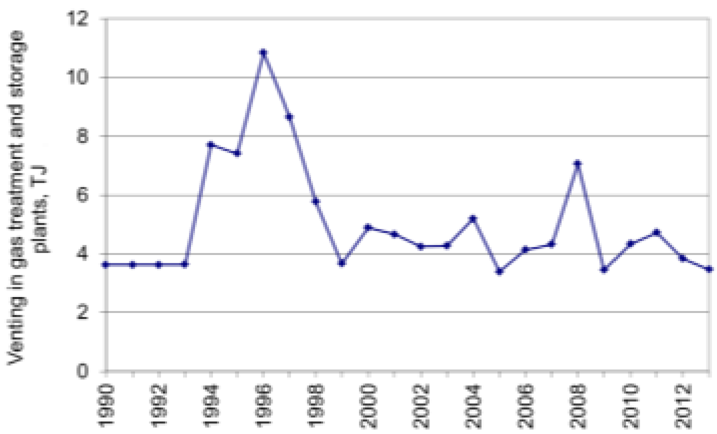


Figure 3.5.7 Amount vented in gas treatment and storage plants.

Flaring

Flaring rates for the two Danish refineries are given in their environmental reports and in additional data provided by the refineries directly to DCE.

From 2006 flaring amounts are given in the EU ETS reporting. Data are not available for the years 1990-1993. The flaring amount for 1994 has been adopted for the previous years. Flaring rates are shown in Figure 3.5.8.

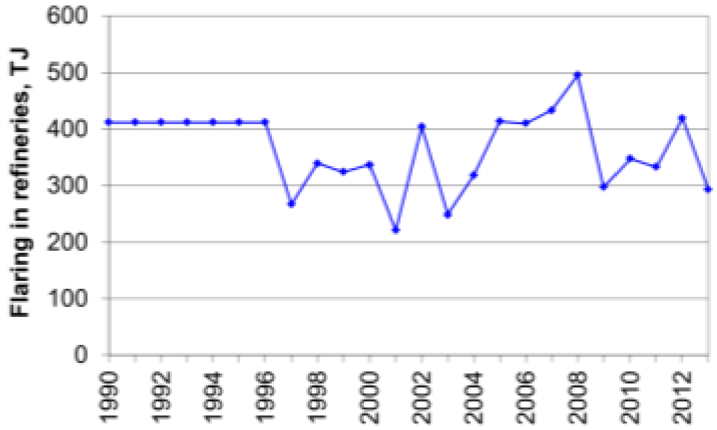


Figure 3.5.8 Amount flared in refineries (annual environmental reports from A/S Dansk Shell and Statoil A/).

Offshore flaring amounts are given in Denmark's oil and gas production (Danish Energy Agency, 2014a) while flaring in treatment/storage plants are given in DONG Energy's environmental reports (Dong Energy, 2014a; Dong Energy, 2014b; Energinet.dk, 2014). Flaring rates are shown in Figure 3.4.9 and 3.4.10.

Offshore flaring amounts have been decreasing over the last 10 years period in accordance with the decrease in production as seen in Figure 3.4.3. Further, there is focus on reduction of the amount being flared for environmental reasons.

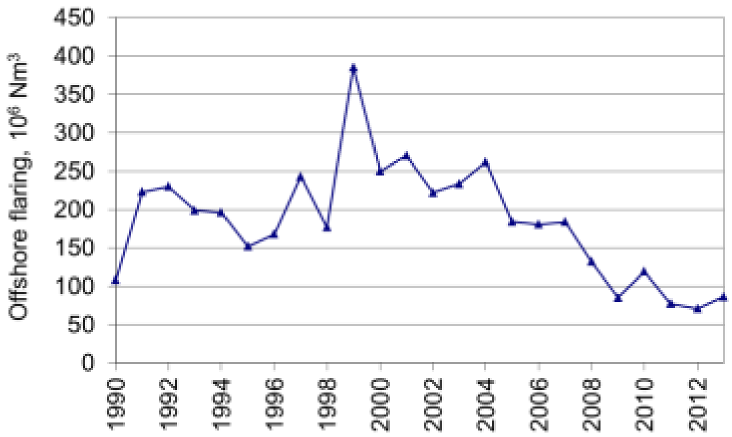


Figure 3.5.9 Amount flared in gas treatment and storage plants.

Flaring rates in gas treatment and gas storage plants are not available before 1994. The mean value for 1994-1998 has been adopted as basis for the emission calculation for the years 1990-1993. The large amount of flared gas in 2007 owe to a larger maintenance work at the gas treatment plant.

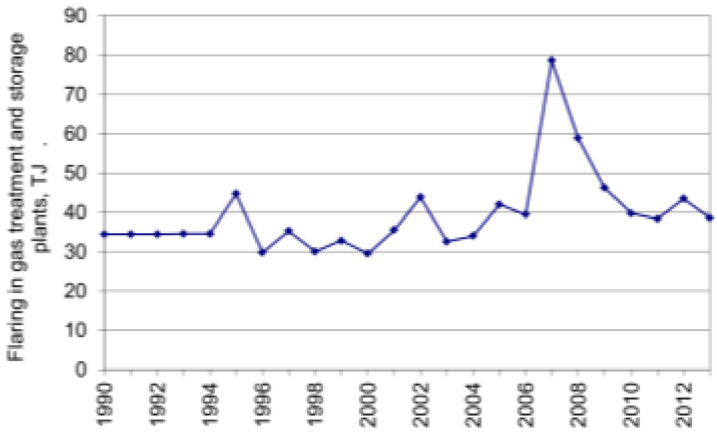


Figure 3.5.10 Amount flared in gas treatment and storage plants.

3.5.4 Emission factors

Exploration of oil and gas

Annual implied CO_2 emission factors for exploration of gas are based on composition data for explored oil and gas. Separate composition data are available for the exploration and appraisal wells (E/A wells) separately, except for a few E/A wells, for which the composition for the latest E/A well are used for emission calculation. The emission factors used to calculate emissions from offshore flaring are applied for the remaining pollutants (see Table 3.5.13).

Extraction of oil and gas

Standard emission factors from the 2006 IPCC Guidelines (IPCC 2006) are used to calculate emissions from extraction of oil and gas. The emission factors are listed in Table 3.5.8.

Oil terminal

Implied emission factors are calculated annually for CH_4 and NMVOC based on emission provided in the environmental reports for the raw oil terminal (DONG Oil Pipe A/S, 2014). CO_2 emissions are calculated from the standard emission factor given in the 2006 IPCC Guidelines (IPCC 2006), and implied emission factors are calculated for use in the reporting template on the basis of the amount of oil extracted. Implied emission factors for 2013 are listed in table 3.5.8.

Table 3.5.8 Emission factors for extraction of oil and gas

	CO_2	CH_4	NMVOC	Reference
Extraction of oil, Gg/1000m^3	4,30E-08	5,90E-07	7,40E-07	IPCC 2006
Extraction of gas, Gg/Mm3	1,40E-05	3,80E-04	9,10E-05	IPCC 2006
Oil terminal, g/Mg oil extracted	0.54	77.6	62.0	IPCC 2006, DONG Oil Pipe A/S 2014

Loading of ships

In the EMEP/EEA Guidebook standard emission factors for different countries are given (EMEP/EEA, 2013). In the Danish emission inventory the Norwegian emission factors are used for estimation of fugitive emissions from loading of ships onshore and offshore for the years 1990-2009. During 2009 new emission reducing technologies (degassing unit) were installed at the crude oil terminal. Measurements were carried out at the terminal before and after installation show a decrease of 21 % of the CH_4 emission and 25 % of the NMVOC emission from loading of ships. The reduced emission factors used for 2010 onwards are listed in Table 3.5.9.

Table 3.5.9 Emission factors for loading of ships onshore and offshore.

	CH_4, fraction of loaded		NMVOC, fraction of loaded	
	1990-2009	2010 onwards	1990-2009	2010 onwards
Ships offshore *	0.00005	0.00005	0.001	0.001
Ships on-shore **	0.00001	0.0000079	0.0002	0.00015

* EMEP/EEA, 2013.

** EMEP/EEA, 2013; Miljøcenter Odense, 2010.

Oil refining

The refineries provide information on consumption of fuel gas and fuel oil. The calorific values are given by the refineries in the reporting to the EU ETS from 2006. Before 2006 the calorific values given by the refineries were used when available. When not available standard calorific values given in the basic data tables from the Danish Energy Agency combined with the conversion factor between fuel gas and fuel oil given by the refinery were used for calculation.

Emissions of SO_2, NO_x and VOC are given by the refineries. Only one of the two refineries has made a split between NMVOC and CH_4. For the other refinery it is assumed that 10 % of the VOC emission is CH_4 and the remaining 90 % is NMVOC (Hjerrild & Rasmussen, 2014).

Service stations

For information on NMVOC emissions from service stations, please refer to chapter 3.4 in the Danish Informative Inventory Report (Nielsen et al., 2015).

Transmission, storage and distribution of gas

The fugitive emissions from transmission, storage and distribution of natural gas are based on data on gas losses from the companies and on the average annual natural gas composition given by Energinet.dk (2014c) (Table 3.5.11). For distribution of town gas the emission factor is reduced due to the admixture of 50 % atmospheric air to the natural gas.

Table 3.5.11 Annual gas composition, lower heating value and density for Danish natural gas (Energinet.dk, 2014c).

		Unit	1990	2000	2005	2010	2011	2012	2013
Methane	CH_4	molar-%	90.92	86.97	88.97	89.95	89.10	88.84	89,82
Ethane	C_2H_6	molar-%	5.08	6.88	6.14	5.71	5.98	6.11	5,65
Propane	C_3H_8	molar-%	1.89	3.17	2.50	2.19	2.36	2.44	2,00
i-Butane	i-C_4H_{10}	molar-%	0.36	0.43	0.40	0.37	0.37	0.37	0,32
n-Butane	n-C_4H_{10}	molar-%	0.50	0.61	0.55	0.54	0.55	0.54	0,46
i-Petane	i-C_5H_{12}	molar-%	0.14	0.11	0.11	0.13	0.13	0.13	0,11
n-Petane	n-C_5H_{12}	molar-%	0.10	0.08	0.08	0.08	0.09	0.08	0,08
n-Hexane and heavier hydrocarbons	C^{6+}	molar-%	0.09	0.06	0.05	0.06	0.06	0.06	0,05
Nitrogen	N_2	molar-%	0.31	0.34	0.29	0.31	0.37	0.36	0,55
Carbon dioxide	CO_2	molar-%	0.60	1.35	0.90	0.66	0.98	1.06	0,96
Lower heating value	H_n	MJ/m^3_n	39.176	40.154	39.671	39.461	39.507	39.548	39.988
Density	ρρ	kg/m^3_n	0.808	0.846	0.825	0.816	0.824	0.827	0.814

Venting and flaring

Venting

Emissions of CH_4 and NMVOC from venting are given in the environmental reports for the gas storage plants (DONG Energy, 2014a; Energinet.dk, 2014). CO_2 emissions from venting are calculated from country specific emission factors based on annual natural gas composition published by Energinet.dk.

Flaring in refineries

The composition of fuel gas is given for 2008 by one of the two refineries. As the composition for fuel gas is marked different than the composition of natural gas, which has been used in earlier year's calculations, the same fuel gas composition is used in calculations for the other Danish refinery.

The CH_4 and NMVOC emission factor based on these data are applied for both refineries for the entire time series. The CO_2 emission factor is based on the refineries reporting to the EU ETS for the years 2006 and onwards. Before 2006 corresponding data are not available, and the average of CO_2 emission factors for 2006-2010 for each refinery is applied. The emission factor applied for N_2O is based on the OLF (1993) for flaring in oil and gas extraction as no value are given for flaring in refineries. The emission factors are listed in Table 3.5.12. For information on emissions of other pollutants, please refer to chapter 3.4 in the Danish Informative Inventory Report (Nielsen et al., 2015).

Table 3.5.12 Emission factors for flaring in refineries for 2013.

Pollutant	Emission factor	Unit
CH_4	18.1	g per GJ
CO_2 *	47.47 / 54.49	kg per GJ
N_2O	0.47	g per GJ

** The CO_2 emission is based on the refineries reports for ETS and is plant specific.

Flaring offshore

The emission factors for offshore flaring are shown in Table 3.5.13. Since 2006 the CO_2 emission factor is calculated according to the reporting for EU ETS. Corresponding data are not available for earlier years and therefore the CO_2 emission factor is assumed to follow the same time series as for natural gas combusted in stationary combustion plants. Emission factors for N_2O are based on IPCC (2000) and emission factor for CH_4 is based on OLF (1993). For information on emissions of other pollutants, please refer to chapter 3.4 in the Danish Informative Inventory Report (Nielsen et al., 2015).

Emissions from flaring in gas treatment and storage plants are calculated from the same emission factors which are used for offshore flaring. Only difference is the CO_2 emission factor for the years from 2006 onwards. The emission factors used for the plants are based on the same data source, the reporting for EU ETS, but the values are different than for offshore flaring. The gas that are flared in the treatment and storage plants are natural gas with the same composition as natural gas distributed in Denmark. Therefore, the emission factors in the EU ETS reports are the same as the one calculated on basis of the gas composition given by Energinet.dk.

Table 3.5.13 Emission factors for offshore flaring for 2013.

Pollutant	Emission factor	Unit
CH_4	10.56	g per Nm^3
CO_2	2.516	kg per Nm^3
N_2O	1.590	g per Nm^3

3.5.5 Emissions

Exploration and extraction of oil and gas, loading of ships and oil tanks

CH_4 and CO_2 emissions from exploration and extraction of oil and gas, and from loading of ships are listed in Table 3.5.14 and Table 3.5.15, along with emissions from the oil terminal given in the environmental reports from DONG Oil Pipe (2014). A degassing system has been established at the crude oil terminal leading to reduced VOC emissions from storage and handling. The degassing system has been in operation since the summer of 2009 and measurements of VOC emissions were carried out in September 2009 after a period with constant operation. The CH_4 emission factor from the oil terminal has decreased by 16 % from 2008 to 2009 and further by 18 % from 2009 to 2010. CO_2 emissions from oil pipeline and storage tanks, as well as from extraction are calculated from standard emission factors (IPCC 2006). For information on emissions of NMVOC, please refer to chapter 3.4 in the Danish Informative Inventory Report (Nielsen et al., 2015).

Table 3.5.14 CH_4 (Mg) from onshore activities related to extraction of oil and gas.

CH_4, Mg	1990	1995	2000	2005	2010	2011	2012	2013
Exploration of oil	0,02	0,015	0,011	0,02	NO	NO	NO	0,013
Exploration of gas	30,54	0,002	0,591	7,53	NO	NO	NO	0,001
Extraction of oil	4	6	12	13	8	8	7	6
Extraction of gas	1952	2402	4300	4379	3061	2474	2134	1788
Onshore loading of ships	34	62	109	125	63	56	71	41
Offshore loading of ships	NO	NO	201	167	83	76	67	48
Oil terminals	783	1209	1700	2100	984	822	766	680

Table 3.5.16 CO_2 (Mg) from onshore activities related to extraction of oil and gas.

CO_2, Mg	1990	1995	2000	2005	2010	2011	2012	2013
Exploration of oil	4,7	3,4	2,6	4,6	NO	NO	NO	3
Exploration of gas	8,2541	0,0004	0,1646	2,0577	NO	NO	NO	0,0003
Extraction of oil	0,0003	0,0005	0,0009	0,0009	0,0006	0,0006	0,0005	0,0004
Extraction of gas	0,072	0,088	0,158	0,161	0,113	0,091	0,079	0,066
Oil terminals	0,003	0,005	0,008	0,009	0,006	0,006	0,005	0,005

Oil refining

Table 3.5.18 holds CH_4 emissions from the Danish refineries for selected years in the time series based on data provided annually by the refineries. For information on emissions of NMVOC and SO_2 from oil refining, please refer to chapter 3.4 in the Danish Informative Inventory Report (Nielsen et al., 2015).

Table 3.5.18 Emissions of CH_4 from oil refining.

	1990	1995	2000	2005	2010	2011	2012	2013
CH_4 emission, Mg	435	592	503	416	609	609	616	619

Service stations

For information on emissions of NMVOC, please refer to chapter 3.4 in the Danish Informative Inventory Report (Nielsen et al., 2015).

Transmission, storage and distribution of gas

The gas transmission company reports emissions of CH_4 for the years 1999 and onwards. Calculations of the CH_4 emissions for transmission are based on registered loss in the transmission grid and the emission from the natural gas consumption in the pressure regulating stations. The distribution companies give data on fugitive losses, and the CH_4 emissions are estimated due to the gas quality given by Energinet.dk. For the years 1991-1998 the CH_4 emissions for transmission are estimated on the basis of registered loss provided by the transmission company and the annual composition of Danish natural gas given by Energinet.dk. Transmission loss is not available for 1990, why the average for 1991-1995 is applied.

As the pipelines in Denmark are relatively new and made of plastic, most emissions are due to construction and maintenance. The decrease of emissions from transmission in 2007 (Table 3.4.16) is caused by the completion of a greater construction work and rerouting of a major pipeline. In preparation for construction work on a new compressor station, there has been laid a number of new line valve stations in 2011. Before this work could be done, larger amounts of natural gas were vented to drain the pipes. Therefore emissions from transmission of natural gas are significantly high in 2011.

The distribution companies provide emissions of CH_4 for the years 1997 and onwards. For the years 1995-1996 CH_4 emissions are calculated from the registered loss from distribution and the annual composition of Danish natural gas given by Energinet.dk. As distribution losses are not available for the years 1990-1994, the percentage loss for 1995 is used. Emissions from distribution of gas mainly owe to excavations and maintenance of the pipelines, but also difference between the calendar year and the meter reading year might influence the annual variations.

Data on distribution of town gas is limited as more companies are closed. For the active companies, data are available for part of the time series only. Gap filling and extrapolation of distribution and loss amounts to early years are done in collaboration with the individual companies to the extent possible. As the town gas distribution network is significant older the gas losses and thus the emissions are larger than for the natural gas distribution network, even though the distribution rates for natural gas far exceeds the rates for town gas. Emissions from distribution of town gas show large decreases in 2003 and 2005 due to the close down of two distribution companies and following no town gas distribution in those areas.

Emissions of CH_4 from transmission of natural gas (including storage) and distribution of natural gas and town gas are shown in Table 3.5.20 and Table 3.5.21, respectively. Emissions of CO_2 from transmission and distribution are very limited amounts and therefore not included in the tables. For information on emissions of NMVOC, please refer to chapter 3.4 in the Danish Informative Inventory Report (Nielsen et al., 2015).

Table 3.5.20 CH_4 emission from transmission of natural gas and distribution of natural gas and town gas for selected years.

CH_4, Mg	1990	1995	2000	2005	2010	2011	2012	2013
Transmission	190	597	86	141	26	171	14	16
Distribution, natural gas	56	99	49	66	37	49	71	64
Distribution, town gas	202	211	176	176	106	106	75	58

Venting and Flaring

Venting

Venting is limited to the gas storage plants and the emissions are of minor importance. Emissions of CH_4 and NMVOC are given in the environmental reports for the gas storage plants (DONG Energy, 2014a; Energinet.dk, 2014a). Calculation of CO_2 emissions are based on venting amounts and annual composition of Danish natural gas. Venting emissions are included in Figure 3.5.12.

Flaring in refineries

The composition of fuel gas is given for 2008 by one of the two refineries. As the composition for fuel gas is marked different than the composition of natural gas, the provided fuel gas composition data are used in calculations for the other Danish refinery.

Table 3.5.23 Emissions from flaring in refineries.

	1990	1995	2000	2005	2010	2011	2012	2013
CH_4, tonnes	7	7	6	8	6	6	8	5
CO_2,1000 tonnes	23	23	19	23	19	19	22	17
N_2O, tonnes	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.1

Flaring offshore

The time series for the emission of CO_2 from offshore flaring fluctuates due to the fluctuations in the fuel rate and to a minor degree due to the CO_2 emission factor. As shown in Figure 3.5.11, there was a marked increase in the amount of offshore flaring in 1997 and especially in 1999. The increase in 1997 was due to the new Dan field and the completion of the Harald field. The increase in 1999 was due to the opening of the three new fields Halfdan, Siri and Syd Arne.

The CO_2 emission factor is based on gas quality measurements. From 2006 the calorific values for flare gas are given at installation level in the EU ETS. This information is incorporated in the inventory for the years 2006-2007 for part of the offshore installations, and from 2008 and onwards for all installations. This has led to an increase of the CO_2 emission factor. The average of the emission factors for 2008-2010 is adopted for 1990-2007. Fuel rate and CO_2 emission are shown in Figure 3.5.11.

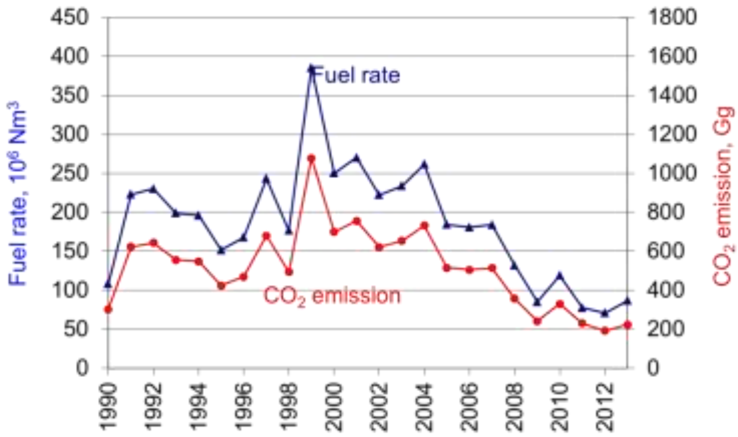


Figure 3.5.11 Fuel rate and CO_2 emission from offshore flaring of gas.

The CH_4 and N_2O emissions from offshore flaring are estimated from the same emission factors for all years and the variations reflect only the variations in the flared amounts. Emissions of CH_4 from flaring and venting are shown in Figure 3.5.12.

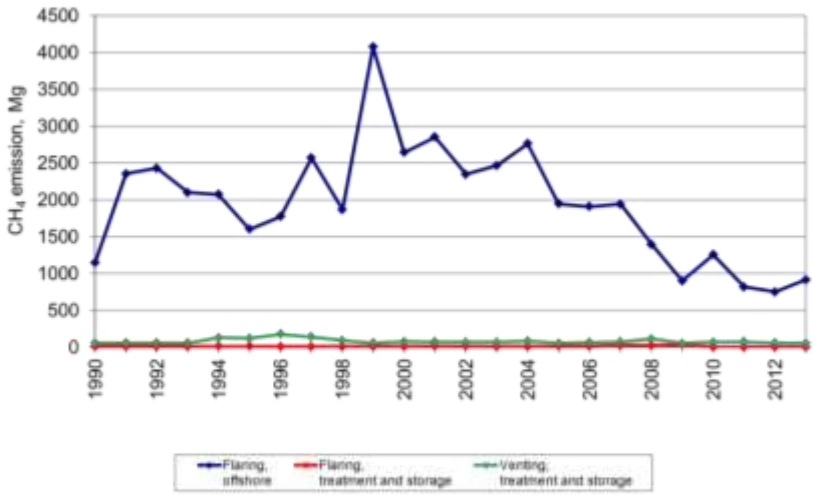


Figure 3.5.12 CH_4 emissions from venting and flaring of gas.

Emissions from gas storage and treatment plants have decreased from 2009 to 2010 due to a change from continuous to regulating power operation of the power producing gas turbine at the gas storage plant.

Table 3.5.22 Emissions from flaring offshore and in gas treatment/storage plants.

Year	1990	1995	2000	2005	2010	2011	2012	2013
CH_4, tonnes	1 152	1 614	2 650	1 959	1 259	819	750	916
CO_2, 1000 tonnes	305	428	701	518	333	232	195	221

3.5.6 Uncertainties and time series consistency

Two set of uncertainty estimates are made for the Danish emission inventory for greenhouse gases based on Tier 1 and Tier 2 methodology, respectively. The uncertainty models follow the methodology in IPCC Good Practise Guidance (IPCC, 2000). Tier 1 is based on the simplified uncertainty analysis (error propagation method) and Tier 2 is based on Monte Carlo simulations.

Uncertainty estimates are made for total emissions in the base year (only Tier 2), in the latest inventory year and for the emission trend for the corresponding time series. Uncertainty estimates are made for the GHGs separately and summarized.

Input data

The Tier 1 uncertainty model is based on emission data, uncertainty levels for activity data and uncertainty levels for emission factors for base year and latest inventory year. The Tier 2 model is based on activity data and emission factors for the same years and the same uncertainty levels as in Tier 1. Emission data, activity data and emission factors are described in Chapter 3.5.3, 3.5.4 and 3.5.5.

The uncertainty levels used in the uncertainty models are based on different sources, e.g. IPCC Good Practice Guidance, EMEP/EEA Guidebook and reports under the EU ETS. Further, a number of the uncertainty levels are given as NERI assumptions. DCE assumptions are based on source and/or plant specific uncertainty levels for part of the SNAP category and assumptions for the remaining sources and/or plants in the category.

Input data are aggregated on SNAP level. Estimates are made for the greenhouse gases CO_2, CH_4 and N_2O both separately and summarized (GHG). Uncertainty levels for activity data and emission factors are listed in Table 3.5.23. Uncertainty levels are given in percentage related.

Table 3.5.23 Uncertainty levels for activity rates and emission factors.

Pollutant	Source	Activity data uncertainty level, %	Emission factor uncertainty level, %
CO_2	Exploration, oil	2 N	10 N
CO_2	Off-shore activities, oil	2 N	100 I
CO_2	Land based activities, oil	2 N	40 S
CO_2	Exploration, gas	2 N	10 N
CO_2	Off-shore activities, gas	2 N	100 S
CO_2	Transmission of natural gas	15 G	2 Q
CO_2	Distribution of natural gas	25 G, N	10 Q, N
CO_2	Venting in gas storage	15 G, N	2 Q
CO_2	Flaring, refinery gas	11 E	2 E
CO_2	Flaring, natural gas	7,5 E	2 E
CH_4	Exploration, oil	2 N	125 N
CH_4	Off-shore activities, oil	2 N	100 I
CH_4	Land based activities, oil	2 N	40 S
CH_4	Petroleum product processing	1 E, N	125 N
CH_4	Exploration, gas	2 N	125 N
CH_4	Off-shore activities, gas	2 N	100 I
CH_4	Transmission of natural gas	15 G	2 Q
CH_4	Distribution of natural gas	25 G, N	10 Q, N
CH_4	Venting in gas storage	15 G, N	2 Q
CH_4	Flaring, refinery gas	11 E	15 H, N
CH_4	Flaring, natural gas	7,5 E	125 G
N_2O	Exploration, oil	2 N	1.000 N
N_2O	Exploration, gas	2 N	1.000 N
N_2O	Flaring, refinery gas	11 E	1.000 I
N_2O	Flaring, natural gas	7,5 E	1.000 I

N: DCE assumption.
I: IPCC Good Practice Guidance (default value).
S: Statistisk Sentralbyrå, Statistics Norway, 2008.
E: EU Emission Trading Scheme (EU ETS).
G: EMEP/EEA Guidebook, 2013.
H: Holst, 2009 and Statoil A/S, 2010.
Q: Annual gas quality, Energinet.dk.

The CO_2 emission factors for flaring offshore and in refineries and the CO_2 and CH_4 emission factors for natural gas transmission, distribution and venting, are the most accurate as they are calculated on basis of gas composition measurements. Emissions factors for flare gas are available in the EU-ETS reporting while emissions factors for natural gas are published by Energinet.dk.

The calculation of CO_2 emissions from exploration of oil and gas is based on information on oil and gas quality for most drillings. As the uncertainty levels of the measurements are not available, the double of the uncertainty for flaring in oil and gas extraction (before EU ETS standards) has been used.

The CO_2 emission factor for extraction of oil and gas is based on standard emission factors from IPCC (2006) and the corresponding uncertainties of 100 % are applied in the uncertainty analysis.

The uncertainty level for the emission factor for fugitive CH_4 emissions from refineries is dominated by a large uncertainty for one refinery. Further, measurements of fugitive emissions from the refineries are only available for one and two years, respectively, and these measurements indicate larger emissions than earlier estimates. As more measurements become available the uncertainty level is expected to decrease.

The emission factors for loading of ships are given as quality C in EMEP/EEA (2013), corresponding an uncertainty level of 50-200 %. The lower level is assumed to be most plausible for Danish conditions.

For onshore activities, the emission factor uncertainty corresponds to the uncertainty for onshore loading by Statistics Norway (2008), and the same uncertainty level is assumed for the CH_4 emission factor for onshore activities.

According to IPCC (2006) the emission factor for N_2O is the least reliable. An uncertainty level of 500 % is adopted in the Danish uncertainty model for all fugitive sources (exploration and flaring of oil and gas).

The Tier 2 uncertainty model is based on Monte Carlo simulations and the input uncertainty levels are given for the 95 % confidence interval assuming a log-normal distribution. The input uncertainty levels are the same as those used in the Tier 1 uncertainty model (Table 3.5.20). For more information on the Tier 2 methodology, please see Chapter 1.7.I

Results

The results of the Tier 1 uncertainty model for 2013 are shown in Table 3.5.24. In 2013 N_2O has the largest uncertainty for the total emission followed by CH_4 and CO_2. Due to the emission trend CO_2 has the largest uncertainty followed by N_2O and CH_4. The estimated uncertainty for the total GHG emission is 107 % and the GHG emission trend is -25 % ± 8 %-point.

Table 3.5.24 Uncertainty estimates for total emissions and emission trends from the Tier 1 uncertainty model.

	Emission, Gg CO_2 eqv	Emission, Gg CO_2 eqv	Uncertainty, %	Trend 1990-2013, %	Uncertainty, %
	Base year	2013	Lower and upper (±)		Lower and upper (±)
CO_2	341	238	7	-30	7
CH_4	123	107	53	-12	7
N_2O	53	41	999	-22	30
GHG	516	387	107	-25	8

Table 3.5.25 show the results from the Tier 2 uncertainty model for 1990 and 2013. The overall emission uncertainty in 2013 is -19/+74 %. The Tier 2 trend estimate is -26 % -18/+13 %-point.

Table 3.5.25 Uncertainty estimates for total emissions in 1990 and 2013 and for the emission trends from the Tier 2 uncertainty model.

	1990			2013			1990-2013		
	Median emission Gg CO_2 eqv	Uncertainty, %		Median emission Gg CO_2 eqv	Uncertainty, %		Median trend, %	Uncertainty, %	
		Lower (-)	Upper (+)		Lower (-)	Upper (+)		Lower (-)	Upper (+)
CO_2	341	15	18	238	7	7	-3	24	3
CH_4	131	37	71	39	93	779	-34	63	72
N_2O	50	91	743	115	37	72	-78	47	40
GHG	539	20	68	402	19	74	-26	18	13

Tier 1 and Tier 2 emissions and uncertainties are shown together in Figure 3.5.13. The figures show that the emissions and median emissions from Tier 2 are very similar. Further, the uncertainty estimates are in the same range for Tier 1 and Tier 2. The N_2O uncertainty is leaved out of Figure 3.5.13 b as the N_2O uncertainties are much higher than for CO_2 and CH_4. It must be noted that the uncertainty models, especially the Tier 1 model, are not suitable for very large uncertainty levels and therefore the uncertainty estimates for N_2O may only be seen as an indicator for a large uncertainties while the values are less accurate. The Tier 2 model has been developed to be more suitable for very large uncertainties, as it is possible to apply truncation for uncertainties. This has been included in the uncertainty calculation for fugitive emissions in case of N_2O, as the uncertainty level for the emission factors is 500 %. A truncation of 1 000 % has been applied to ensure that the emission factor interval is within an order of magnitude as given in IPCC Good Practice Guidance.

a) b)

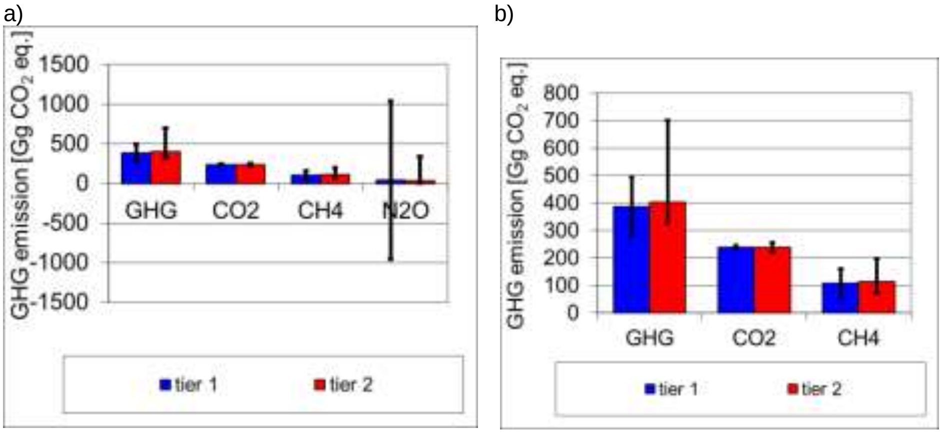


Figure 3.5.13 Emissions and uncertainty estimates from the Tier 1 and Tier 2 models; a) GHG, CH_4, CO_2 and N_2O, b) as figure a, but without N_2O.

3.5.7 Source specific QA/QC and verification

The elaboration of a formal QA/QC plan started in 2004 and has recently been updated (Nielsen et al., 2013). The plan describes the concepts of quality work and definitions of sufficient quality, critical control points and a list of Points of Measuring, PM (Figure 3.5.14). Please refer to the general Chapter 1.6 for further information.

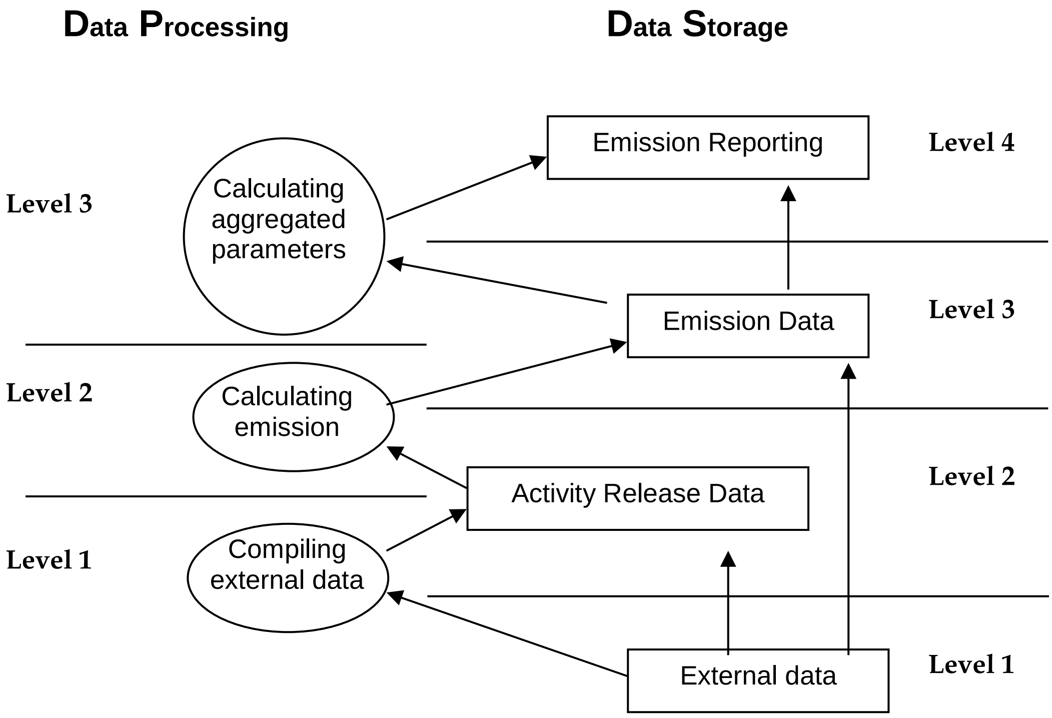


Figure 3.5.14 The general data structure for the Danish emission inventory (Nielsen et al., 2013).

Data storage level 1

Data storage level 1 refers to the data collected by DCE before any processing or preparing. Table 3.5.26 lists the external data deliveries used for the inventory of fugitive emissions. Further the table holds information on the contacts at the data delivery companies.

Table 3.5.26 List of external data sources.

Category	Data description	Activity data, emission factors or emissions	Reference	Contact(s)	Data agreement/ Comment
Exploration of oil and gas	Dataset for extraction of oil and gas, including amounts and composition.	Activity data	The Danish Energy Agency	Jan H. Andersen	Data agreement
Production of oil and gas	Gas and oil production. Dataset for production of oil, gas and number of platforms. Amounts of offshore loading of ships	Activity data	The Danish Energy Agency	Jan H. Andersen	Not necessary due to obligation by law
Offshore flaring	Flaring offshore in oil and gas extraction (ETS data)	Activity data	The Danish Energy Agency	Dorte Maimann	Data agreement
Service stations	Data on gasoline sales from the Danish energy statistics.	Activity data	The Danish Energy Agency	Jane Rusbjerg	Data agreement
Gas transmission	Natural gas from the transmission company, sales and losses (meter differences)	Activity data	Energinet.dk	Christian Friberg B. Nielsen	Not necessary due to obligation by law
Onshore activities	Amounts of oil transport in pipeline and onshore loading to ships. Emissions from storage of raw oil in the terminal.	Activity data and emission data	DONG Olierør A/S	Stine B. Bergmann	No formal data agreement.
Gas distribution	Natural gas from the distribution company, sales and losses (meter differences)	Activity data	Naturgas Fyn, HMN Aalborg Forsyning	Hanne Mochau, Søren K. Andersen Andreas Bech Jensen	No formal data agreement.
Air emissions from refinery	Fuel consumption and emission data.	Activity data and emission data	Statoil A/S, A/S Danish Shell	Anette Holst, Lis Rønnow Rasmussen	No formal data agreement.
Storage and treatment of gas	Environmental reports from plants defined as large point sources (Lille Torup, Stenlille, Nybro)	Activity data	Various plants		Not necessary due to obligation by law
CO_2 emission factors for different sources	Reports according to the CO_2 emission trading scheme (ETS)	Activity data	Various plants		Not necessary due to obligation by law
Emission factors	Emission factors origin from a large number of sources	Emission factors	See chapter regarding emission factors		

Data Storage level 1	1. Accuracy	DS.1.1.1	General level of uncertainty for every dataset including the reasoning for the specific values.

The uncertainty for every dataset included in the inventory of fugitive emissions are evaluated and included in the Tier 1 and Tier 2 uncertainty calculations with short descriptions of the reasoning that underlie the specific values.

The general levels of uncertainty are relatively low. The largest uncertainties are expected for emissions from refineries and distribution of town gas, the latter being of minor importance to the total fugitive emissions.

For further comments regarding uncertainties, see Chapter 3.5.6.

Data Storage level 1	2.Comparability	DS.1.2.1	Comparability of the emission factors/calculation parameters with data from international guidelines, and evaluation of major discrepancies.

Systematic inter-country comparison has only been made on Data Storage Level 4. Refer to DS 4.3.2.

Data Storage level 1	3.Completeness	DS.1.3.1	Ensuring that the best possible national data for all sources are included, by setting down the reasoning behind the selection of datasets.

External data sources are the Danish Energy Agency, EU ETS reports and annual environmental reports from plants which are obligated to publish environmental reports. Further, annual reports from the gas distribution companies and the raw oil terminal are used. Some environmental reports and annual reports are supplemented with data and information from the given companies.

Only one national data set is found for most fugitive sources, and all data set is expected to be complete and include all activities/emissions form the source. Data on flaring offshore, in refineries and in gas storage and treatment plants are available both in annual environmental reports and in EU-ETS reports. Data are compared and if any differences occur, this is checked with the data supplier. Minor differences may owe to the allocation of fuels, e.g. if pilot gas are included in the flare gas or the fuel gas amount.

Energy statistics

The Danish Energy Agency reports fuel consumption statistics on the SNAP level based on a correspondence table developed in co-operation with DCE. Both traded and non-traded fuels are included in the Danish energy statistics. Data on offshore extraction, offshore flaring and gasoline sales are used for estimation of fugitive emissions.

Environmental reports

A large number of plants are obligated by law to publish an environmental report annually with information on fuel consumption and emissions, among other things. DCE compares data with those from previous years, discrepancies are checked and large fluctuations are verified.

Annual reports

The gas distribution companies and the raw oil terminal are not obligated to publish environmental reports. Instead the self-regulation reports, annual reports and/or additional data and information are used. All information is compared with previous years.

Reports for the European Union Greenhouse Gas Emission Trading System (EU ETS)

CO_2 emission factors for flaring offshore and in refineries are taken from the EU ETS reports since 2006 when the EU ETS reports became available. EU ETS reports are available for the individual Danish oil/gas production fields and for the refineries.

Emission factors from a wide range of sources

For specific references, see Chapter 3.5.4 regarding emission factors.

Data Storage level 1	4.Consistency	DS.1.4.1	The original external data has to be archived with proper reference.

All external data are stored in the inventory file system and are accessible for all inventory staff members. Data processing is carried out in separate spread sheets or databases to ensure that the external data are always available in the original form. Refer to Section 1.3.

Data Storage level 1	6.Robustness	DS.1.6.1	Explicit agreements between the external institution holding the data and DCE about the conditions of delivery

Formal agreements are made with the Danish Energy Agency. Annual environmental reports are available due to legal requirements in this regard. The remaining data are published or delivered by the companies on voluntary basis. See Table. 3.5.26

Data Storage level 1	7.Transparency	DS.1.7.1	Listing of all archived datasets and external contacts.

See DS 1.3.1 and Table 3.5.26

Data Processing Level 1

Data Processing level 1	1. Accuracy	DP.1.1.1	Uncertainty assessment for every data source not part of DS.1.1.1 as input to Data Storage level 2 in relation to type and scale of variability.

Refer to Section 1.7 in the Danish NIR and the QA/QC Section 3.5.7.

Data Processing level 1	2.Comparability	DP.1.2.1	The methodologies have to follow the international guidelines suggested by UNFCCC and IPCC.

The methodologies in the inventory follow the principles in international guidelines by UNFCCC and IPCC.

Data Processing level 1	3.Completeness	DP.1.3.1	Identification of data gaps with regard to data sources that could improve quantitative knowledge.

Data gaps are found for distribution of town gas, as more companies are closed before the source was included in the Danish inventory. Emissions, which account for only a limited part of the total fugitive emissions, are calculated on a scarce data foundation.

More detailed data on emissions from extraction of oil and gas would be preferred, as well as more detailed data material regarding the VOC emissions from refineries.

Data Processing level 1	4.Consistency	DP.1.4.1	Documentation and reasoning of methodological changes during the time series and the qualitative assessment of the impact on time series consistency.

Since 2006 the EU-ETS data have been available for a number of sources. In all cases the new data replace use of data assumed to be less accurate. Therefore the CO_2 emission factors have been updated for all years, and no methodological change occur in the time series.

A change in the calculating procedure would entail elaboration of an updated description in Chapter 3.5.

Data Processing level 1	5.Correctness	DP.1.5.2	Verification of calculation results using time series

Time series for activity data on SNAP level as well as emission factors is used to identify possible errors in the calculation procedure.

Data Processing level 1	5.Correctness	DP.1.5.3	Verification of calculation results using other measures

For fugitive sources only one data set is available for calculation, and no verification using other measures are possible.

Data Processing level 1	7.Transparency	DP.1.7.1	The calculation principle, the equations used and the assumptions made must be described.

Descriptions are included in the NIR in Chapter 3.5.

Data Processing level 1	7.Transparency	DP.1.7.2	Clear reference to dataset at Data Storage level 1

Notes on data sources are included in the calculation files for all input data.

Data Processing level 1	7.Transparency	DP.1.7.3	A manual log to collect information about recalculations.

A log holding information on recalculations are included in the national inventory system. Further, a log is prepared annually holding information on status of the inventory work and recalculations for each source in the fugitive sector.

Data storage level 2

Data Storage level 2	5.Correctness	DS.2.5.1	Check if a correct data import to level 2 has been made

To ensure a correct connection between data on level 2 to data on level 1, different controls are in place, e.g. control of sums and random tests.

Data storage level 4

Data Storage level 4	4.Consistency	DS.4.4.3	The IEFs from the CRF are checked both regarding level and trend. The level is compared to relevant emission factors to ensure correctness. Large dips/jumps in the time series are explained.

Time series for IEFs are checked to identify large fluctuations, which are afterwards investigated and explained. The level of the IEFs are compared to other relevant EFs, e.g. in standard EFs in guidebooks and guidelines.

The IEFs for transmission and distribution of natural gas are low compared to other countries as the Danish distribution network is relatively new and made of plastics, leading to negligible fugitive losses under normal circumstances. Only fugitive losses are due to excavations and maintenance and construction work.

Other QC procedures

A list of QA/QC tasks are performed directly in relation to the fugitive emission part of the Danish emission inventories. The following procedures are carried out to ensure the data quality:

- The emission from the large point sources (refineries, gas treatment and gas storage plants) is compared with the emission reported the previous year.
- Annual environmental reports are kept for subsequent control of plant-specific emission data.
- Checks of data transfer are incorporated in the fugitive emission models, e.g. sum checks.
- Verification of activity data from external data when data are available through more data sources (offshore fuel and flaring rates).
- Data sources are incorporated in the fugitive emission models
- A manual log table in the emission databases is applied to collect information about recalculations.
- Comparison with the inventory of the previous year. Any major changes are verified.
- Total emission, when aggregated to reporting tables, is compared with totals based on SNAP source categories (control of data transfer).
- Checking of time series in the NFR and SNAP source categories. Significant dips and jumps are controlled and explained.

The QC work will continue in future years.

National external review

In 2009 a sector report for fugitive emissions from fuels was published (Plejdrup et al. 2009). The report was reviewed by Anette Holst from the Statoil A/S refinery.

3.5.8 Recalculations

The following recalculations regarding fugitive emissions from fuels have been applied for the time series. For information regarding other pollutants, please refer to chapter 3.4 in the Danish Informative Inventory Report (Nielsen et al., 2015).

Exploration of oil and natural gas

Exploration has been included as a new source in the emission inventory as activity data has now been made available by the Danish Energy Agency. Emissions only occur in years with exploration and appraisal wells (E/A wells) (1990-2000, 2002, 2005, 2009 and 2013). The largest E/A productions occurred in 1990 and 2002, contributing 3.8 % and 4.0 % to the fugitive CO_2 emission, 0.6 % and 1.0 % to the fugitive CH_4 emission, and 2.6 % and 3.9 % to the fugitive N_2O emission.

Refineries

The methodology for estimating CH_4 from one refinery has been changed, resulting in an increase of the CH_4 emissions for the years 1994-2003 and a decrease for the years 2004-2012. The refinery report annual VOC emissions based on results from measurement campaigns, the last in carried out in 2006. In previous inventories, the split between CH_4 and NMVOC given by the refinery has been use. This methodology has been changed, as the CH_4 share was much higher than for the other Danish refinery, and also much higher than corresponding shares found in a literature study. The CH_4 share of VOC has been changed to 10 % for all years, as given by the other Danish refinery and supported by shares of 10-20 % found for Swedish refineries. Previously, the shares were 1 % (1994-2003), 20 % (2004-2005), and 44 % (2006-2012). The largest decrease of the CH_4 emissions is estimated for the years 2006-2012 (1 611 tonnes per year), corresponding 17 % - 35 % of the total fugitive CH_4 emissions (17 % in 2006 and 35 % in 2012).

Gas transmission and distribution

Activity data has been updated for one town gas distribution company for the year 2012. The change of 0.22 tonnes CH_4 has insignificant impact on the total fugitive emissions (< 0.01%).

Venting

Activity data and direct CH_4 emission has been corrected for one gas storage plant for 2012 according to the annual environmental report. The change of 0.002 tonnes CH4 is insignificant for the total fugitive CH_4 emissions (< 0.01%).

Flaring in refineries

The CO_2 emission factor has been updated for 1994-2006 to the average of first five years with ETS data available (2007-2011) for two refineries. For a third refinery that was closed down in 1996 the CO_2 emission factor has been updated for the years 1994-1996 according to the 2013 EMEP/EEA Guidebook. The changes of the emissions are largest in 1994 with an increase of 3 Gg CO_2, corresponding 0.5 % of the total fugitive emission.

Flaring in oil and gas extraction

The implied emission factor for CO_2 has been updated for the years 1990-2007 to the average of ETS data for the years 2008-2012 instead of the previously applied average of the years 2008-2010. The increase of the CO_2 emission factor is 1 %, and the increase of the emissions is 2.9 Gg CO_2 (1990) to 10.4 Gg CO_2 (1999), corresponding 0.6 % and 0.9 % of the total fugitive CO_2 emissions, respectively.

Flaring in gas storage and treatment plants

CH_4 emissions are updated according to the environmental report for the gas treatment plant for 2012. CH_4 has been changed from 0.502 tonnes to

0.027 tonnes. The decrease of the CH_4 emissions accounts for 0.01 % of the total fugitive emissions.

Flaring in gas transmission and distribution

Flaring in gas transmission and distribution has been included as a new source in the emission inventory, only occurring in the years 2011-2013. The gas transmission company inform that they have started using a mobile flare in large construction works, and also one distribution company is flaring gas. The largest emissions occur in 2012 with 0.1 Gg CO_2 and 0.7 ktonnes CH_4, corresponding 0.05 % and 0.02 % of the total fugitive emissions.

3.5.9 Source specific planned improvements

The following future improvements are suggested.

- **Emissions from storage of fuels in tank facilities:** The current edition of the Danish emission inventory holds emissions from storage and refining of crude oil and from service stations. To make the inventory complete emissions from storage of fuels outside the refineries in tank facilities will be included in the future if data are available. Work is on-going to locate large tank facilities in Denmark and collect the available data. In cases where no emission estimates or measurements are available a set of emission factors have to be set up.

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4 Industrial Processes and Product Use

4.1 Overview of the sector

The *Industrial Processes and Product Use* (IPPU) sector covers greenhouse gases (GHG) from industrial processes not related to generation of energy along with emissions from product use. The IPPU sector consists of the following CRF source categories:

- 2A Mineral Industry
- 2B Chemical Industry
- 2C Metal Industry
- 2D Non-Energy Products from Fuels and Solvent Use
- 2E Electronics Industry
- 2F Product Uses as Substitutes for Ozone Depleting Substances (ODS)
- 2G Other Product Manufacture and Use

The data presented in Chapter 4 relate to Denmark only, whereas information for Greenland is included in Chapter 16 and for the Faroe Islands in Annex 8.

4.1.1 Methodology overview

Table 4.1.1 gives a brief overview over methodologies applied for IPPU. Further description of the applied methodologies can be found in the following chapters.

Table 4.1.1 Methodology overview.

IPCC code	Process	Substance	Tier	EF	Key category
2A1	Cement production	CO_2	T3	PS	Yes
2A2	Lime production	CO_2	T1	T1	No
2A3	Glass production	CO_2	T3	T3	No
2A4a	Ceramics	CO_2	T2	CS	No
2A4b	Other uses of soda ash	CO_2	T1	T3	No
2A4d	Other process uses of carbonates	CO_2	CS/T3	T3	No
2B2	Nitric acid production	N_2O	T1	PS	Yes
2B10	Catalyst production	CO_2	T2	PS	No
2C1	Iron and steel production	CO_2	T2	T1	No
2C4	Magnesium production	SF_6	T1	T1	No
2C5	Secondary lead production	CO_2	T1	T1	No
2D1	Lubricant use	CO_2	T1	T1	No
2D2	Paraffin wax use	CO_2, N_2O, CH_4	T2	T2	Yes
2D3	Paint application	CO_2	CS/T2	CS/T2	No
2D3	Degreasing, dry cleaning and electronics	CO_2	CS/T2	CS/T2	No
2D3	Chemical products manufacturing or processing	CO_2	CS/T2	CS/T2	No
2D3	Other use of solvents and related activities	CO_2	CS/T2	CS/T2	No
2D3	Road paving with asphalt	CO_2, CH_4	T2	T2	No
2D3	Asphalt roofing	CO_2	T2	T2	No
2D3	Urea from fuel consumption	CO_2	T3	T3	No
2E	Electronics industry	PCFs	T1	T1	No
2F1	Refrigeration and air conditioning	HFCs, PFCs	T1	T1	Yes
2F2	Foam blowing agents	HFCs	T1	T1	Yes
2F4	Aerosols	HFCs	T1	T1	No
2F5	Solvents	PFCs	T1	T1	No
2G1	Electrical equipment	SF_6	T1	T1	No
2G2	SF_6 and PFCs from other product use	SF_6	T1	T1	Yes
2G3a	Medical application	N_2O	T1	T1	No
2G3b	Propellant for pressure and aerosol products	N_2O	T1	T1	No
2G4	Fireworks	CO_2, CH_4, N_2O	T2	T2	No
2G4	Tobacco	CH_4, N_2O	T2	T2	No
2G4	Charcoal for barbeques	CH_4, N_2O	T2	T2	No

4.1.2 Key categories

Key Category Analysis (KCA) for the years 1990 and 2013 as well as for the trend has been carried out. The result for the IPPU sector is shown in Table 4.1.2. A detailed KCA is presented in Chapter 1.5 and Annex 1.

Cement production is identified as key category according to Approach 1 for level in 1990 and 2013 and for trend. Nitric acid production is identified as key category in 1990 and the trend is also identified as key according to both Approach 1 and Approach 2. The CO_2 emission from paraffin wax use and the SF_6 emission from other product use are both identified as key categories for trend according to Approach 2. Two key categories were identified for the emission of HFCs; refrigeration and air conditioning for trend and level in 2013 (both Approach 1 and Approach 2) and foam blowing agents for trend and level in 1990 (Approach 2).

Table 4.1.2 Key Category Analysis for *Industrial Processes and Product Use*.

IPCC code	Process	Substance	Approach 1 1990	Approach 1 2013	Approach 1 1990-2013	Approach 2 1990	Approach 2 2013	Approach 2 1990-2013
2A1	Cement production	CO_2	Level	Level	Trend			
2B2	Nitric acid production	N_2O	Level		Trend	Level		Trend
2D2	Paraffin wax use	CO_2						Trend
2F1	Refrigeration and air conditioning	HFCs		Level	Trend		Level	Trend
2F2	Foam blowing agents	HFCs				Level		Trend
2G2	SF_6 and PFCs from other product use	SF_6						Trend

Only source categories identified as key categories are presented in Table 4.1.2, for a full overview of the source categories included in this inventory please refer to Table 4.1.1.

4.1.3 Emissions overview

An overview of the six most significant sources in 2013 covered by IPPU is presented in Table 4.1.3; these six source categories compile 90 % of emissions in CO_2 equivalents from IPPU. The table below also gives an indication of the contribution to the total emission of greenhouse gases in 2013 in the IPPU sector. The emissions are extracted from the CRF tables.

Table 4.1.3 Overview of the largest sources to greenhouse gas emissions in the IPPU sector in 2013.

Process	IPCC Code	Substance	Emission Gg CO_2 eq.	%*
Cement production	2A1	CO_2	867	40.6
Refrigeration and air conditioning	2F1	HFCs, PFCs	711	33.3
SF_6 from other product uses	2G2	SF_6	117	5.5
Paraffin wax use	2D2	CO_2, CH_4, N_2O	85	4.0
Solvent use	2D3	CO_2, CH_4	74	3.5
Other uses of carbonates	2A4	CO_2	67	3.2
Total of six largest sources			1922	90

*of total CO_2 equivalent emissions from the IPPU sector.

For 2013, the subsector *Mineral Industry* (2A) constitutes 47% of the GHG emissions from the IPPU sector and *Product Uses as Substitutes for ODS* (2F) constitutes 37 %. *Non-Energy Products from Fuels and Solvent Use* (2D) and *Other Product Manufacture and Use* (2G) constitutes 9 and 7 % respectively, while *Chemical Industry* (2B), *Metal production* (2C) and *Electronics Industry* (2E) each constitutes below 0.2 %. The total emission of greenhouse gases (excl. LULUCF) in Denmark in 2013 is estimated to 54.6 Tg CO_2 equivalents of which IPPU contribute with 2.13 Tg CO_2 equivalents (3.9 %). The emission of GHG from IPPU from 1990-2013 are presented in Figures 4.1.1 and 4.1.2.

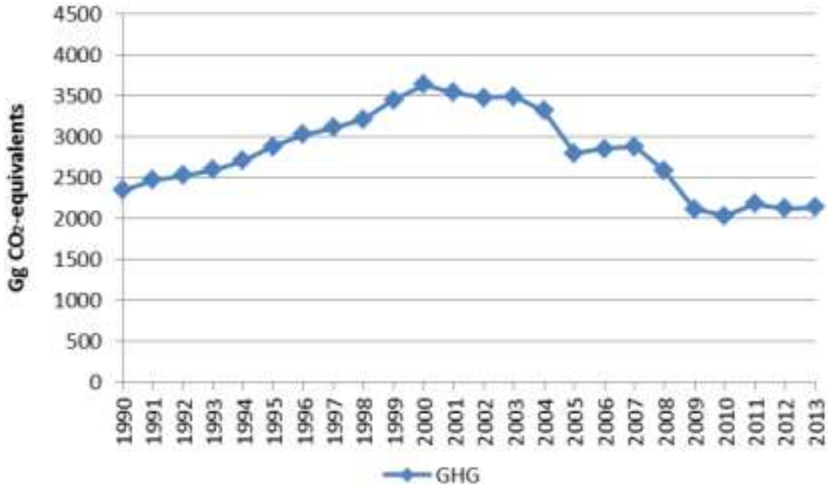

Figure 4.1.1 Emission of greenhouse gases IPPU (CRF Sector 2) from 1990-2013.

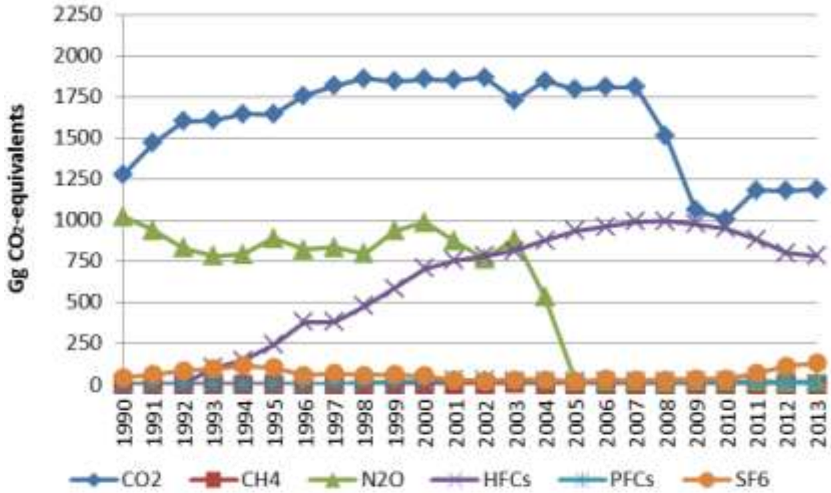

Figure 4.1.2 Emission of greenhouse gases from industrial processes (CRF Sector 2) from 1990-2013.

The majority of CO_2 emissions in the IPPU sector are emitted from the cement production, the small drop in CO_2 emissions in 2003 and the larger decrease in 2007-2010 are caused by a lower production of cement for these years. The production of nitric acid closed down during 2004 causing the N_2O emission to drop drastically. The use of HFCs in mainly refrigeration and air conditioning has increased significantly in the time series 1990-2013.

4.1.4 EU-ETS (EU Emission Trading Scheme)

Guidelines for calculating company specific CO_2 emissions are developed by the EU (EU Commission, 2007). The guidelines present standard methods for minor companies and methods for developing individual plans for major companies. The standard methods include default emission factors similar to the default emission factors presented by IPCC (e.g. for limestone), whereas, the major companies have to use individual methods to determine the actual composition of raw materials (e.g. purity of limestone or Ca per Mg ratio in dolomite) or the actual CO_2 emission from the specific process. Where data from the EU ETS are used more detail is provided on the specific methodologies used in the specific chapter.

4.2 Mineral Industry

4.2.1 Source category description

The sector *Mineral Industry* (CRF 2A) cover the following industries relevant for the Danish air emission inventory:

- 2A1 Cement production (SNAP 040612); see section 4.2.3.
- 2A2 Lime production (SNAP 040614); see section 4.2.4.
- 2A3 Glass Production (SNAP 040613); see section 4.2.5.
- 2A4a Ceramics (SNAP 040691, 040692); see section 4.2.6.
- 2A4b Other uses of soda ash (SNAP 040619); see section 4.2.7.
- 2A4d Flue gas desulphurisation (SNAP 040618); see section 4.2.8.
- 2A4d Mineral wool production (SNAP 040618); see section 4.2.9.

Cement production is identified as key category according to Approach 1 for level in 1990 and 2013 and for trend; see *Annex 1: Key Category Analyses*.

4.2.2 Emissions

Total greenhouse gas emissions from the Mineral Industry sector are available in the CRF Table 10. The emission time series for the source categories within *Mineral Industry* (2A) are presented in Figure 4.2.1 and individually in the subsections below (Sections 4.2.3 – 4.2.9). The following figure gives an overview of which source categories contribute the most throughout the time series.

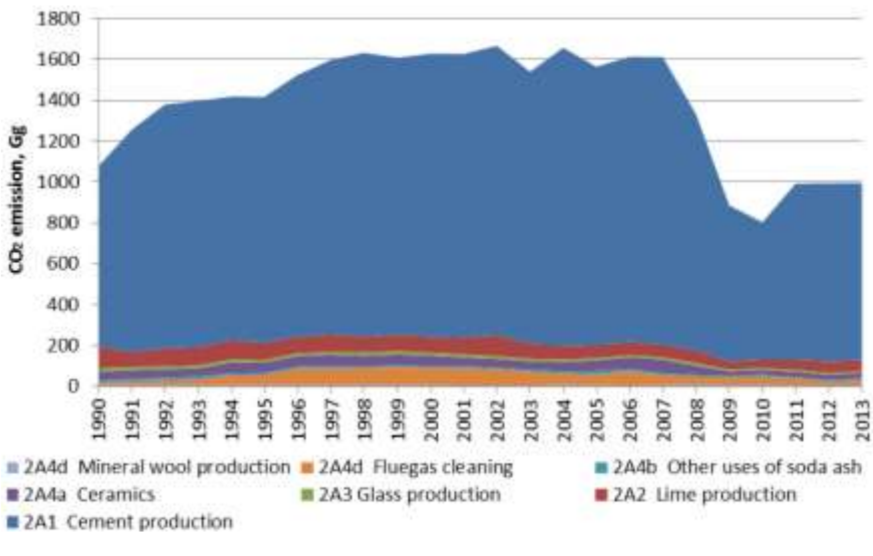

Figure 4.2.1 Emission of CO_2 from the individual source categories compiling *2A Mineral Industry*, Gg.

Greenhouse gas emissions from *Mineral Industry* are made up mostly by CO_2 emissions from the production of cement; min. 82 % (1990) to max. 88 % (2004).

Emissions from *Mineral Industry* increased with 48 % from 1990 to the time series peak in 1997 (1598 Gg). The overall development in the CO_2 emission for 1990 to 2013 shows a decrease from 1078 Gg to 995 Gg CO_2, i.e. by 7.7 %.

The increase from 1990 to 1997 can be explained by the increase in the annual cement production. The emission factor has only changed slightly as the distribution between types of cement especially grey/white cement has been almost constant from 1990-1997. The decrease during the latest years may be explained by the decrease in the construction activity.

4.2.3 Cement production

The production of cement in Denmark is concentrated at one company: Aalborg Portland A/S situated in Aalborg. The following SNAP-code is covered:

- 04 06 12 Cement (decarbonising)

Emissions associated with the fuel use are estimated and reported in the energy sector.

Methodology

Process emissions are released from the calcination of raw materials (chalk and sand). The overall process for calcination is:

$$CaCO_3 \rightarrow CaO + CO_2$$

The primary raw materials are sand, chalk and water and the main products are grey cement, white cement and cement clinker for sale.

Aalborg Portland uses a semi-dry process. The first step is production of raw meal. The chalk slurry and the grounded sand are mixed as slurry that is injected into a drier crusher. The raw materials are converted into raw meal that releases carbon dioxide (CO_2) in the calciner.

In a rotary kiln the material is burned to clinker that afterwards is grounded to cement in the cement mill. During the process, cement kiln dust is recirculated.

The emission of CO_2 depends on the ratio: white/grey cement and the ratio between three types of clinker used for grey cement: GKL-clinker/FKH-clinker/SKL-RKL-clinker.

For 1990-1997, the ratio white/grey cement and the ratio GKL-clinker/FKH-clinker/SKL-RKL-clinker is known. White cement peaked in 1990 and decreased thereafter. The production of SKL/RKL-clinker peaks in 1991 and decreases hereafter. FKH-clinker is introduced in 1992 and increases to a share of 35 % in 1997. The CO_2 emission is calculated according to the following equation:

$$M_{CO_2} = M_{grey} * \frac{M_{GLK} * EF_{GLK} + M_{FKH} * EF_{FKH} + M_{SKL/RKL} * EF_{SKL/RKL}}{M_{GLK} + M_{FKH} + M_{SKL/RKL}} + M_{white} * EF_{white}$$

M_{grey}	Grey cement	Mg
M_{white}	White cement	Mg
M_{GLK}	GKL clinker (rapid cement)	Mg
M_{FKH}	FKH clinker (basis cement)	Mg
$M_{SKL/RKL}$	SKL/RKL clinker (low alkali cement)	Mg
EF_{white}	CO_2 emission factor	Mg/Mg white cement
EF_{GLK}	CO_2 emission factor	Mg/Mg GLK clinker
EF_{FKH}	CO_2 emission factor	Mg/Mg FKH clinker
$EF_{SKL/RKL}$	CO_2 emission factor	Mg/Mg SKL/RKL clinker

The company has at the same time stated that data until 1997 cannot be improved as there is no further information available.

From 1998-2004 carbonate content of the raw materials has been determined by loss on ignition methodology. Determination of loss of ignition takes into account all the potential raw materials leading to release of CO_2 and omits the Ca-sources leading to generation of CaO in cement clinker without CO_2 release. The applied methodology is in accordance with EU guidelines on calculation of CO_2 emissions (Aalborg Portland, 2008).

From the year 2005 the CO_2 emission determined by Aalborg Portland independently verified and reported under the EU-ETS is used in the inventory (Aalborg Portland, 2014a). The reporting to EU-ETS also provides detailed information of alternative fuels used in the production of clinker.

Activity data

Production statistics for cement production are presented in Table 4.2.1.

Table 4.2.1 Production statistics for cement production (Aalborg Portland, 2008, 2014a, b).

Year	1990	1991	1992	1993	1994	1995	1996	1997
Mg TCE	1 619 976	1 998 674	2 214 104	2 244 329	2 242 409	2 273 775	2 418 988	2 718 923
Mg clinker[1]	1 406 212	1 811 958	2 089 393	2 117 895	2 192 402	2 353 123	2 481 792	2 486 475
	1998	1999	2000	2001	2002	2003	2004	2005
Mg TCE	2 754 405	2 559 575	2 612 721	2 660 972	2 698 459	2 546 295	2 861 471	2 706 371
Mg clinker	2 462 249	2 387 282	2 452 394	2 486 146	2 508 415	2 363 610	2 611 617	2 520 788
	2006	2007	2008	2009	2010	2011	2012	2013
Mg TCE	2 842 282	2 946 294	2 551 346	1 663 126	1 454 043	1 766 561	1 818 293	1 825 146
Mg clinker	2 632 112	2 706 048	2 269 687	1 493 230	1 313 654	1 582 023	1 628 506	1 612 834

[1] 1990-1997: Amount of clinker produced has not been measured as for 1998-2008. Therefore, the amount of GLK-, FKH-, SKL-/RKL-clinker and white cement is used as an estimate of total clinker production (Aalborg Portland, 2008).

Emission factors

The calculated implied emission factors (IEF) for cement production are presented in Table 4.2.2.

Table 4.2.2 Implied emission factors for CO_2 for cement production.

Year	1990	1991	1992	1993	1994	1995	1996	1997
IEF Mg CO_2 per Mg TCE[1,2,3]	0.545	0.544	0.539	0.537	0.532	0.529	0.530	0.530
IEF Mg CO_2 per Mg clinker[3,4]	0.628	0.600	0.571	0.569	0.544	0.512	0.517	0.580
Year	1998	1999	2000	2001	2002	2003	2004	2005
IEF Mg CO_2 per Mg TCE[1,2,3]	0.505	0.529	0.530	0.517	0.529	0.532	0.510	0.504
IEF Mg CO_2 per Mg clinker[3,4]	0.564	0.568	0.565	0.558	0.565	0.563	0.559	0.541
Year	2006	2007	2008	2009	2010	2011	2012	2013
IEF Mg CO_2 per Mg TCE[1,2,3]	0.491	0.478	0.453	0.460	0.462	0.488	0.479	0.475
IEF Mg CO_2 per Mg clinker[3,4]	0.530	0.520	0.509	0.512	0.512	0.545	0.535	0 538

1) 1990-1997: IEF based on information provided by Aalborg Portland (2005).

2) 1998-2004: IEF based on information provided by Aalborg Portland (2008).

3) 2005-2013: IEF based on emissions reported to EU-ETS (Aalborg Portland, 2014a and previous versions).

4) 1998-2013: IEF based on clinker production statistics provided by Aalborg Portland (2014b).

The IEF for CO_2 from the calcination process is expressed per Mg of cement/clinker and depends on the actual input of chalk/limestone in the process. The IEF will therefore vary as the allocation of different cement/clinker types produced varies. When the implied CO_2 emission factor in 1990 is markedly higher than for the remaining time series it is because the production of white cement was higher in 1990 than for the following years, leading the ratio white/grey cement to be higher for 1990. The share of white cement decreases significantly through the early part of the 1990's causing the IEF to decrease as well. In 1990, 25 % of cement produced was white cement; in 1991-1997 that same share fluctuates around 21 % (20 % in 1992 to 22 % in 1995). As presented in Table 4.2.3, emission factors are higher for white than for grey cement resulting in a higher IEF for 1990. The production of different cement types are shown in the Verification section below, see Table 4.2.5.

Table 4.2.3 Emission factors for white cement and (grey) clinkers (Aalborg Portland, 2008).

Product	Value	Unit
White cement	0.669	Mg CO_2/Mg white cement
GLK clinker	0.477	Mg CO_2/Mg GLK clinker
FKH clinker	0.459	Mg CO_2/Mg FKH clinker
SKL/RKL clinker	0.610	Mg CO_2/Mg SKL/RKL clinker

For the entire time series, the emission factor (carbon content) has been estimated from the loss on ignition determined for the different kinds of clinkers produced (1990-1997) or different raw materials used (1998-2013). Determination of loss on ignition estimates the CO_2 emissions based on full oxidation of all carbonate materials and omits the Ca-sources leading to generation of CaO in cement clinker without CO_2 release. As a result, there is no need to consider uncalcined cement kiln dust (CKD) not recycled to the kiln. The applied methodology is in accordance with EU guidelines on calculation of CO_2 emissions (Aalborg Portland, 2008).

The company reporting to the EU ETS applies the following EFs for the most important raw materials used in 2013, similar data are available back to 2006 (Aalborg Portland 2014a) and to a less detailed degree back to 1998 (Aalborg Portland, 2014b).

Table 4.2.4 Emission factors for raw materials used in 2013 (Aalborg Portland, 2014a).

Raw material	Mg CO_2 per Mg raw material
Limestone	0.44
Magnesium carbonate	0.522
Sand	0.0053-0.0301
Fly ash	0.1298
CKD	0.361-0.525

The EFs for limestone and magnesium carbonate are in accordance with the stoichiometric factors and the emission factors for the remaining raw materials and CKD are determined by individual and yearly analysis.

Emission trends

The emission trend for the CO_2 emission from cement production is available in the CRF tables but is also presented in Figure 4.2.2.

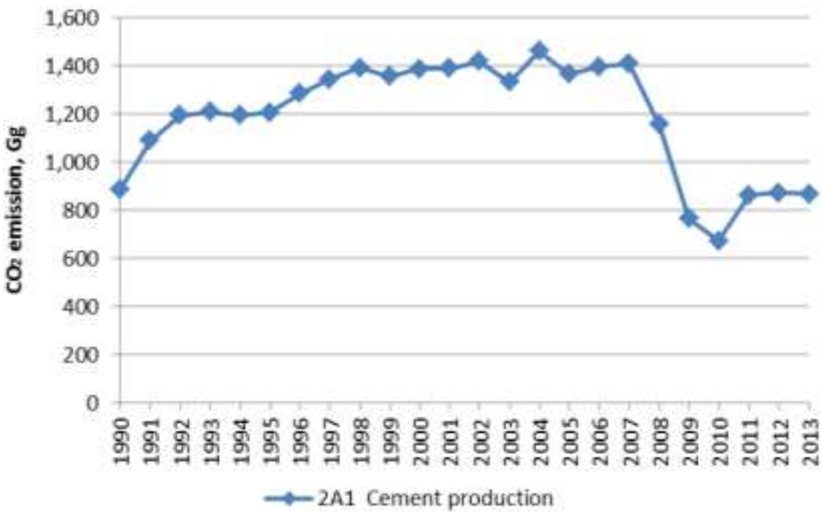

Figure 4.2.2 Emission of CO_2 from cement production.

The increase in CO_2 emission from the production of cement from 1990 to 1997 can be explained by the increase in the annual cement production. The most significant change to occur in the time series is the significant decline in emission from 2007-2010, the decrease is due to reduced production resulting from the economic recession caused by the global financial crisis. The emissions increased in 2011-2013, but the emissions are still far below the pre-recession levels. The overall development in the CO_2 emission from 1990 to 2013 is a decrease from 882 to 867 Gg CO_2, i.e. by 1.7 %. The maximum emission occurred in 2004 and constituted 1 459 Gg CO_2.

EU-ETS data for cement production

The applied methodology for Aalborg Portland is specified in the individual monitoring plan that is approved by Danish authorities (DEA) prior to the reporting of the emissions. Cement production applies the Tier 3 methodology for calculating the CO_2 emission.

The implied CO_2 emission factor for Aalborg Portland is plant specific and based on the reporting to the EU Emission Trading Scheme (EU ETS). The EU ETS data have been applied for the years 2006 – 2013.

The CO_2 emission for cement production is based on measurements of the consumption of calcium carbonate to the calcination process. These measurements fulfil a Tier 3 methodology (± 1.6 %) as defined in the EU decision (EU Commission, 2007). The emission factor is based on continuous measurements with flow meters, density meters, X-ray and CaO analysis. (Aalborg Portland, 2013b)

Verification

Information on production, import and export of cement and clinker for the years 1990–1997 were investigated in order to ensure that the Tier 1 method is being implemented in accordance with the IPCC Good Practice Guidance (IPCC, 2000).

The supply of cement clinker, grey cement and white cement in Denmark is shown in Table 4.2.5; however, the mass balance is incomplete due to missing information. The missing information may be explained by confidentiality as the statistics can be kept confidential, if there are fewer than three producers.

Table 4.2.5 Production, import, export and supply of cement, Gg (Statistics Denmark, 2014).

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Cement clinker										
Produced	NAV	NAV	NAV	NAV	NAV	NAV	NAV	139	119	112
Import	0.4	0.3	0.0	0.4	0.2	0.01	0.2	0.03	0.2	0.03
Export	17	45	24	40	189	281	245	139	117	112
Supply	-	-	-	-	-	-	-	-0.1	3	0.04
Portland cement, white										
Produced	412	398	426	492	492	531	576	529	537	563
Import	0	0	0.05	1.2	1.4	0.0	0.0	5.8	3.2	9.9
Export	367	445	481	634	477	473	496	455	638	509
Supply	44	-48	-55	-141	17	58	80	80	-98	64
Portland cement, grey										
Produced	1,244	1,621	1,646	1,778	1,935	2,053	2,052	2,015	2,011	1,859
Import	190	176	256	262	257	272	277	263	222	214
Export	19	449	704	763	829	790	910	766	509	466
Supply	1,414	1,349	1,198	1,277	1,363	1,535	1,419	1,512	1,724	1,607

Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Cement clinker										
Produced	103	103	153	62	53	43	5	21	16	0.12
Import	0.002	0	4	27	23	31	44	40	42	33
Export	90	99	103	67	54	56	12	10	7	8
Supply	12	4	53	22	21	18	37	51	51	25
Portland cement, white										
Produced	551	532	510	582	679	715	797	722	607	462
Import	11	0.03	0.14	1	5	15	38	19	33	30
Export	546	462	531	507	315	508	745	639	490	422
Supply	17	70	-21	76	369	222	90	102	150	70
Portland cement, grey										
Produced	1,985	2,044	2,035	1,998	2,213	2,166	2,140	2,149	1,932	1,116
Import	238	254	275	191	184	215	235	229	263	177
Export	634	769	731	652	761	732	545	484	443	125
Supply	1,589	1,529	1,578	1,538	1,636	1,650	1,830	1,895	1,751	1,168

Year	2010	2011	2012	2013
Cement clinker				
Produced	4	0.03	24	0
Import	22	27	27	26
Export	12	3	25	0.05
Supply	14	24	26	26
Portland cement, white				
Produced	482	514	496	531
Import	23	30	30	24
Export	501	497	499	506
Supply	3	47	27	50
Portland cement, grey				
Produced	1,085	1,338	1,321	1,322
Import	160	214	183	183
Export	201	251	271	249
Supply	1,044	1,301	1,233	1,256

NAV Personal communication with the single Danish producer of cement makes it clear what it unfortunately is not – and will never be, possible to achieve these data for 1990-1997.

Table 4.2.5 and Table 4.2.1 show the produced amount of cement (grey and white) according to Statistics Denmark and the amount produced according to Aalborg Portland respectively. The two datasets show good agreement in spite of different methodologies. The fluctuations are believed mainly to be caused by changes in stocks, and the overall sum of produced cement only differs 0.6 % (8.2 Gg) through the time series (1990-2013). The most comprehensive activity data is assumed to be the information on yearly produced amount of cement clinker obtained from the Danish producer. A comparison between the two datasets is presented in Table 4.2.6.

Table 4.2.6 Production data for Portland cement as given by Aalborg Portland and Statistics Denmark respectively.

Year		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Aalborg Portland	Gg TCE	1620	1999	2214	2244	2242	2274	2419	2719	2754	2560
Statistics Denmark	Gg	1656	2019	2072	2270	2427	2584	2629	2544	2548	2422
Difference	Gg	-36	-21	142	-26	-185	-310	-210	175	207	137
Year		2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Aalborg Portland	Gg TCE	2613	2661	2698	2546	2861	2706	2842	2946	2551	1663
Statistics Denmark	Gg	2536	2575	2545	2580	2893	2881	2937	2871	2539	1579
Difference	Gg	77	85	154	-34	-31	-174	-95	75	13	85
Year		2010	2011	2012	2013						
Aalborg Portland	Gg TCE	1454	1767	1818	1825						
Statistics Denmark	Gg	1567	1853	1817	1852						
Difference	Gg	-113	-86	1	-27						

The activity data for clinker production provided by the company includes clinker used in cement production while clinker data from Statistics Denmark only includes the amount of clinker sold. The production data for clinker can therefore not be compared.

Table 4.2.7 compares the default emission factor from IPCC (2006) with the measured/calculated implied emission factor for 1992-2013. The average IEF for these years is 0.54 Mg per Mg clinker. The comparison shows good agreement between the two methods.

Table 4.2.7 Comparison of default (Tier 1) and calculated implied (Tier 3) CO_2 emission factors for cement production.

Methodology	Value	Unit	Source
Tier 1	0.52	Mg/Mg clinker	IPCC (2006)
Tier 3[1]	0.51-0.58	Mg/Mg clinker	Aalborg Portland (2008, 2014a, b)

[1]1992-2013.

1990 and 1991 are both outliers because the production of white cement (EF: 0.669 Mg/Mg) and SKL/RKL clinker (EF: 0.610 Mg/Mg) peeked in these years, resulting in overall IEFs of 0.63 and 0.60 Mg per Mg clinker respectively.

Time series consistency and completeness

Since Denmark only has one cement factory, all data collected from the production are in fact plant specific data.

For 1990-1997, activity data for grey cement production fulfil the Tier 2 methodology while activity data for white cement (20-25 %) only fulfil the Tier 1 methodology (IPCC, 2006). The company has informed that data until 1997 cannot be improved as there is no further information available.

Since 1998, the determination of activity data for cement production has met the requirements of the Tier 3 methodology.

Emission factors have for the entire time series been determined by analysed loss on ignition which fulfil the requirements of the Tier 3 methodology.

The methodology behind the chosen activity data for cement production is therefore not consistent, but CO_2 emission factors are.

The inventory on cement production is considered complete in accordance with IPCC (2006).

4.2.4 Lime production

The production of limestone and lime/burned lime/quicklime is located at a few localities: Faxe Kalk (Lhoist group) situated in Faxe, dankalk A/S situated in Løgstør with limestone quarries/limeworks in Aggersund, Mjels, Poulstrup and Batum.

In addition to the marketed lime production is the lime production related to production of sugar. Sugar production is concentrated at one company: Nordic Sugar (previously Danisco Sugar A/S) located in Assens, Nakskov and Nykøbing Falster (Danisco Sugar Assens, 2007; Danisco Sugar Nakskov, 2008; Danisco Sugar Nykøbing, 2008; Nordic Sugar Nakskov, 2013; Nordic Sugar Nykøbing, 2013). The following SNAP-code is covered:

- 04 06 14 Lime (decarbonising)

Emissions associated with the fuel use are estimated and reported in the energy sector.

Methodology

Calculation of CO_2 emissions from oxidation of carbonates follows the general process:

$$CaCO_3 + heat \rightarrow CaO + CO_2$$

The emission of CO_2 results from heating of the carbonates in the lime-kiln. The lime-kilns can be located either at the location for limestone extraction or at the location for use of burned lime.

The CO_2 emission from the production of marketed burnt lime (quicklime) has been estimated from the annual production figures, registered by Statistics Denmark and emission factors.

Since 2006, process CO_2 emissions from Faxe Kalk have been calculated by the company and reported to EU-ETS. These calculations are based on the assumption of pure CaO product and are therefore not corrected for impurities. For the sake of consistency, the same method has been applied for the entire time series and for all producers. However, since 2008, Faxe Kalk has measured and included the content of MgO in the process emissions reported to EU-ETS; this causes a slight increase and small fluctuations in the implied emission factor for de recent years (Faxe Kalk, 2013).

Total production statistics for production of sugar available from Statistics Denmark (2014) and the company information from the environmental reports are used for calculating the allocation of production/sale between the three locations.

Activity data

Plant specific activity data for marketed lime only exist for one company (Faxe Kalk) that constitutes about 66% (2006-2013 average) of the Danish activity; see Table 4.2.8. The plant specific data are available back to 1995. A number of smaller companies account for the remaining of the Danish production.

Statistics from Statistics Denmark (2014) have been chosen as data source to ensure consistent data throughout the period from 1990. However, after EU-ETS data have become available from 2006; the company specific production data have been included and the data from Statistics Denmark adjust to only cover producers not covered by EU-ETS.

Table 4.2.8 Production of marketed burnt lime, Mg (Statistics Denmark, 2014 and Faxe Kalk, 2014a, b).

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Faxe Kalk						46340			71480	76348
Other producers						54449			17442	18829
Total production	127978	86222	104526	106587	112480	100789	95028	102587	88922	95177
Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Faxe Kalk	62489	70537	69827	63258	64085	57302	62817	57004	57812	38349
Other producers	29513	25949	52814	24291	13759	13937	15835	18500	17169	7853
Total production	92002	96486	122641	87549	77844	71239	78652	75504	74981	46202
Year	2010	2011	2012	2013						
Faxe Kalk	25623	21312	29798	30293						
Other producers	24774	38118	39338	36512						
Total production	50397	59430	69136	66805						

The production of hydrated lime (slaked lime) from burnt lime does not emit any greenhouse gasses. All burnt lime that is later slaked, is included in the statistics shown in the table above. Adding the production of slaked lime to the activity data, would therefore result in double counting. Dolomitic lime is not produced in Denmark.

Production statistics for production of sugar are available in the environ-mental reports for the years since 1996, however, each 12 month period going from May 1 - April 30 (Danisco Sugar Assens, 2007; Danisco Sugar Nakskov, 2008; Danisco Sugar Nykøbing, 2008; Nordic Sugar Nakskov, 2013; Nordic Sugar Nykøbing, 2013). Therefore, the yearly production does not correspond with the yearly sale registered by Statistics Denmark (Statistics Denmark, 2014). During nine years (1996-2004) the sale is 4.8% above the production. The information from Statistics Denmark covers the whole period and therefore the amount of sugar for sale is used as activity data. The company information is used for calculating the allocation of production/sale between the three locations. The consumption of lime is estimated from the production statistics and a number of assumptions: consumption of 0.02 Mg $CaCO_3$ per Mg sugar and precipitation of 90 % CaO resulting in an emission factor at 0.0088 Mg CO_2 per Mg sugar (consumption: 2 % $CaCO_3$ per Mg sugar beets, 10 % sugar in sugar beets). The assumptions are based on environmental reports covering the year

2002. Production statistics and the calculated lime consumption are presented in Table 4.2.9.

Table 4.2.9 Production of sugar at different locations, Gg.

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Assens	151.7	152.9	141.2	145.3	148.8	177.7	129.5	146.2	167.1	160.5
Nakskov	202.3	203.9	188.2	193.7	198.4	133.2	172.7	195.0	222.8	214.0
Nykøbing	151.7	152.9	141.2	145.3	148.8	133.2	129.5	146.2	167.1	160.5
Total (Statistics Denmark)	505.7	509.8	470.6	484.3	496.0	444.1	431.8	487.4	557.0	535.1
$CaCO_3$-eq	5.7	5.7	5.3	5.4	5.6	5.0	4.8	5.5	6.2	6.0
Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Assens	133.0	168.7	152.4	153.2	135.5	151.9	137.4	0	0	0
Nakskov	177.3	224.9	203.2	204.3	180.7	202.6	183.2	170.2	208.6	222.4
Nykøbing	133.0	168.7	152.4	153.2	135.5	151.9	137.4	159.6	191.6	206.1
Total (Statistics Denmark)	443.2	562.4	508.1	510.8	451.7	506.5	458.0	329.8	400.3	428.4
$CaCO_3$-eq	5.0	6.3	5.7	5.7	5.1	5.7	5.1	3.7	4.5	4.8
Year	2010	2011	2012	2013						
Assens	0	0	0	0						
Nakskov	137.9	114.7	137.9	140.0						
Nykøbing	124.2	103.3	124.2	125.0						
Total (Statistics Denmark)	262.1	218.1	262.0	265.0						
$CaCO_3$-eq	2.9	2.4	2.9	3.0						

1990-2006: Activity data based on information from Statistics Denmark and distribution between the three plants: 0.3/0.4/0.3.

2007-2009: Production data based on environmental reports from Nakskov and Nykøbing.

2010-2013: Activity data based on information from Statistics Denmark and distribution between the two plants: 0.53/0.47 (distribution calculated from environmental reports from 2005-2009).

Emission factors

The emission factor for calcination of both marketed and non-marketed calcium carbonate is based on stoichiometric relations; the emission factor applied is 0.785 kg CO_2 per kg CaO. The content of MgO in burned lime from Danish producers has been assumed negligible. It is also assumed that the degree of calcination is 100 % and no lime kiln dust (LKD).

Since 2008, Faxe Kalk has reported measured emissions factors to EU-ETS. These emission factors take into account the content of MgO and varies from 0.787-0.788 Mg CO_2 per Mg lime produced (Faxe Kalk, 2014a). The measured emission factors show that the MgO content in the product has a negligible impact on the emissions; 0.3 % in average for 2008-2013.

Emission trends

The emission trend for the CO_2 emission from lime production, including sugar production; is available in the CRF tables but is also presented in Figure 4.2.3.

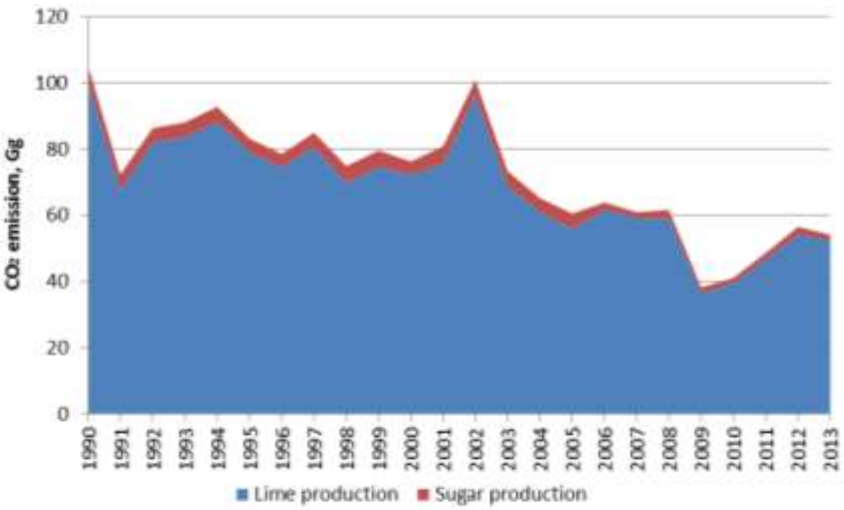

Figure 4.2.3 Emission of CO_2 from lime production.

The emission from sugar production only comprise 3 % (2007) to 7 % (2005) of the total CO_2 emission from lime production; 5 % in average over the time series.

EU-ETS data for lime production

The applied methodology for Faxe Kalk is specified in the individual monitoring plan that is approved by Danish authorities (DEA) prior to the reporting of the emissions. Lime production applies the Tier 2 methodology for the activity data and Tier 3 for the emission factor.

The implied CO_2 emission factor for Faxe Kalk is plant specific and based on the reporting to the EU Emission Trading Scheme (EU ETS). The EU ETS data have been applied for the years 2006 – 2013.

The CO_2 emission for lime production is based on sales (± 1.0 %) and measurements of the MgO content in the product (assuming the product is pure CaO/MgO) (Faxe Kalk, 2013).

Verification

For verification, the implied emission factors are calculated and presented in the following table.

Table 4.2.10 Implied emission factors for lime production, Mg per Mg.

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Lime production (marketed)	0.785	0.785	0.785	0.785	0.785	0.785	0.785	0.785	0.785	0.785
Sugar production	0.785	0.785	0.785	0.785	0.785	0.785	0.785	0.785	0.785	0.785
Overall	0.785	0.785	0.785	0.785	0.785	0.785	0.785	0.785	0.785	0.785
Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Lime production (marketed)	0.785	0.785	0.785	0.785	0.785	0.785	0.785	0.785	0.787	0.787
Sugar production	0.785	0.785	0.785	0.785	0.785	0.785	0.750	0.750	0.750	0.750
Overall	0.785	0.785	0.785	0.785	0.785	0.785	0.784	0.784	0.785	0.785
Year	2010	2011	2012	2013						
Lime production (marketed)	0.786	0.786	0.786	0.786						
Sugar production	0.750	0.750	0.750	0.750						
Overall	0.785	0.784	0.784	0.785						

If the simple Tier 2 methodology had been used for the entire time series, instead of partially using EU-ETS data, then the emission from marketed lime production in 2006-2013 would be 1 % (2007) to 16% (2008) lower; average of 2006-2013 is 8 %.

Time series consistency and completeness

The chosen activity data for both marketed and non-marketed lime production are consistent throughout the time series.

The applied methodology for calculation of the CO_2 emission from marketed lime is consistent for all producers for 1990-2005. From 2006, the CO_2 emission from the largest Danish producer (Faxe Kalk) is gathered from EU-ETS, but in spite of this, the methodology continues to be consistent until 2008 because Faxe Kalk uses the same emission factor when calculating emissions. In 2008 an inconsistency occurs when emissions reported by Faxe Kalk to EU-ETS begins to takes into account the otherwise negligible amount of MgO in the product, leading to a miniscule increase in the implied emission factor.

The time series for non-marketed lime production at the sugar factories is considered inconsistent as emissions are based on total sugar production for 1990-2005 and on carbonate consumption for 2006 onward. Please refer to the subsection “Lime production” in Chapter 4.2.11.

After excessive search, no indications of non-marketed lime production, other than that of the sugar industry, was found. The Danish inventory on lime production is therefore considered to be complete.

4.2.5 Glass production

Glass production covers production of:

- Flat glass
- Container glass
- Glass wool

The production of flat glass (SNAP 03 03 14 Flat glass) is concentrated at few European producers and none of these have plants in Denmark. The processes in Denmark are limited to mounting of sealed glazing units. The mounting process is not considered to contribute to emission of pollutants to air in Denmark.

The production of container glass for packaging is concentrated at one company: Ardagh Glass Holmegaard A/S (previously Rexam Glass Holmegaard A/S) and for art industrial glass products: Holmegaard A/S both situated in Fensmark, Næstved. Saint-Gobain Isover situated in Vamdrup produces glass wool. The following SNAP-code is covered:

- 04 06 13 Glass (decarbonising)

Emissions associated with the fuel use are estimated and reported in the energy sector.

Methodology

For the production of both container glass, art glass and glass wool, the main raw materials are soda ash (Na_2CO_3), dolomite ($CaMg(CO_3)_2$), limestone ($CaCO_3$) and recycled glass (cullets).

Emissions are calculated for each carbonate raw material individually.

Activity data

The activity data for container glass production are presented in Table 4.2.11. Information on consumption of carbon containing raw materials is available from the environmental reports of the plant since 1997 (Ardagh, 2014b) and from EU-ETS since 2006 (Ardagh, 2014a). For the years prior to 1997 the production of glass is based on information contained in Illerup et al. (1999).

Table 4.2.11 Production of container glass, activity data, Mg.

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Production of glass[1, 2]	164000	159000	145000	140500	150200	140000	140000	140000	186622	197863
Consumption of soda ash[3]	22543	19244	16945	16360	16302	15195	15195	15195	20258	19241
Consumption of limestone[3]	18226	15559	13700	13227	13180	12285	12285	12285	7966	8733
Consumption of dolomite[3]	1237	1056	930	898	895	834	834	834	9522	9808
Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Production of glass[1, 2]	179541	179290	160938	145186	139498	125583	48179	52437	130075	78596
Consumption of soda ash	16391	16668	15816	14106	13611	12996	12831	14060	13882	8464
Consumption of limestone	7739	7881	7050	6347	6036	5650	1325	1693	9171	5383
Consumption of dolomite	9085	8920	8031	7258	7036	6118	5413	5462	5527	3631
Year	2010	2011	2012	2013						
Production of glass[1, 2]	86354	87923	90027	68210						
Consumption of soda ash	8883	8843	9584	6755						
Consumption of limestone	5855	5940	6095	4796						
Consumption of dolomite	4085	4215	4267	2911						

[1] 1990-1997: Illerup et al. (1999).
[2] 1998-2013: Estimated based on 1997 and total consumption of raw materials.
[3] 1990-1996: Estimated based on total production and the consumption of raw materials in 1997.

Only one industrial art glass producer with virgin glass production exists in Denmark; Holmegaard A/S. Emissions from this production is included in the data on container glass above.

The activity data for glass wool production are presented in Table 4.2.12. Information on consumption of carbon containing raw materials is available from the environmental reports of the plant since 1996 (Saint-Gobain Isover, 2014a) and EU-ETS since 2006 (Saint-Gobain Isover, 2014b). For the years prior to 1995/1996 the production of glass wool and consumption of carbonates are estimated.

Table 4.2.12 Production of glass wool, activity data, Mg.

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Production of glass wool[1]	35631	35631	35631	35631	35631	35631	35631	34584	33630	38680
Consumption of soda ash[2]	3566	3566	3566	3566	3566	3566	3589	3654	3455	3095
Consumption of limestone[2]	818	818	818	818	818	818	768	854	831	276
Consumption of dolomite[3]	1021	1021	1021	1021	1021	1021	1021	1021	1021	1021
Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Production of glass wool	39666	36983	34836	37452	41350	37295	42735	40995	41318	33066
Consumption of soda ash	2974	2895	3300	2810	3348	3639	C	C	C	C
Consumption of limestone	213	369	589	425	530	614	C	C	C	C
Consumption of dolomite[3]	1021	1021	1021	1021	1021	1021	C	C	C	C
Year	2010	2011	2012	2013						
Production of glass wool	24899	29817	26752	27894						
Consumption of soda ash	C	C	C	C						
Consumption of limestone	C	C	C	C						
Consumption of dolomite	C	C	C	C						

[1] 1990-1996: Estimated: Assumed constant on the average production from 1997-1999.
[2] 1990-1995: Estimated: Assumed constant on the average consumption from 1996-1998.
[3] 1990-2005: Estimated: Assumed constant on the average consumption from 2006-2008.
C Confidential.

Emission factors

The CO_2 emission factors from using Na_2CO_3 and other carbonate containing raw materials in production of virgin glass and glass wool, based on stoichiometric relationships, are:

- 0.415 Mg CO_2/Mg Na_2CO_3
- 0.44 Mg CO_2/Mg $CaCO_3$
- 0.478-0.522 Mg CO_2/Mg $CaMg(CO_3)_2$

The emission factor for dolomite is 0.478 Mg per Mg for glass wool production and 0.522 Mg per Mg for container glass production. The calcination of all carbonates in all years is assumed to be 100 %.

From 2006 onward the CO_2 emissions are calculated by the companies and reported to EU-ETS (Ardagh, 2014a; Saint-Gobain Isover, 2014a), but the applied emission factors remain the same for the entire time series.

Emission trends

For the years 2006-2013 information on CO_2 emission has been available in the company reports to the EU ETS (Saint Gobain Isover, 2014a). However, this information is confidential and therefore not presented individually.

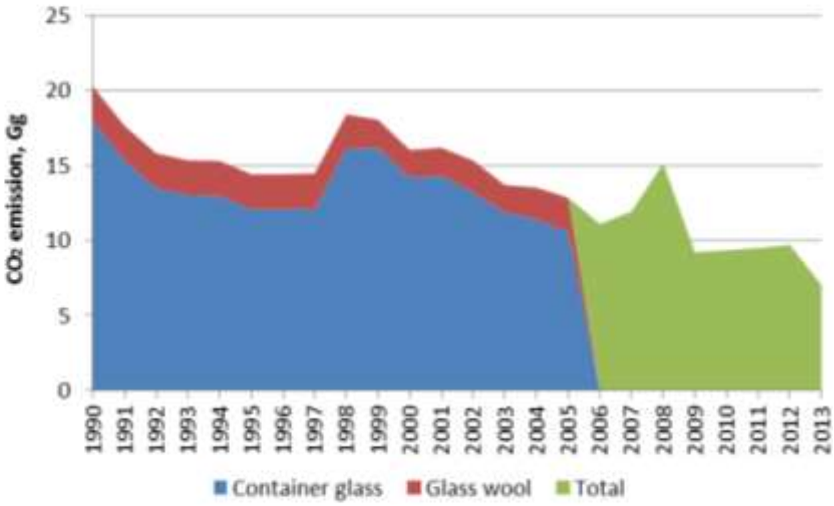

Figure 4.2.4 CO_2 emissions from glass production.

Time series consistency and completeness

Emissions from glass production (including glass wool production) are calculated based on consumption of carbonates and stoichiometric emission factors for the entire time series, the time series is therefore consistent.

Effort has been made to ensure that all glass producers are included in the inventory. Smaller facilities producing art glass do exist in Denmark, but none of these produce their own virgin glass. The source category of glass production is therefore considered to be complete.

4.2.6 Ceramics

This section covers production of bricks, tiles (aggregates or bricks/blocks for construction) and expanded clay products for different purposes (aggregates as absorbent for chemicals, cat litter, and for other miscellaneous purposes). The following SNAP codes are covered:

- 04 06 91 Production of bricks
- 04 06 92 Production of expanded clay products

The production of bricks is found all over the country, where clay is available. Producers of expanded clay products are located in the northern part of Jutland.

Emissions associated with the fuel use are estimated and reported in the energy sector.

Methodology

Emission of CO_2 is related to limestone content in the raw material. Since 2006, the producers of ceramics have measured and reported process CO_2 emissions to EU-ETS and production statistics are known from Statistics Denmark (2014) for the entire time series. From these two datasets, implied emission factors are calculated for 2006-2013 and emissions are calculated for the years back to 1990.

Activity data

The production statistics for bricks and expanded clay products (used as surrogate data) and the consumption of lime in the production (calculated for 1990-2005) are presented in Table 4.2.13.

Table 4.2.13 Statistics for production of bricks and expanded clay products.

Year	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Bricks											
Produced[1]	million pieces	291.3	291.5	303.6	278.5	389.8	362.7	377.7	419.4	423.3	405.2
Consumed lime[2]	Gg $CaCO_3$	56.8	56.9	59.2	54.3	76.1	70.8	73.7	81.8	82.6	79.1
Expanded clay products											
Produced[1]	Gg	331.8	268.9	282.9	288.3	383.8	340.9	368.1	406.7	324.4	329.4
Consumed lime[2]	Gg $CaCO_3$-eqv	37.1	30.0	31.6	32.2	42.9	38.1	41.1	45.4	36.2	36.8
Year		2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Bricks											
Produced[1]	million pieces	414.8	352.0	342.2	342.0	365.4	407.9	465.5	348.9	322.1	226.4
Consumed lime[2]	Gg $CaCO_3$	80.9	68.7	66.8	66.7	71.3	79.6	79.0	86.4	61.8	35.8
Expanded clay products											
Produced[1]	Gg	316.2	232.3	239.7	211.8	281.8	310.9	411.9	504.9	303.9	140.9
Consumed lime[2]	Gg $CaCO_3$-eqv	35.3	25.9	26.8	23.7	31.5	34.7	47.5	61.1	36.6	14.7
Year		2010	2011	2012	2013						
Bricks											
Produced[1]	million pieces	212.1	222.1	185.4	177.4						
Consumed lime	Gg $CaCO_3$	35.1	46.0	39.7	36.7						
Expanded clay products											
Produced[1]	Gg	157.4	172.3	153.3	139.8						
Consumed lime	Gg $CaCO_3$-eqv	13.7	15.1	13.4	23.8						

[1] Statistics Denmark (2014).
[2] 1990-2005: Calculated from production data and the average implied emission factor for 2006-2013.

Emission factors

The emission factor for lime is 0.44 kg CO_2 per kg $CaCO_3$. The calcination factor is assumed to be 1 for all years and all producers.

For 2006-2013 CO_2 emissions are reported by the brickworks to EU-ETS (confidential reports from approximately 20 brickworks). The reported emissions are calculated from measured lime contents of the raw materials and the stoichiometric emission factor 0.44 kg CO_2 per kg $CaCO_3$.

Producers of expanded clay products also report CO_2 emissions to EU-ETS for the years 2006-2013 (Damolin, 2014; Maxit, 2014). The reported emissions are calculated from the difference in C contents measured in the raw materials and products and the stoichiometric emission factor 3.664 kg CO_2 per kg C. The reported emissions are recalculated to match the activity data for brickworks using the stoichiometric factors.

Emission trends

The emission trend for the CO_2 emission from production of bricks and expanded clay products is available in the CRF tables but is also presented in Figure 4.2.5.

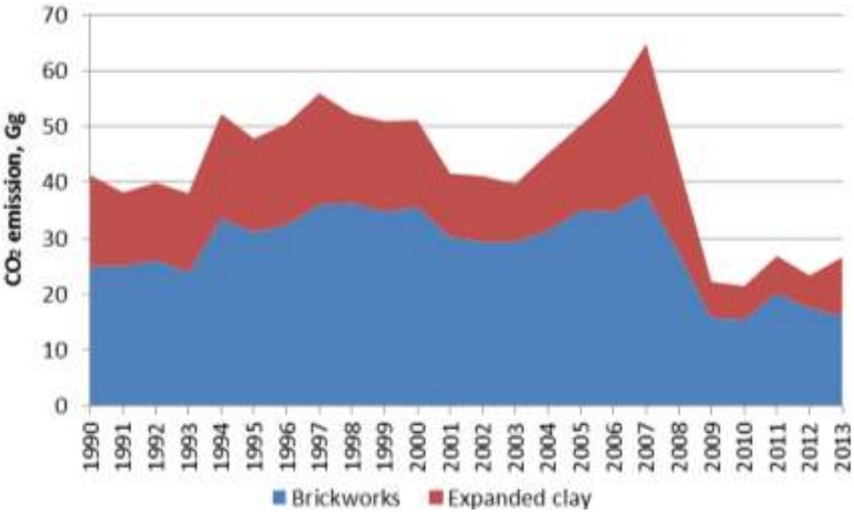

Figure 4.2.5 CO_2 emissions from the production of ceramics.

Emissions from this source category are very dependent on new houses being built as well as old ones being renovated. The significant decline in emissions from 2007-2009 was caused by a reduced production resulting from the economic recession caused by the global financial crisis.

EU-ETS data for ceramics

The applied methodologies for brickworks and expanded clay producers are specified in the individual monitoring plans that are approved by Danish authorities (DEA) prior to the reporting of the emissions. The production of ceramics applies the Tier 2 methodology for calculating the CO_2 emission.

The CO_2 emission for ceramics production is based on measured carbonate content in all raw materials and consumption of the individual carbonate containing raw materials (Tier 2; ± 5.0 %). The implied CO_2 emission factors for the production facilities are based on stoichiometry.

Time series consistency and completeness

The time series is not consistent as emissions from 2006-2013 are known and emissions for 1990-2005 are estimated.

The inventory is based on companies reporting to EU-ETS, but clay is also burned in minor scale e.g. ceramic art workshops and school art classes. These minor sources are however considered to be negligible and for all intents and purposes the source category of ceramics is considered to be complete.

4.2.7 Other uses of soda ash

This section covers the use of soda ash not related to glass production. The following SNAP code is covered:

- 04 06 19 Other uses of soda ash

Methodology

Emissions from other uses of soda ash (Na_2CO_3) are calculated based on national statistics on import/export and the stoichiometric emission factor. There is no production of soda ash in Denmark.

Activity data

National statistics on import/export and the calculated activity data (supply) are presented in Table 4.2.14.

Table 4.2.14 Statistics for other uses of soda ash, Gg.

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Import	54.6	55.8	56.4	52.9	42.1	47.6	44.8	46.7	41.2	41.6
Export	0.1	0.0	0.0	0.2	1.1	2.1	1.1	0.0	0.0	0.2
Glass production	26.1	22.8	20.5	19.9	19.9	18.8	18.8	18.8	23.7	22.3
Supply	28.4	33.0	35.9	32.8	21.1	26.7	25.0	27.8	17.5	19.1
Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Import	42.0	45.3	41.7	43.1	43.1	59.5	44.1	44.1	41.8	28.0
Export	0.3	0.1	0.9	0.1	0.1	0.0	0.0	0.0	0.0	0.5
Glass production	19.4	19.6	19.1	16.9	17.0	16.6	16.9	18.2	17.8	10.9
Supply	22.3	25.7	21.7	26.1	26.1	42.9	27.1	25.9	24.0	16.6
Year	2010	2011	2012	2013						
Import	36.5	22.9	31.7	30.2						
Export	0.1	0.1	0.1	0.1						
Glass production	10.7	10.9	11.2	8.2						
Supply	25.7	11.9	20.4	21.9						

Emission factors

The applied emission factor for other uses of soda ash is 0.415 Mg CO_2 per Mg Na_2CO_3. The calculation assumes a calcination factor of 1.

Emission trends

The emission trend for the CO_2 emission from other uses of soda ash is available in the CRF tables but is also presented in Figure 4.2.6.

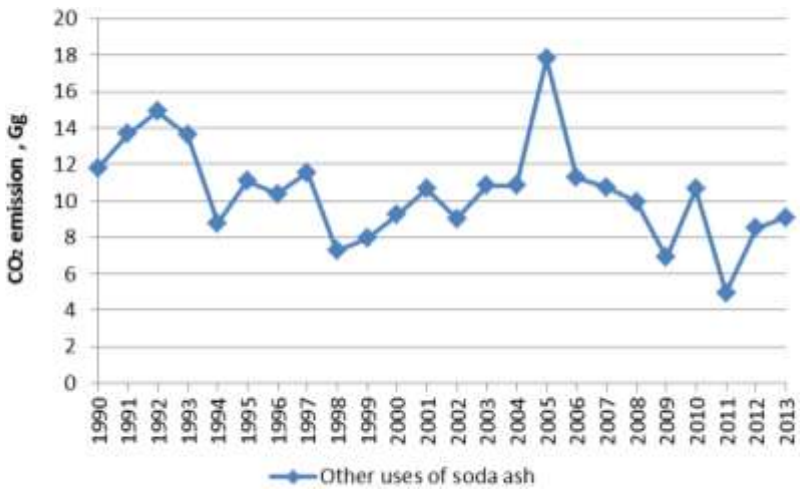

Figure 4.2.6 CO_2 emissions from other uses of soda ash.

Information on the uses of soda ash outside the glass industry is scarce, and descriptions of the trend development are therefore not available.

Time series consistency and completeness

The same methodology is used for calculating emissions for the entire time series, the source category of other uses of soda ash is therefore considered to be consistent. Calculations are based on national statistics and are therefore also considered to be complete.

4.2.8 Flue gas desulphurisation

Flue gas cleaning systems utilising different technologies are primarily present at major combustion plants i.e. power plants, combined heat and power plants as well as waste incineration plants. The following SNAP code is covered:

- 04 06 18 Limestone and dolomite use - Flue gas cleaning, wet, power plants and waste incineration plants

Methodology

The emission of CO_2 from wet flue gas desulphurisation can be calculated from the following equation:

$$SO_2\,(g) + \tfrac{1}{2}O_2\,(g) + CaCO_3\,(s) + 2H_2O\,(l) \rightarrow CaSO_4{,}2H_2O\,(s) + CO_2\,(g)$$

The consumed amount of limestone is used as activity data for the years where these data are available from EU-ETS. Information on limestone consumption is not available before the implementation of the mandatory environmental reports in 1998.

Energinet.dk compile environmental information related to energy transformation and distribution. Since the waste incineration plants with desulphurisation are all power producers, these plants are also included in the data from Energinet.dk (2014). Statistics on the generation of gypsum are available from Energinet.dk (2014) for the entire time series. However, for 2006-2013 information on consumption of $CaCO_3$ at the relevant power plants and waste incineration plants has been compiled from EU-ETS and used in the calculation of CO_2 emission from flue gas cleaning.

The consumption of other carbonates than limestone (e.g. TASP) is measured by the individual power plants and is added to the limestone consumption in $CaCO_3$ equivalents.

Activity data

During the time series this source has increased due to more plants being fitted with desulphurisation. However, since the main use is in coal fired plants, flue gas desulphurisation is decreasing as some of the coal fired power plants are rebuilt to combust biomass and the need for flue gas desulphurisation ceases. Since 2006, three of the nine coal fired power plants have changed to alternative fuels in 2013 and desulphurisation has ceased from these plants.

The Danish waste incineration plants are in general smaller than the coal combustion facilities and owned by smaller companies. Of the approximately 30 waste incineration plants with flue gas desulphurisation only one third uses wet flue gas cleaning.

For 1990-2005 the consumption of gypsum is used for calculating the CO_2 emission and for 2006-2013 the consumption of $CaCO_3$ is used. The limestone consumption data for the environmental reports (1998-2005) has not been used because this would increase the inconsistency. The activity data are presented in Table 4.2.15 and Figure 4.2.7.

Table 4.2.15 Activity data for flue gas desulphurisation, Gg.

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Gypsum production[1]	41.6	82.0	90.5	121.6	209.4	211.5	348.1	346.7	350.4	381.7
$CaCO_3$ consumption[2]	-	-	-	-	-	-	-	-	199.7	202.2
	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Gypsum production[1]	354.3	355.7	331.7	283.4	237.7	220.4	296.4	296.4	215.7	176.4
$CaCO_3$ consumption[2, 3]	209.4	194.6	177.1	168.3	128.3	110.8	156.9	107.4	84.9	85.8
	2010	2011	2012	2013						
Gypsum production[1]	185.8	147.6	100.9	153.3						
$CaCO_3$ consumption[3]	94.0	75.8	41.0	57.9						

[1] Energinet.dk (2014).

[2] 1998-2005: Environmental reports of the individual plants.

[3] 2006-2013: EU-ETS of the individual plants.

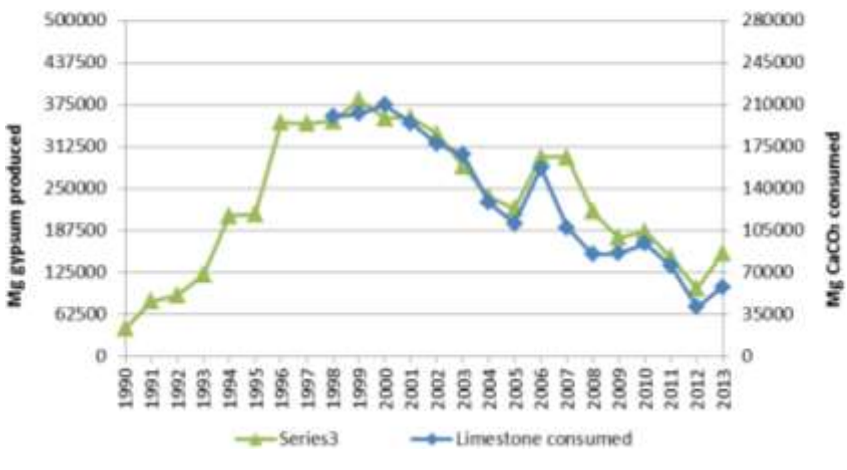

Figure 4.2.7 Activity data for flue gas desulphurisation.

The activity data level varies with the coal consumption that again varies greatly with electricity import/export.

Emission factors

From the chemical reaction equation presented in the "Methodology" section, the stoichiometric emission factor can be calculated to 0.2325 Mg CO_2 per Mg gypsum. This emission factor is used in the inventory when information on calcium carbonate consumption by power plants and waste incineration plants is not available from EU-ETS (1990-2005).

The emission factor applied when using limestone consumption as activity data is the stoichiometric emission factor 0.43971 Mg CO_2 per Mg $CaCO_3$ (2006-2013).

Emission trends

The emission trend for the CO_2 emission from flue gas desulphurisation is available in the CRF tables but is also presented in the "Verification" section below.

Verification

The three datasets generally display a good agreement, see Figure 4.2.8.

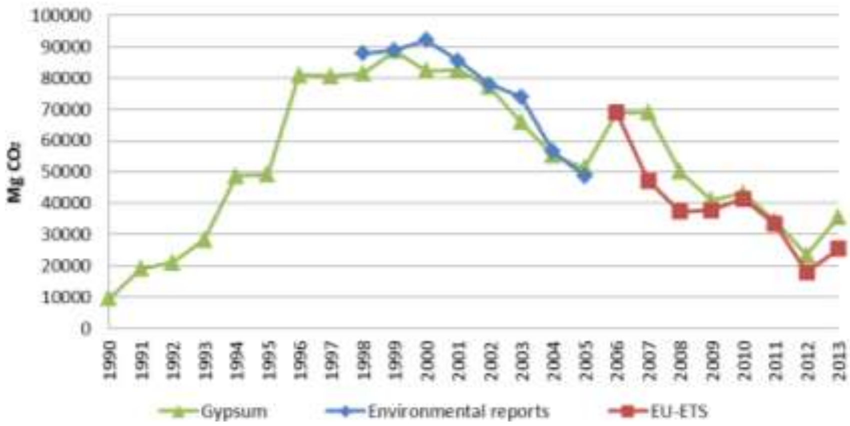

Figure 4.2.8 CO_2 emissions from flue gas desulphurisation calculated from gypsum consumption and limestone consumption compiled by environmental reports and EU-ETS respectively.

Emissions calculated from the limestone consumption data provided by the environments reports vary with -5 % (2005) to +12 % (2000) from the emission based on gypsum production. And emissions calculated from the limestone consumption data provided by the EU-ETS vary with up to 31 % (2007) from the emissions based on gypsum production.

Time series consistency and completeness

The methodology for calculating emission from flue gas desulphurisation is inconsistent; please refer to the "Verification" section above. The source category is considered to be complete.

4.2.9 Mineral wool production

Rockwool situated at three localities in Denmark: Hedehusene[1], Vamdrup and Øster Doense produces mineral wool. The following SNAP-codes are covered:

- 04 06 18 Limestone and dolomite use – Mineral wool production

Emissions associated with the fuel use are estimated and reported in the energy sector.

Methodology

Mineral wool is produced from mineral fibres and a binder. The raw materials are melted in a cupola fired by coke and natural gas, several raw materials contribute to the process CO_2 emission e.g. bottom ash, limestone, dolomite, binder etc.. The consumption of raw material as well as amount of produced mineral wool is confidential.

Information on emissions from 2006-2013 has in combination with yearly raw material consumption been used to extrapolate the emissions to other years. The data have been extracted from company reports (Rockwool, 2014) and EU-ETS. CO_2 process emissions are available for the years 2006-2013 (EU-ETS) and the consumption of raw materials for 1995-2013. Emissions for 1990-1994 are estimated as the constant average of 1995-1999.

Calculations are performed for the three factories individually.

Activity data

The calculated consumed limestone equivalents are presented in Table 9.2.16.

Table 4.2.16 Activity data for mineral wool production, Mg $CaCO_3$ equivalents.

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Carbonate consumption	17856	17856	17856	17856	17856	17963	17238	16500	18632	18948
	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Carbonate consumption	17258	15588	15910	15022	18072	18033	15490	19347	22579	16486
	2010	2011	2012	2013						
Carbonate consumption	17050	16752	15012	13755						

Emission factors

The applied emission factor for mineral wool production is the stoichiometric factor 0.43971 Mg CO_2 per Mg $CaCO_3$.

Emission trends

The emission trend for the CO_2 emission from flue gas desulphurisation is available in the CRF tables but is also presented in Figure 4.2.9 below.

[1] The melting of minerals (cupola) has been closed down in 2002.

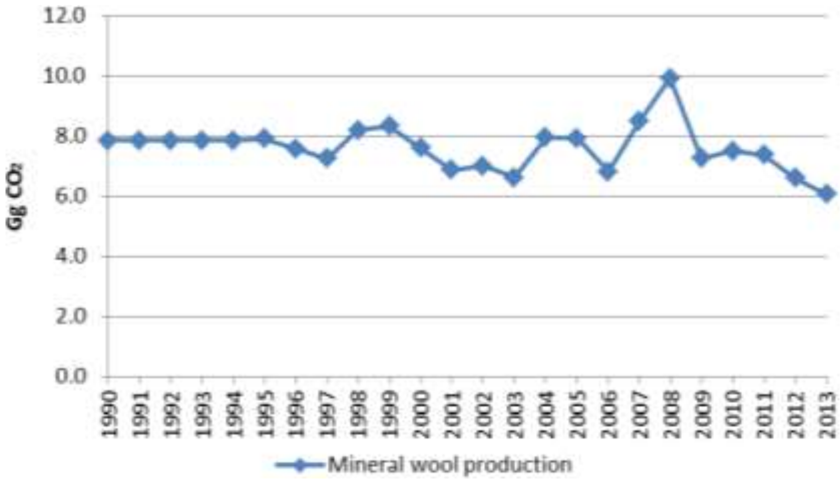

Figure 4.2.9 CO_2 emissions from mineral wool production.

Time series consistency and completeness

The source category of mineral wool production is complete but inconsistent, the inconsistency occurs because emissions for 2006 onward are known (EU-ETS) but emissions for 1990-2004 are estimated.

4.2.10 Source specific recalculations and improvements

Cement production

No recalculations were performed for cement production, but the following improvements to the documentation were included.

Information on production, import and export of cement and clinker was completed for the time series; see the subsection "Verification" in Chapter 4.2.3 and Table 4.2.5.

A comparison and analysis of the difference between produced amount of cement reported by the producer and Statistics Denmark respectively was included; see the subsection "Verification" in Chapter 4.2.3 and Table 4.2.6.

Information on cement kiln dust (CKD) prior to 1998 has been included.

Collection of further information on the production of clinker in 1990-1997 was attempted through contact with the single Danish producer of cement. However, this personal communication makes it clear what it unfortunately is not, and will never be, possible to achieve these data.

The implied emission factors (Mg CO_2 per Mg TCE) was included for the entire time series; see the subsection "Emission factors" in Chapter 4.2.3 and Table 4.2.2.

Further analyses of the high implied emission factor in the beginning of the 90's was included in this year's inventory; see the subsection "Emission factors" in Chapter 4.2.2. And a comparison of the implied emission factor and the default emission factor (IPCC, 2006) was included in the subsection "Verification" in Chapter 4.2.3; see Table 4.2.7.

A description of the EU Emission Trading Scheme (EU ETS) related to the cement production was included in this year's inventory along with an analysis of the consistency and completeness of this source category; see the subsection "EU-ETS data for cement production" and "Time series consistency and completeness" in Chapter 4.2.3.

Lime production

The activity data for lime no longer includes slaked lime and imported burnt lime. Personal communication with the industry made it clear that the inclusion of slacked lime resulted in a double counting, because statistical data on the production of burned lime also includes lime that is later slacked. Also, imported burned lime was by mistake included for 2010-2011 for Faxe Kalk. This recalculation related to slacked lime results in a decreased emission of between 5 % (1999) and 18 % (1991). The double counting of hydrated lime was only a problem for the years 1990-2010 (where EU-ETS data was not available/used) and the inclusion of imported burned lime only affected 2011-2012 (where EU-ETS data was used). The result of these recalculations has been an increase of the implied emission factor, and that the implied emission factors for 1990-2010 now matches the level of those for 2011-2013.

The EU-ETS data from Faxe Kalk for 2006-2010 have been included in this year's inventory; this change has only caused minor recalculation.

The stoichiometric emission factor for lime production has been corrected from 0.7857 to 0.7850 kg CO_2 per kg CaO for the entire time series.

The CO_2 emissions from lime production in the sugar industry have been moved from the CRF category "2H2 Food and Beverages Industry" (previously "2D2 Food and Drink"; IPCC, 1997), to the CRF category "2A2 Lime Production" (IPCC, 2006). The addition of the source category of *Sugar Production* has caused the emission to increase with an average of 5%; see the subsection "Emission trends" in Chapter 4.2.4 and Figure 4.2.3.

Further details on the applied methodology were included in this year's inventory along with an analysis of the consistency and completeness of this source category.

Glass production

A new methodology for calculating emissions from container glass production for 1990-2005 was used in this year's inventory. The resulting recalculations are between -1 % (1995) and +22 % (1998); average for 1990-2005 is an increase of 2 %. More detailed data was found for dolomite in 2006-2007, causing a decrease in emissions of 22 % and 25 % for the two years respectively.

Better estimates for the activity data for container glass in 1998-2012 were calculated for this year's inventory. This change has no influence on the emission but creates more stable implied emission factor.

The consumption of dolomite in the production of glass wool in 1990-2005 has been added as a raw material carbonate; as a result emissions from this production have increased with between 16 % (1999) and 37 % (2000); average for 1990-2005 is 29 %.

In last year's submission, the CO_2 emission from glass wool production in 2009 was mistakenly reported as 2977 Mg, this has now been corrected to 1428 Mg causing a 52 % decrease from this production in 2009.

Ceramics

The methodologies for calculating emissions from both bricks and expanded clay products have been changed for 1990-2005 in this year's inventory. Previously, emissions were based on a number of unverifiable assumptions, such as 50 % of produces bricks are yellow bricks and the lime content in bricks is 18 %. Now the historical years are based on the actual implied emission factors provided by EU-ETS (2006-2013).

This recalculation has resulted in increased emissions from brickworks of 3-10 % (8 % in average) and from expanded clay producers of 9 %.

Other uses of soda ash

The source category of other uses of soda ash is new in this year's inventory.

Flue gas desulphurisation

All activity data from this source category were reassessed and multiple recalculations were performed. Some recalculations were simple corrections of typing errors and some were more general. During the reassessment of flue gas desulphurisation at waste incineration plants, four facilities were removed from this part of the inventory because their desulphurisation is dry or semi-dry technology. It was also discovered that waste incineration plants (being power and gypsum producing) are included in the data from Energinet.dk (2014) and have therefore previously been double counted.

Mineral wool production

The CO_2 emission from mineral wool production was reassessed and found to be underestimated in last year's inventory. The surrogate data used to extrapolate emissions back in time was changed from energy consumption to raw material consumption. Emissions are now also calculated for 1995-2002 based on surrogate data instead of kept constant. Emissions have more than doubled for some years.

4.2.11 Source specific planned improvements

There are no planned improvements for the source categories of cement production, glass production, ceramics, other uses of soda ash, flue gas desulphurisation or mineral wool production.

Lime production

Unfortunately, it was not possible to complete improvements to the source category of sugar production for this year's inventory; other improvements and the implementation of the 2006 IPCC Guidebook have been prioritised. Planned improvements include:

- It will be attempted to collect activity data on the amount of lime being used as raw material in the sugar production. If this improvement is possible, it will result in increased consistency in the lime production source category (marketed lime and sugar production).
- If there is still a consistency gap for the methodology used throughout the time series, after completing the improvements mentioned above; then the calculation of CO_2 emission from sugar production between the two methods will be provided.

4.3 Chemical Industry

4.3.1 Source category description

The sector *Chemical industry* (2B) covers the following industries relevant for the Danish air emission inventory:

- 2B2 Nitric acid production (SNAP 040402); see section 4.4.3.
- 2B10 Catalyst production (SNAP 040416); see section 4.4.4.

Nitric acid production is identified as a key category in 1990 and the trend is also identified as key according to both Approach 1 and Approach 2, however this is due to the closing of the lone plant producing nitric acid in Denmark in 2004.

4.3.2 Emissions

Total greenhouse gas emissions from the Chemical Industry sector are available in the CRF Table 10. The emission time series for the source categories within *Chemical Industry* (2B) are presented in Figure 4.4.1 and individually in the subsections below (Sections 4.4.3 – 4.2.4). The following figure gives an overview of which source categories that contribute the most throughout the time series.

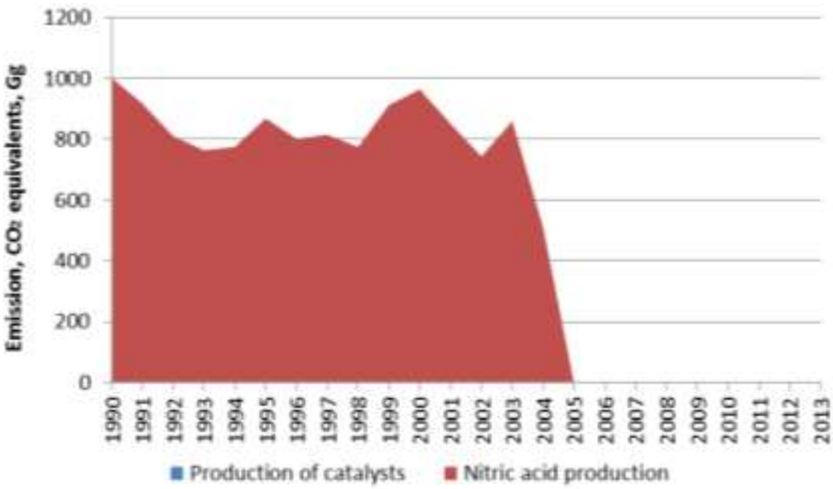

Figure 4.3.1 Emission of CO_2 equivalents from the individual source categories compiling *2B Chemical Industry*, Gg.

Greenhouse gas emissions from *Chemical Industry* are made up almost entirely by N_2O emissions from the production of nitric acid; only 0.1 % (1990-2003) to 0.2 % (2004) stems from the production of catalysts, making the emission invisible in the figure above. The production of nitric acid ceased in the middle of 2004.

4.3.3 Nitric acid production

The production of nitric acid as well as NPK fertilisers has been concentrated at one company: Kemira GrowHow A/S situated in Fredericia (Kemira GrowHow, 2005). The production ceased in the summer of 2004. The following SNAP code is covered:

- 04 04 02 Nitric acid

Methodology

The information on the N_2O emissions from the production of nitric acid/fertiliser is obtained from environmental reports (Kemira GrowHow, 2005), contact to the company as well as information from the county. Information on emissions of N_2O is available for 2002. For the remaining years the N_2O emission has been estimated from annual production statistics from the company and an emission factor based on 2002.

Specific information on applied technology is not available; however, the EF measured by the Danish nitric acid plant is in accordance with the default emission factors presented by IPCC (1997).

The production of nitric acid in Denmark ceased in the middle of 2004 and the company relocated the production to a more modern facility in another country.

Activity data

The applied activity data for production of nitric acid are presented in Table 4.3.1.

Table 4.3.1 Production of nitric acid, Gg (Kemira GrowHow, 2005).

	1990	1991	1992	1993	1994	1995	1996	1997
Nitric acid	450	412	364	343	348	390	360	366
	1998	1999	2000	2001	2002	2003	2004	
Nitric acid	348	410	433	382	334	386	229	

In the time series, the production of nitric acid peaked in 1990 with 450 Gg (and 807 Gg fertiliser) and then fluctuated around the average of 380 Gg nitric acid (694 Gg fertiliser) from 1990-2003 until the factory closed down in the summer of 2004; 2004 production of 229 Gg nitric acid and 395 Gg fertiliser.

Emission factors

Standard emission factors given by IPCC (2006) are presented in Table 4.3.2 together with the Danish value.

Table 4.3.2 Emission factors for production of nitric acid in Denmark compared with standard emission factors (IPCC, 2006) (kg per Mg nitric acid).

	Danish IEF 2002	Standard EF
N_2O	7.476	2-2.5[1]
		5[2]
		7[3]
		9[4]

[1] Modern, NSCR, process-integrated or tailgas N_2O destruction.
[2] Atmospheric pressure plant (low pressure).
[3] Medium pressure combustion plants.
[4] High pressure plants.

Emission trends

The emission trend for the N_2O emission from nitric acid production is available in the CRF tables but is also presented in Figure 4.3.1.

The trend for N_2O from 1990 to 2003 shows a decrease from 3.4 to 2.9 Gg, i.e. -14 %, and a 41 % decrease from 2003 to 2004. However, the activity and the corresponding emission show considerable fluctuations in the period considered and the decrease from 2003 to 2004 can be explained by the closing of the plant in the middle of 2004.

Time series consistency and completeness

The applied methodology regarding N_2O is considered to be consistent. The activity data is based on information from the specific company. The emission factor applied has been constant for the whole time series and is based on measurements in 2002. The production equipment has not been changed during the period. The source category of nitric acid production is complete.

4.3.4 Catalyst production

Production of a wide range of catalysts and potassium nitrate (fertiliser) is concentrated at one company: Haldor Topsøe A/S situated in Frederikssund. The following SNAP code is covered:

- 04 04 16 Other: catalysts

Methodology

The processes involve carbonate compounds i.e. the process leads to emissions of CO_2. The company has estimated the emission of CO_2 from known emission factors for incineration of natural gas and LPG and from information on the raw materials containing carbonate. The contribution from carbonate compounds is estimated to be the difference between the total CO_2 emission reported in the environmental reports (Haldor Topsøe, 2013) and the CO_2 emission from energy consumption reported to EU-ETS (Haldor Topsøe, 2014). Implied emission factors were calculated for 2003-2009 using this method. For the years 1990-1995, the production is estimated as the constant average of the production in 1997-2001.

Activity data

The activity data applied for production of catalysts and potassium nitrate are presented in Table 4.3.3.

Table 4.3.3 Production of catalysts and potassium nitrate, Gg. (Haldor Topsøe, 2014).

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Catalysts[1]	17.0	17.0	17.0	17.0	17.0	17.0	17.0	16.9	14.4	17.0
Potassium nitrate[1]	18.4	18.4	18.4	18.4	18.4	18.4	18.4	18.8	15.6	18.1
Catalysts+KNO_3[1]	35.4	35.4	35.4	35.4	35.4	35.4	35.4	35.6	30.0	35.1
	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Catalysts	17.2	19.5	19.3	15.3	22.0	23.2	20.3	20.7	28.1	22.5
Potassium nitrate	19.2	20.4	21.7	19.6	27.1	23.3	24.9	27.0	31.4	22.1
Catalysts+KNO_3	36.4	39.9	41.0	34.8	49.2	46.5	45.2	47.7	59.5	44.6
	2010	2011	2012	2013						
Catalysts	20.5	22.3	22.9	23.0						
Potassium nitrate	25.9	25.3	32.9	33.0						
Catalysts+KNO_3	46.4	47.5	55.8	56.0						

[1] 1990-1996: assumed to be the average of 1997-2001.

Emission factors

The average calculated implied emission factor for 2003-2009 is 0.0241 Mg CO_2 per Mg product; this factor is applied for the entire time series.

Emission trends

From 1990 to 2013, the emission of CO_2 from the production of catalysts/fertilisers has increased from 0.9 to 1.3 Gg with maximum in 2013, due to an increase in the activity as well as changes in raw material consumption.

The trend for the CO_2 emission from the production of catalysts and fertilisers is presented in the CRF tables but is also presented in Figure 4.3.2.

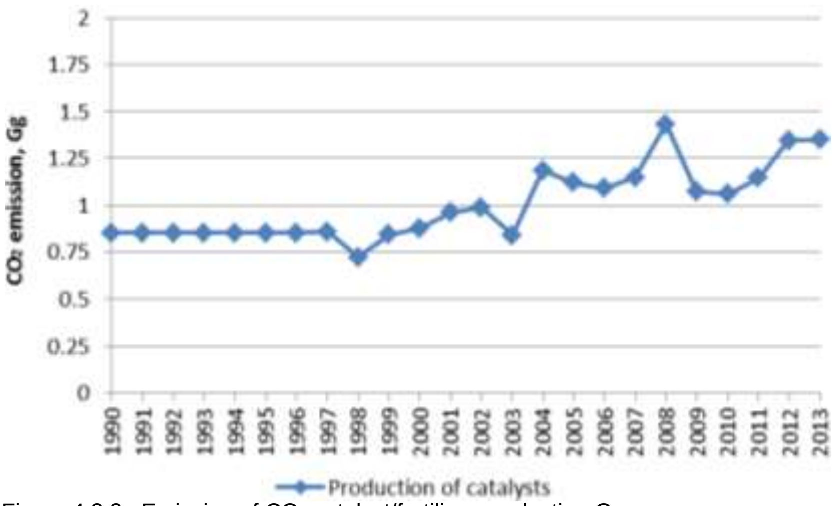

Figure 4.3.2 Emission of CO_2 catalyst/fertiliser production Gg.

Time series consistency and completeness

There is an inconsistency between the methodology applied for 1997-2013 and the one applied for 1990-1996. The source category of catalyst production is complete.

4.3.5 Source specific recalculations and improvements

There are no performed recalculations or improvements for the source categories of nitric acid production.

The process related CO_2 emission from production of catalysts/fertilisers was recalculated for the years 1990-1996 leading to a small increase; the production for these years is now calculated as the average production for 1997-2001.

4.3.6 Source specific planned improvements

There are no planned improvements for the source categories in this subsector.

4.4 Metal industry

4.4.1 Source category description

The sector *Metal Industry* (CRF 2C) cover the following industries relevant for the Danish air emission inventory:

- 2C1 Iron and steel production (SNAP 040207, 040208); see section 4.4.3
- 2C4 Magnesium production (SNAP 040304); see section 4.4.4
- 2C5 Secondary lead production (SNAP 030307); see section 4.4.5

4.4.2 Emissions

The time series for emission of CO_2 from *Metal production* (2C) is presented in the CRF tables and in Figure 4.4.1 below.

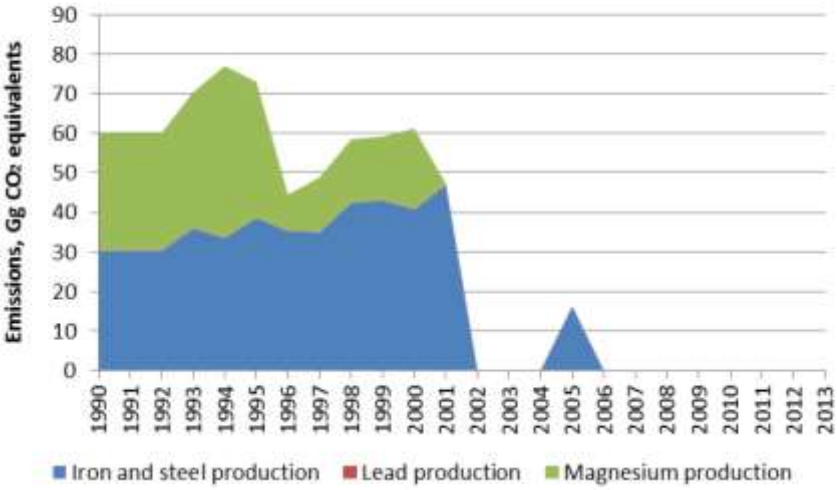

Figure 4.4.1 Emission of greenhouse gasses from the individual source categories compiling *2C Metal Industry*, Gg CO_2 equivalents.

From 1990 to 2001, the CO_2 emission from the electro-steelwork increased by 55 % and from 1990-2000 SF_6 from magnesium production decreased with 32 %. The changes in the greenhouse gas emission is similar to the increase and decrease in the activity as the consumption of metallurgical coke per amount of steel sheets and bars produced has almost been constant during the period and the emission factor for magnesium production is constant throughout the time series.

Emissions from secondary lead production are miniscule (0.3 % for 1990-2000), but are the only emissions in the *Metal Industry* sector that occur for the entire time series.

The electro-steelwork was shut down in 2001 and reopened and closed down again in 2005. In 2000, the SF_6 emission from the magnesium production ceased.

Grey iron foundries are active for the entire time series. But while this production does not result in any greenhouse gas emissions from the process the same cannot be said about the fuel consumption. Emissions related to the consumption of coke in iron foundries are included under CRF category 1A2a in the Energy sector.

4.4.3 Iron and steel production

The production of semi-manufactured steel products (e.g. steel sheets/plates and bars) is concentrated at one company: Det Danske Stålvalseværk A/S situated in Frederiksværk. The following SNAP codes are covered:

- 04 02 07 Electric furnace steel plant
- 04 02 08 Rolling mill

The steelwork has been closed down in January 2002 and parts of the plant have been re-opened in November 2002. The production of steel sheets/plates was reopened by DanSteel in 2003, the production of steel bars was reopened by DanScan Metal in March 2004, and the electro steelwork was reopened by DanScan Steel in January 2005. The production at DanScan Metal and Steel ceased in the last part of 2005 and in June 2006 DanScan Metal was taken over by Duferco; the future for the electro steelwork (DanScan Steel) is still uncertain and the plant has not been in operation since 2005. The timeline is presented in Figure 4.4.2.

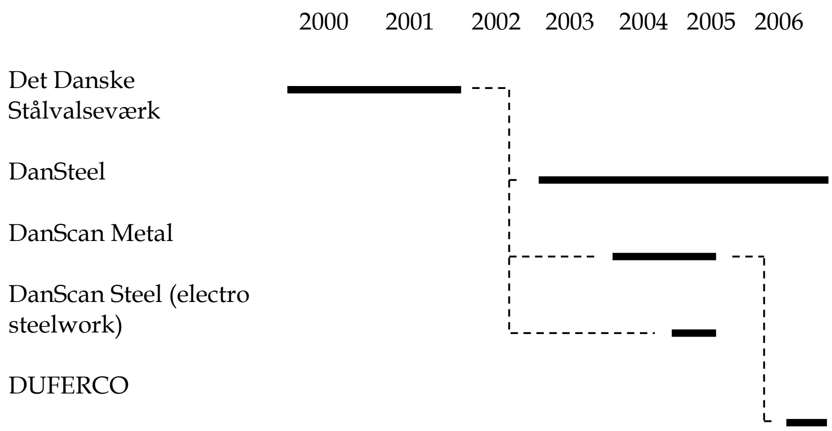

Figure 4.4.2 Timeline for production at the Danish steelwork.

Methodology

Metallurgical coke is used in the melting process to reduce iron oxides and to remove impurities. The overall process is:

$C + O_2 \rightarrow CO_2$

The CO_2 emission from the consumption of metallurgical coke at steelworks has been estimated from the annual production of steel sheets and steel bars combined with the consumption of metallurgical coke per produced amount (Stålvalseværket, 2002). The carbon source is assumed to be coke and all the carbon is assumed to be converted to

CO_2 as the carbon content in the products is assumed to be the same as in the iron scrap. The emission factor (consumption of metallurgical coke per Mg of product) has been almost constant from 1994 to 2001; steel sheets: 0.012-0.018 Mg metallurgical coke per Mg and steel bars: 0.011-0.017 Mg metallurgical coke per Mg.

Production data for 1990-1991 and for 1993 have been determined with extrapolation and interpolation, respectively and data on the consumption of metallurgical coke for 1990-1992 have been extrapolated.

Activity data

Statistical data on activities, i.e. amount of steel sheets and bars produced as well as consumption of metallurgical coke are available in environmental reports from the single Danish plant (Stålvalseværket) supplemented with other literature. In 2002, production stopped. For 2005 the production has been assumed to be one third the production in 2001 as the steelwork was operating between 4 and 6 months in 2005. The activity data are presented in Table 4.4.1.

Table 4.4.1 Overall mass flow for Danish steel production, Gg (Stålvalseværket, 2002; DanSteel, 2014).

		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Det danske stålvalseværk											
Raw material	Iron and steel scrap	-	630[1]	557	-	673	657	664	735	737	691
Intermediate product	Steel slabs etc.	-	-	599	-	730	654	744	794	800	727
Product	Steel sheets	444[2]	444[2]	444	451[3]	459	478	484	571	514	571
	Steel bars	170[2]	170[2]	170	217[3]	264	239	235	245	238	226
	Products, total	614[2]	614[2]	614	668[3]	722	717	720	816	752	798
DanSteel											
Raw material	Steel slabs	-	-	-	-	-	-	-	-	-	-
Product	Steel sheets	-	-	-	-	-	-	-	-	-	-
		2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Det danske stålvalseværk											
Raw material	Iron and steel scrap	731	680	-	-	-	-	-	-	-	-
Intermediate product	Steel slabs etc.	803	746	-	-	-	-	-	-	-	-
Product	Steel sheets	380	469	-	-	-	-	-	-	-	-
	Steel bars	251	256	-	-	-	-	-	-	-	-
	Products, total	631	725	-	-	-	250[4]	-	-	-	-
DanSteel											
Raw material	Steel slabs	-	-	-	553	600	515	561	635	590	254
Product	Steel sheets	-	-	-	469	506	433	468	520	484	211
		2010	2011	2012	2013						
Det danske stålvalseværk											
Raw material	Iron and steel scrap	-	-	-	-						
Intermediate product	Steel slabs etc.	-	-	-	-						
Product	Steel sheets	-	-	-	-						
	Steel bars	-	-	-	-						
	Products, total	-	-	-	-						
DanSteel											
Raw material	Steel slabs	457	490	338	460						
Product	Steel sheets	381	390	275	379						

[1]Jensen & Markussen (1993).
[2]Extrapolation.
[3]Intrapolation.
[4]Assumed.

The mass balances / flow sheets presented in the annual environmental reports do not for all years tell about the changes in the stock and therefore the balance cannot be checked off.

Emission factors
The emission factors for carbon dioxide from using metallurgical coke in manufacturing of iron and steel from scrap is the stoichiometric ratio 3.667 Mg CO_2 per Mg C.

Emission trends
The greenhouse gas emissions from the steel production are presented in the CRF tables and in Figure 4.4.3. The production ceased in 2001 and reopened and closed again in 2005; see Figure 4.4.2.

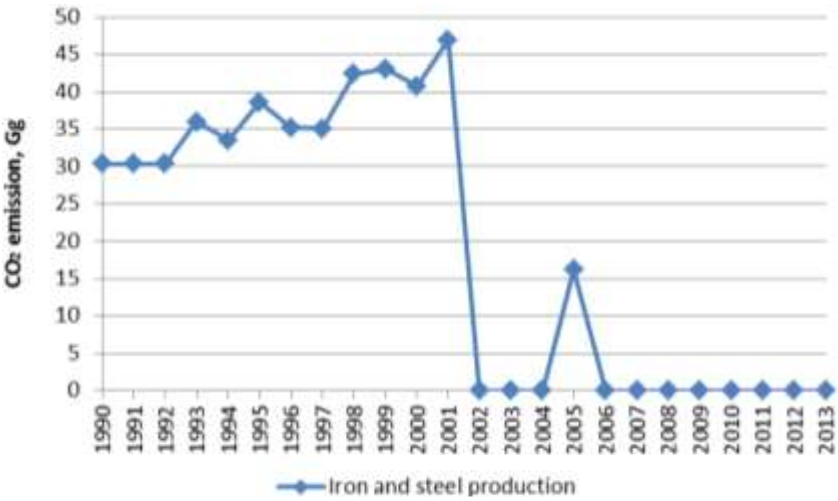

Figure 4.4.3 Emission of greenhouse gasses from the production of steel from scrap.

Time series consistency and completeness
The time series for secondary steel production is considered to be consistent as the same methodology has been applied for the whole period. The time series is also considered to be complete.

There is no metallurgical coke production in Denmark.

4.4.4 Magnesium production

For the production of magnesium in Denmark the following SNAP-code is covered:

- 04 03 04 Consumption of SF_6 in magnesium foundries

Methodology
The consumption of SF_6 in the magnesium production is known from Poulsen (2015). Activity data can be calculated from the SF_6 consumption and the default Tier 1 emission factor known from IPCC (2006).

A release of 100 % is assumed.

Activity data
Table 4.4.2 presents the calculated activity data.

Table 4.4.2 Production of magnesium, Mg.

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Magnesium produced	1300	1300	1300	1500	1900	1500	400	600	700	700	891

Emission factors

The applied emission factor is 1 kg SF_6 per Mg produced magnesium (IPCC, 2006).

Emission trends

The greenhouse gas emissions from the production of magnesium are presented in the CRF tables and in Figure 4.4.4 below. The consumption of SF_6 ceased in 2000.

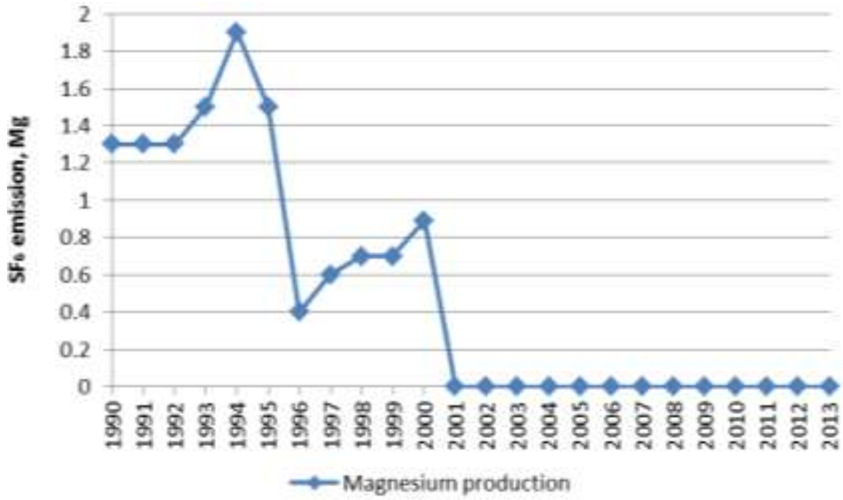

Figure 4.4.4 Emission of greenhouse gasses from the production of magnesium.

Time series consistency and completeness

The time series for magnesium production is considered to be both consistent and complete.

4.4.5 Secondary lead production

One Danish company producing secondary lead has been identified; Hals Metal. The following SNAP code is covered:

- 03 03 07 Secondary lead production

Methodology

Only one Danish company; Hals Metal, has been identified as producing secondary lead from scrap metal. In addition to Hals metal, old lead tiles from castles, churches etc. are melted and recast on site during preservation of the many historical buildings in Denmark.

Activity data

Activity data from Hals Metal is provided by the company. A clause affected in 2002 meant that Hals Metal could no longer burn cables containing lead. The processing of cables was therefore stopped and the company's activity changed to smelting. This transition resulted in a low activity in 2003.

The activity of recasting lead tiles is not easily found because it is spread out on many craftsmen and poorly regulated. However, an estimate by Lassen et al. (2004) stated that 200-300 Mg lead tiles were recast in 2000. Since the building stock worthy of preservation is constant, it is considered reasonable to also let the activity of recasting of lead tiles be constant.

Activity data for secondary lead is shown in Table 4.4.3.

Table 4.4.3 Activity data for secondary lead production (Hals metal, 2014 and Lassen et al., 2004), Mg.

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Hals metal	540	540	540	750	750	750	540	540	540	540
Lead tiles	250	250	250	250	250	250	250	250	250	250
Total	790	790	790	1000	1000	1000	790	790	790	790
	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Hals metal	540	1080	419	64	520	691	500	670	582	780
Lead tiles	250	250	250	250	250	250	250	250	250	250
Total	790	1330	669	314	770	941	750	920	832	1030
	2010	2011	2012	2013						
Hals metal	635	938	412	533						
Lead tiles	250	250	250	250						
Total	885	1188	662	783						

Emission factors

The applied CO_2 emission factor for secondary lead production is 0.2 Mg per Mg product.

Emission trends

The greenhouse gas emissions from the production of secondary lead are presented in the CRF tables and in Figure 4.4.5 below.

Figure 4.4.5 Emission of greenhouse gasses from secondary lead production.

Time series consistency and completeness

The time series for secondary lead production is considered to be both consistent and complete.

4.4.6 Source specific recalculations and improvements

A correction was made for the activity data for steel production in 1992, this recalculation has resulted in small increases in emissions for 1992 and the extrapolated/interpolated years 1990-1991 and 1993.

For magnesium production, activity data are now calculated from the consumption of SF_6 and the default IPCC (2006) emission factor is applied, however this change has no influence on the emission.

CO_2 emissions related to the production of secondary lead are new in this year's inventory.

4.4.7 Source specific planned improvements

There are no planned improvements for the source categories in this subsector.

4.5 Non-Energy Products from Fuels and Solvent Use

4.5.1 Source category description

Non-energy products from fuels and solvent use (CRF 2D) includes the following categories:

- Lubricant use (CRF 2D1, SNAP 060604)
- Paraffin wax use (CRF 2D2, SNAP 060606)
- Solvent use (CRF 2D3 Other, SNAP 0601, 0602, 0603, 0604)
- Road paving with asphalt (CRF 2D3 Other, SNAP 040611)
- Asphalt roofing (CRF 2D3 Other, SNAP 040610)
- Urea from fuel consumption (CRF 2D3 Other)

The CO_2 emission from paraffin wax use is identified as key categories for trend according to Approach 2.

Methodologies, activity data, emission factors are described in their respective sections below.

4.5.2 Lubricant use

Methodology

The category Lubricant use (CRF 2D1) covers the following process:

- Oxidation of lubricants during use

Lubricants consumed in machinery and combusted during use and collection of waste lubricants with subsequent combustion are reported in the energy and waste sectors, respectively.

The emission of CO_2 from oxidation of lubricants during use is calculated according to the equation (IPCC, 2006):

$$E_{CO2} = LC \bullet CC_{lubricant} \bullet ODU_{lubricant} \bullet 44/12 \qquad \text{(Eq. 4.5.1)}$$

Where E_{CO2} is the CO_2 emission in tonnes, LC is the consumption of lubricants in TJ, $CC_{lubricant}$ is the carbon content factor of 20.0 kg C/GJ (default), $ODU_{lubricant}$ is the Oxidised During Use factor of 0.2 for grease, and 44/12 is the mass ratio of CO_2/C.

Equation 4.5.1 represents a Tier 1 approach where LC is the total amount of lubricant consumed in Denmark with no differentiation between greases and oils.

Activity data

The time series for consumption of lubricant oil in TJ is obtained from the Danish Energy Agency. Complete time series can be seen in Annex 3C-1

Table 4.5.1 Consumption of lubricant oil (TJ) (Danish Energy Agency).

2D1	1990	1995	2000	2005	2010	2011	2012	2013
Lubricants	3 372	3 314	2 693	2 550	2 251	2 150	2150	2150

Emission factors

The product $CC_{lubricant}$ * $ODU_{lubricant}$ * 44/12 in Eq 4.5.1, yields an emission factor of 14.74 kg CO_2/TJ. This is constant for the entire time series.

Emission trends

The time series for CO_2 emission from oxidation of lubricants during use (2G) is presented in Table 4.5.2. Complete time series can be seen in Annex 3C-2

Table 4.5.2 Time series for emission of CO_2 (kt) from oxidation of lubricants during use.

2D1	1990	1995	2000	2005	2010	2011	2012	2013
Lubricants	49.7	48.8	39.7	37.6	33.2	31.7	31.7	31.7

The emission of CO_2 from oxidation of lubricants during use is decreasing from 49.7 kt in 1990 to 31.7 kt in 2013.

The applied methodology has been the same for all years (1990 to 2013) with activity data based on information from Danish Energy Agency and using the same emission factor. The methodology is therefore considered to be consistent.

4.5.3 Paraffin wax use

Methodology

The category Paraffin wax use (CRF 2D2) covers the following activity:

- Combustion of candles

Paraffin waxes are used in applications such as candles, corrugated boxes, paper coating, board sizing, adhesives, food production, packaging, wax polishes, surfactants (used in detergents or in wastewater treatment), and many others. Emissions from the use of paraffin waxes occur primarily when they are combusted during use, e.g. candles, or when incinerated or used in waste water treatment. The latter cases should be reported in the energy or waste sectors, respectively (IPCC, 2006).

In the Danish inventory emissions of CO_2, N_2O and CH_4 only from the combustion of candles, which is considered to be the main emission source, are included. This implies that the ODU factor in Eq. 5.5 in IPCC (2006) describing the Tier 2 emission is unity.

The emission of e.g. CO_2 from combustion of candles is calculated according to the simple equation

$$E_{CO2} = AD \bullet EF_{CO2} \qquad \text{(Eq. 4.5.2)}$$

Where E_{CO2} is the CO_2 emission in Gg per year, AD is the consumption of paraffin wax candles in Gg per year and EF_{CO2} is the emission factor in Gg CO_2/Gg use.

Activity data

Activity data in Gg used candles are derived from import, export and production data from Statistics DK (2014). Complete time series can be seen in Annex 3C-3

Table 4.5.3 Use of paraffin wax candles (Gg) (Statistics DK, 2014).

2D2	1990	1995	2000	2005	2010	2011	2012	2013
Paraffin wax use	7.4	9.1	16.9	34.4	35.3	30.2	27.9	29.1

Emission factors

Default emission factors that are constant for all years are compiled from the scientific literature, see below.

Table 4.5.4 Emission factors for use of paraffin wax candles (Gg/Gg).

CO_2	2,91[1)]
N_2O	2.41E-05[2)]
CH_4	1.21E-04[2)]

[1)] Shires et al. (2004)
[2)] Shires et a. (2009)

Emission trends

The time series for CO_2, N_2O and CH_4 emissions from paraffin wax use (2D2) is shown in Table 4.5.5. Complete time series can be seen in Annex 3C-4

Table 4.5.5 Time series for emissions of CO_2 (Gg), N_2O (Mg) and CH_4 (Mg) from combustion of paraffin wax candles.

	1990	1995	2000	2005	2010	2011	2012	2013
CO_2 (Gg)	21.7	26.5	49.3	100	103	87.8	81.1	84.7
N_2O (Mg)	0.18	0.22	0.41	0.83	0.85	0.72	0.67	0.70
CH_4 (Mg)	0.90	1.10	2.05	4.17	4.27	3.65	3.37	3.52

The emissions have increased with a factor of approximately four for all gasses, which is caused by an equal increase in use amounts since the emission factors are constant in the time period.

4.5.4 Solvent use

Methodology

The category Solvent use (CRF 2D3 Other) is aggregated according to the following four categories, which correspond to the grouping in IPCC (2006) and EMEP/EEA (2013):

- Paint application (SNAP 0601)
- Degreasing, dry cleaning (SNAP 0602)
- Chemical products manufacturing or processing (SNAP 0603)
- Other use of solvents and related activities (SNAP 0604)

Only NMVOC, which is subsequently oxidised to CO_2 in the atmosphere, is relevant for these categories.

Description of methodology can be found in Nielsen et al. (2015) chapter 4.5.1.

Activity data

Description of compilation of activity data can be found in Nielsen et al. (2015) chapter 4.5.1.

Table 4.5.6 Activity data (AD) in Gg per year. Complete time series can be seen in Annex 3C-5.

	1985	1990	1995	2000	2005	2010	2011	2012	2013
Paint application (SNAP 0601)	83.2	83.2	92.1	105	75.2	45.8	43.8	43.3	47.3
Degreasing, dry cleaning (SNAP 0602)	1.41	1.41	1.53	0.59	0.37	0.25	0.22	0.055	0.097
Chemical products manufacturing or processing (SNAP 0603)	406	406	504	567	740	641	640	516	518
Other use of solvents and related activities (SNAP 0604)	197	197	247	230	204	170	169	169	180

Emission factors

Description of derivation of emission factors can be found in Nielsen et al. (2015) chapter 4.5.1.

Table 4.5.7 Emission factors in Gg CO_2 per Gg AD. Complete time series can be seen in Annex 3C-6.

	1985	1990	1995	2000	2005	2010	2011	2012	2013
Paint application (SNAP 0601)	0.19	0.16	0.16	0.16	0.14	0.15	0.17	0.17	0.17
Degreasing, dry cleaning (SNAP 0602)	2.8E-05	2.7E-05	2.7E-05	2.7E-05	2.7E-05	2.7E-05	2.7E-05	2.7E-05	2.7E-05
Chemical products manufacturing or processing (SNAP 0603)	0.098	0.048	0.044	0.030	0.021	0.020	0.019	0.024	0.022
Other use of solvents and related activities (SNAP 0604)	0.31	0.31	0.29	0.29	0.24	0.26	0.26	0.26	0.27

Emission trends

Table 4.5.8 and Figure 4.5.1 show the emissions of CO_2 from 1985 to 2013. From 1985 to 1990 the emission level is set constant equal to the 1990 emission level, due to missing reliable data. A general increase is seen for all sectors from 1990 to 1996 followed by a decrease from 1997 to 2006 and stagnation in the period 2007 to 2012, with a slight increase in 2013. Further information can be found in Nielsen et al. (2015) chapter 4.5.1.

Table 4.5.8 Emissions in Gg CO_2 per year. Complete time series can be seen in Annex 3C-7.

	1985	1990	1995	2000	2005	2010	2011	2012	2013
Paint application (SNAP 0601)	31.0	13.2	15.0	16.3	10.7	6.91	7.26	7.23	7.83
Degreasing, dry cleaning (SNAP 0602)	5.9E-05	3.8E-05	4.1E-05	1.6E-05	9.7E-06	6.6E-06	6.0E-06	1.5E-06	2.6E-06
Chemical products manufacturing or processing (SNAP 0603)	26.2	19.4	22.0	17.0	15.6	12.5	12.0	12.2	11.6
Other use of solvents and related activities (SNAP 0604)	98.6	60.6	71.3	66.8	49.2	44.0	44.0	43.7	48.3
Total CO_2	156	93.3	108	100	75.5	63.4	63.3	63.1	67.8

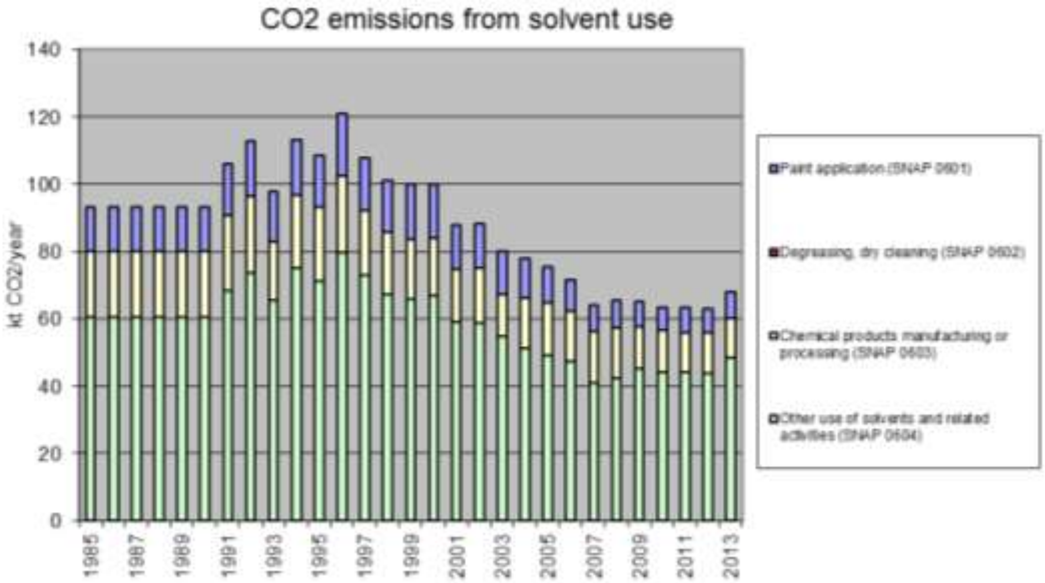

Figure 4.5.1 CO_2 emissions in Gg CO_2 per year. Figures can be seen in Table 4.5.8 and in Annex 3C-3.

4.5.5 Road paving with asphalt

Methodology

Road paving with asphalt is an activity that can be found all over the country and especially in relation to establishing new traffic facilities. The raw materials for construction of transport facilities are prepared on one of the plants located near the locality of application to limit the transport distance. The asphalt concrete is mixed and brought to the locality of application on a truck.

Transport facilities are constructed by a number of different layers:

- a load bearing layer (e.g. course gravel)
- an adhesive layer (liquefied asphalt e.g. "cutback" asphalt or asphalt emulsion)
- a wearing coarse (e.g. hot mix asphalt concrete)

Different qualities of "cutback" asphalt (e.g. asphalt dissolved in organic solvents/petroleum distillates) and asphalt emulsion contains different kinds and amounts of solvent. Cutback asphalt contains 25-45%v/v solvent e.g. heavy residual oil, kerosene-type solvent, naphtha or gasoline solvent. Approximately 500.000 liter solvent evaporates annually from the use of "cutback" asphalt (Asfaltindustrien, 2003). This amount of solvent, which is added to the asphalt, is comprised in the category 2D3 Other: Solvent use, described above with an emission factor of approximately unity. This means that NMVOC emissions from "cutback" asphalt in Road paving only include emissions from the asphalt fraction which is included in Table 4.5.9.

Emissions are calculated for CO_2 from NMVOC emissions, CH_4 and CO.

Activity data

The use amounts of asphalt for road paving have been compiled from production, import and export statistics of asphalt products in Statistics Denmark (2014).

Table 4.5.9 Activity data for asphalt in road paving in Gg per year. Complete time series can be seen in Annex 3C-8.

2D3	1985	1990	1995	2000	2005	2010	2011	2012	2013
Road paving with asphalt	2370	2370	3144	2933	3879	3005	3896	3233	3339

Emission factors

Emission factors are compiled from EMEP/EEA (2013) and US EPA (2004).

Table 4.5.10 Emission factors for CO_2, CH_4 and CO from road paving with asphalt.

		Road paving with asphalt (incl. cutback)
CO_2	g/t	39.1
CH_4	g/t	4.85
CO	g/t	75

Emission trends

Table 4.5.11 CO_2, CH_4 and CO emissions in Gg per year from road paving with asphalt. Complete time series can be seen in Annex 3C-9.

	1990	1995	2000	2005	2010	2011	2012	2013
CO_2	0.093	0.123	0.115	0.115	0.118	0.152	0.126	0.131
CH_4	0.011	0.015	0.014	0.019	0.015	0.019	0.016	0.016
CO	0.178	0.236	0.220	0.291	0.225	0.292	0.242	0.250

4.5.6 Asphalt roofing

Methodology

The category Asphalt roofing (CRF 2D3 Other) covers:

- CO_2 from NMVOC emissions and CO from asphalt blowing in asphalt roofing

The asphalt industry produces a number of products, e.g. roofing and siding shingles, for use in roofing. Key steps in the total production and roofing process include asphalt storage, asphalt blowing, felt saturation, coating and mineral surfacing.

Asphalt blowing is the process of polymerising and stabilising asphalt to improve its weathering characteristics, and it may take place in an asphalt processing or roofing plant, or in a refinery. Only asphalt blowing is covered in IPCC (2006) and in the Danish inventory, as it leads to the highest emissions of NMVOC and CO in the total production and roofing process.

Activity data

The use amounts of asphalt for roofing have been compiled from production, import and export statistics of asphalt products in Statistics Denmark (2014).

Table 4.5.12 Activity data for asphalt roofing in Gg per year. Complete time series can be seen in Annex 3C-10.

	1985	1990	1995	2000	2005	2010	2011	2012	2013
Asphalt roofing (NFR 2D3c)	120	120	123	204	187	105	134	131	125

Emission factors

Default emission factors are derived from EMEP/EEA (2013) and US EPA (2004).

Table 4.5.13 Emission factors for NMVOC and CO from asphalt roofing.

		Asphalt roofing
CO_2	g/Mg	234.7
CO	g/Mg	9.5

Emission trends

Table 4.5.14 CO_2 from NMVOC and CO emissions in Gg per year from asphalt roofing. Complete time series can be seen in Annex 3C-11.

	1985	1990	1995	2000	2005	2010	2011	2012	2013
CO_2	0.0282	0.0282	0.0290	0.0478	0.0439	0.0247	0.0315	0.0307	0.0294
CO	0.00114	0.00114	0.00117	0.00194	0.00178	0.00100	0.00128	0.00124	0.00119

There is a 4% increase in emissions from 1990 to 2013, due to a similar increase in use amounts of asphalt for asphalt roofing. Emission factors are held constant throughout the time period.

4.5.7 Urea from fuel consumption

Methodology

The category Urea from fuel consumption (CRF 2D3 Other) covers:

- CO_2 from use of urea in catalytic reaction in heavy duty vehicles to bring down NO_x emissions

The consumption of urea by SCR catalysts for heavy duty vehicles is estimated with the DCE emission model for road transport by using fuel consumption totals and urea consumption rates for relevant engine technologies. The DCE model uses the COPERT IV detailed methodology as explained in Chapter 3.3. SCR catalysts are used by Euro V and VI trucks and to a smaller extent by Euro IV trucks as an emission abatement technology in order to bring down NOx emissions.

Activity data

According to COPERT IV, the consumption of urea is 5-7 % by volume of fuel for Euro IV/V heavy duty vehicles (6 % is used) and 3-4 % for Euro VI heavy duty vehicles (3.5 % is used).

Table 4.5.15 Activity data for use of urea in Gg per year. Complete time series (2001 – 2013) can be seen in Annex 3C-12.

	2001	2005	2010	2011	2012	2013
Urea (CRF 2D3 Other)	0.00217	0.0367	10.201	15.286	20.187	24.961

Emission factors

For each vehicle layer, the emissions of CO_2 are subsequently estimated as the product of urea consumption and a CO_2 emission factor of 0.26 kg CO_2/l urea.

Emission trends

Table 4.5.16 CO_2 from use of urea in Gg per year. Complete time series can be seen in Annex 3C-13.

	2001	2005	2010	2011	2012	2013
CO_2	0.00052	0.0087	2.433	3.646	4.815	5.954

There is a significant increase in urea consumption and CO_2 emissions from 2001 to 2010, and a smaller (145 %) increase from 2010 to 2013.

4.5.8 Source specific recalculations and improvements

- The amount of solvent, which is added to the asphalt in "cutback", is comprised in Solvent use (CRF 2D3 Other), with an emission factor of approximately unity. This amount was previously included in Road paving with asphalt (CRF 2D3 Other) as "cutback". In the improved inventory NMVOC emissions from "cutback" asphalt in Road paving (CRF 2D3 Other) only include emissions from the asphalt fraction.
- A change in allocation of amounts from Statistics Denmark (2014) has caused an increase in activity data for Asphalt roofing (CRF 2D3 Other), e.g. 2012: from 75.5 Gg to 131 Gg, and a relatively small increase for Road paving (CRF 2D3 Other), e.g. for 2012: from 3223 Gg to 3233 Gg.
- Emission factors for NMVOC and CO have been updated with values from EMEP/EEA (2013) and US EPA (2004) for Road paving and Asphalt roofing.
- CH_4 emissions from Road paving with asphalt (CRF 2D3 Other) have been included.
- CH_4 emissions from use of candles (CRF 2D2 Paraffin wax use) have been included.
- CO_2 emissions from the use of urea in fuel consumption has been included in Urea in fuel consumption (CRF 2D3 Other).

4.5.9 Source specific planned improvements

- Other uses of paraffin wax will be investigated.

4.6 Electronics Industry

4.6.1 Source category description

This category includes use of HFCs and PFCs in the production of fibre optics. There is no production of semiconductors, TFT flat panels or photovoltaics resulting with use of f-gases. No use of HFCs or PFCs as heat transfer fluids occur in Denmark.

As a result the only relevant category is:

- 2E5: Other: HFC-23, PFC-14 (CF_4), PFC-318 (c-CF_4F_8)

The description of consumption and emission of f-gases given below is based on an inventory published as (Poulsen, 2015). For further details refer to this report.

4.6.2 Emissions

The use of f-gases in the production of fibre optics did not start until 2006 and hence the time-series covers the years 2006-2013. The emission time series for *Electronics Industry* (2E) are presented in Figure 4.6.1 and Table 4.6.1.

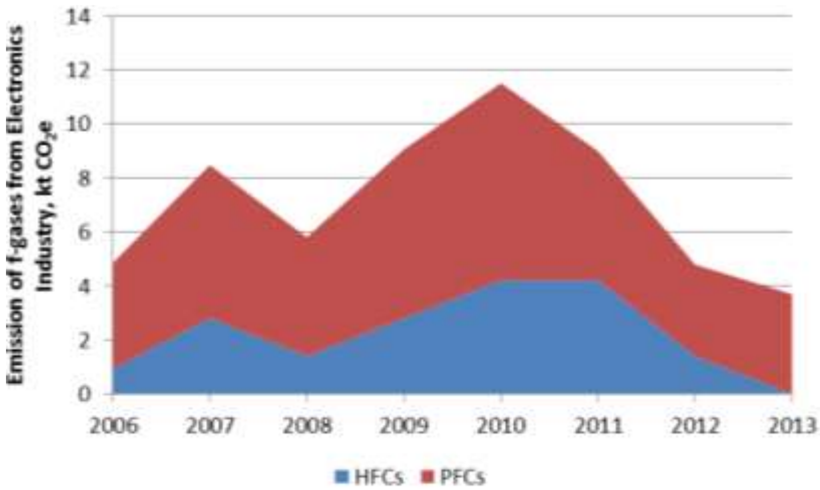

Figure 4.6.1 Emissions of HFCs and PFCs from *Electronics Industry.*

Table 4.6.1 Emission from Electronics industry.

	Unit	2006	2007	2008	2009	2010	2011	2012	2013
HFC-23	tonnes	0.08	0.24	0.12	0.24	0.36	0.36	0.12	NO
PFC-14 (CF_4)	tonnes	0.25	0.14	0.11	0.36	0.36	0.20	0.18	0.50
PFC-318 (c-C_4F_8)	tonnes	0.20	0.45	0.35	0.45	0.45	0.40	0.20	NO
HFC-23	kt CO_2e	0.94	2.81	1.40	2.81	4.21	4.21	1.40	0.00
PFC-14 (CF_4)	kt CO_2e	1.86	1.03	0.80	2.34	2.66	1.30	1.33	3.70
PFC-318 (c-C_4F_8)	kt CO_2e	2.06	4.64	3.61	3.92	4.64	3.48	2.06	0.00
Total	kt CO_2e	4.86	8.48	5.81	9.06	11.51	8.99	4.79	3.70

4.6.3 Other electronics industry

Methodology

Both HFCs and PFCs are usually used for technical purposes in Danish optics fibre production. HFC-23 and PFCs (PFC-14 & PFC-318) are used as protection and cleaning gases in the production process. Consumption data are directly available from the importer supplying the gases for producing fibre optics and process specific emission factors are used, hence the methodology corresponds to the IPCC Tier 3 method.

Activity data

The consumption of PFCs from fibre optics production was 0.5 tonnes in 2013. This sector usually uses both PFC-14 and PFC-318 for technical purposes, but in 2013, only PFC-14 has been used. There was no use of HFC-23 in 2013. The consumption data are provided in Table 4.6.2 below.

Table 4.6.2 Consumption of f-gases in production of fibre optics, tonnes

	2006	2007	2008	2009	2010	2011	2012	2013
HFC-23	0.08	0.24	0.12	0.24	0.36	0.36	0.12	NO
PFC-14 (CF_4)	0.25	0.14	0.11	0.36	0.36	0.20	0.18	0.50
PFC-318 (c-C_4F_8)	0.20	0.45	0.35	0.45	0.45	0.40	0.20	NO

Emission factors

Since both HFC-23 and the PFCs are used as protection and cleaning gases in the production process, the emission factor is defined as 100 per cent release during production.

Time series consistency and completeness

The time-series is considered complete and consistent. The estimates are based on information directly from the importer supplying this sector in Denmark.

4.6.4 Source specific recalculations and improvements

With the exception of change in GWP values, no recalculations have been made for this sector.

4.6.5 Source specific planned improvements

There are no planned improvements.

4.7 Product Uses as Substitutes for Ozone Depleting Substances (ODS)

4.7.1 Source category description

The sub-sector *Product uses as substitutes for ODS* (2F) includes the following source categories and the following f-gases of relevance for Danish emissions:

- 2F1: Refrigeration and air conditioning: HFC-32, -125, -134a, -152a, -143a, PFC-218 (C_3F_8)
- 2F2: Foam blowing agents: HFC-134a, -152a
- 2F4: Aerosols: HFC-134a
- 2F5: Solvents: PFC-218 (C_3F_8)

It must be noted that the inventories for the years 1990-1994 might not cover emissions of these gases in full. The choice of base-year for these gases under the Kyoto Protocol is 1995 for Denmark.

Two key categories were identified for the emission of HFCs in the sub-sector *Product uses as substitutes for ODS* (2F); refrigeration and air conditioning for trend and level in 2013 (both Approach 1 and Approach 2) and foam blowing agents for trend and level in 1990 (Approach 2).

The description of consumption and emission of f-gases given below is based on an inventory published as (Poulsen, 2015). For further details refer to this report.

4.7.2 Emissions

The emission time series for *Product uses as substitutes for ODS* (2F) are presented in Figure 4.7.1 and Table 4.7.1.

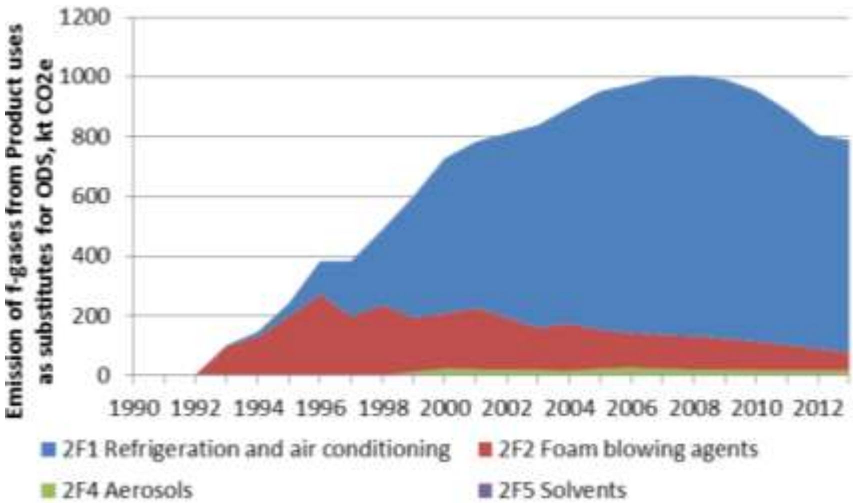

Figure 4.7.1 Emission of f-gases from the individual source categories within *2F Product uses as substitutes for ODS*, kt CO_2e.

Table 4.7.1 Emission of f-gases from *2F Product uses as substitutes for ODS*, kt CO_2e.

	1990	1995	2000	2005	2010	2011	2012	2013
2F1 Refrigeration and air conditioning	NO	43.2	520.8	799.4	841.6	787.6	715.8	711.0
2F2 Foam blowing agents	NO	199.5	184.1	130.6	95.9	85.2	72.7	60.7
2F4 Aerosols	NO	NO	20.8	23.1	18.4	17.5	17.4	17.7
2F5 Solvents	NO	NO	2.4	NO	NO	NO	NO	NO
Total	NO	242.8	728.1	953.1	955.9	890.2	805.9	789.3

General trends

The phase out of f-gases has in particular been effective within the foam blowing sector and refrigeration and air conditioning installations. Regarding foam blowing, there was a stepwise phase-out of HFC-134a used for foam blowing in hard and soft foam production, during the period 2001-2004. In 2006, all foam productions plants in Denmark have substituted HFCs. Especially the phase-out of HFCs in soft foam is significant for the emission in this period.

Since the introduction of taxes on HFCs in 2001, the consumption decreased in 2002-2003, but then the consumption of HFCs for refrigeration purposes increased again. Especially HFC-404a and HFC-134a increased. This increase is explained with other initiatives in Danish legislation, where new refrigeration systems containing HCFC-22 (ODS) was banned from 2001. It caused a boom in refrigeration systems using HFCs during 2002-2004, because the HFC technology was cheap and well proven. The consumption of HFCs for refrigeration changed significantly after 1 January 2007, where new larger HFC installations with charges exceeding 10 kg are banned. Alternative refrigeration technologies based on CO_2, propane/butane and ammonia is now introduced and available for customers.

There has been no import of PFC-218 (C_3F_8) since 2008, and it is expected that this refrigerant is phased out of the marked. Emissions occur from the existing stock but are naturally decreasing. The use of PFC-218 (C_3F_8) as a solvent only occurred from 2000 to 2002.

A quantitative overview is given below for each of these source categories and each f-gas, showing their emissions in tonnes through the times-series.

The sub-sectors will be described below in the following sections:

- 2F1: Refrigeration and air conditioning
- 2F2: Foam blowing agents
- 2F4: Aerosols
- 2F5: Solvents

The emission of HFCs increased rapidly in the 1990s and, thereafter, increased more modestly due to a modest increase in the use of HFCs as a refrigerant and a decrease in foam blowing. The f-gases have been regulated in two ways since 1 March 2001. For some types of use there is a ban on use of the gases in new installations and for other types of use, taxation is in place. These regulations seem to have influenced emissions so that in the latest years a decreasing trend can be observed.

4.7.3 General methodology

The data for emissions of HFCs and PFCs have been obtained in continuation of the work on previous inventories. The determination includes the quantification and determination of any import and export of HFCs and PFCs contained in products and substances in stock form. This is in accordance with the IPCC guidelines (IPCC, 2006).

For the Danish inventories of f-gases, a Tier 2 bottom-up approach is basically used. In an annex to the f-gas inventory report (Poulsen, 2015), there is a specification of the approach applied for each sub-source category.

The following sources of information have been used:

- Importers, agency enterprises, wholesalers and suppliers
- Consuming enterprises, and trade and industry associations
- Recycling enterprises and chemical waste recycling plants
- Statistics Denmark
- Danish Refrigeration Installers' Environmental Scheme (KMO)
- Previous evaluations of HFCs, PFCs and SF_6

Suppliers and/or producers provide consumption data of f-gases. Emission factors are primarily defaults from the IPCC guidelines, which are assessed to be applicable in a national context. In case of commercial refrigerants and Mobile Air Conditioning (MAC), information from Danish suppliers has been used. The actual amount of f-gas used for refilling is used as an estimate on the actual emission.

Import/export data for sub-source categories where import/export is relevant (MAC, fridges/freezers for households) are quantified on estimates from import/export statistics of products + default values of the amount of gas in the product. The estimates are transparent and described in appendix 3 of Poulsen (2015).

The Tier 2 bottom-up analysis used for determination of emissions from HFCs and PFCs covers the following activities:

- Screening of the market for products in which f-gases are used
- Determination of averages for the content of f-gases per product unit
- Determination of emissions during the lifetime of products and disposal
- Identification of technological development trends that have significance for the emission of f-gases
- Calculation of import and export on the basis of defined key figures, and information from Statistics Denmark on foreign trade and industry information

The determination of emissions of f-gases is based on a calculation of the actual emission. The actual emission is the emission in the evaluation year, accounting for the time lapse between consumption and emission. The actual emission includes Danish emissions from production, from products during their lifetimes and from disposal.

Consumption and emissions of f-gases are, whenever possible, determined for individual substances, even though the consumption of certain HFCs has been very limited. This has been carried out to ensure transparency of evaluation in the determination of GWP values. However, the continued use of a category for *Unspecified mix of HFCs* has been necessary since not all importers and suppliers have specified records of sales for individual substances.

Table 4.7.2 Content (w/w%)[1] of "pure" HFC in HFC-mixtures, used as trade names.

HFC mixtures	HFC-32	HFC-125	HFC-134a	HFC-143a	HFC-152a	HFC-227ea
	%	%	%	%	%	%
HFC-365						8
HFC-401a					13	
HFC-402a		60				
HFC-404a		44	4	52		
HFC-407a	23	25	52			
HFC-410a	50	50				
HFC-507a		50		50		

1. The mixtures do also contain substances that do not have GWP values and therefore, the substances do not sum up to 100 %.

The substances have been accounted for in the survey according to their trade names, which are mixtures of HFCs used in the CRF, etc. In the transfer to the "pure" substances used in the CRF reporting tables, the ratios provided in Table 4.7.2 have been used.

The national inventories for f-gases are provided and documented in an annual report (Poulsen, 2015). Furthermore, detailed data and calculations are available and archived in an electronic version. The report contains summaries of methods used and information on sources as well as further details on methodologies.

4.7.4 Refrigeration and air conditioning

2F1 Refrigeration and air conditioning consists of the following subcategories:

- 2F1a Commercial refrigeration
- 2F1b Domestic refrigeration
- 2F1c Industrial refrigeration (included under commercial)
- 2F1d Transport refrigeration
- 2F1e Mobile air-conditioning
- 2F1f Stationary air-conditioning (included under commercial)

The use of HFCs in industrial refrigeration was previously surveyed and the conclusion was that large-scale industrial refrigeration e.g. slaughterhouses, fish factories and medico companies use ammonia based refrigeration units. This is particularly caused by the tax on HFCs in Denmark that makes HFC based refrigeration units with large charges too expensive and furthermore the ban from 2007. Smaller HFC based units will occur in industry, but is then similar to commercial refrigeration units. Since it is not possible to separate small-scale industrial and commercial refrigeration units, all consumption and emissions are reported under commercial refrigeration.

For stationary air-conditioning, the same gases as frequently used in commercial refrigeration are used, e.g. HFC-404a and HFC-407c. It is difficult to estimate the share of these gases going to the different uses as the same suppliers are servicing both types of units. As a consequence the consumption and emissions are reported under commercial refrigeration.

Methodology

For refrigeration and air-conditioning, Denmark uses mainly the Tier 2 top-down approach (Tier 2b). However, for Domestic Refrigeration the methodology is a combination of Tier 2a and 2b. For more information on the applied methodology please refer to Poulsen (2015).

According to Danish law, refrigerators and air-conditioning equipment must be emptied before decommissioning by recovery, reuse or destruction of the remaining gases.

Activity data

The data collection is described in the Chapter 4.7.3 General methodology.

The activity data expressed as total amount of HFCs and PFCs filled into new products, present in operating systems and remaining in products at decommissioning are included in the CRF tables and are not repeated here.

Emission factors

The applied EFs are presented in Table 4.7.3. The EFs for commercial refrigerators, mobile A/C, and transport refrigeration has been assessed and compared with national conditions (Poulsen, 2003), this has been re-evaluated and the values have been found to still be applicable for Danish conditions (Poulsen, 2015).

Table 4.7.3 Applied EFs for refrigeration and air-condition systems (Poulsen, 2015).

	Assembly, %	Stock, % per annum	Lifetime
Household fridges and freezers	2	1	15 years
Commercial refrigerators	1.5	10	
Mobile air conditioning systems	0.5	33	
Transport refrigeration	0.5	17	6-8 years

Detailed information on the amount of HFCs used for refilling of mobile A/C has been available for 2009 - 2011, and therefore, a new approach has been implemented in the calculation of emissions. HFCs for mobile A/C are only used for refilling, and therefore the amount used for mobile A/C is assumed to be the same as the amount emitted during use (Poulsen, 2015):

Consumption of HFC for MAC = refilled stock = emission

Emission trends

Figure 4.7.2 present the emissions of f-gases from consumption of HFCs and PFCs in refrigeration and air-conditioning systems.

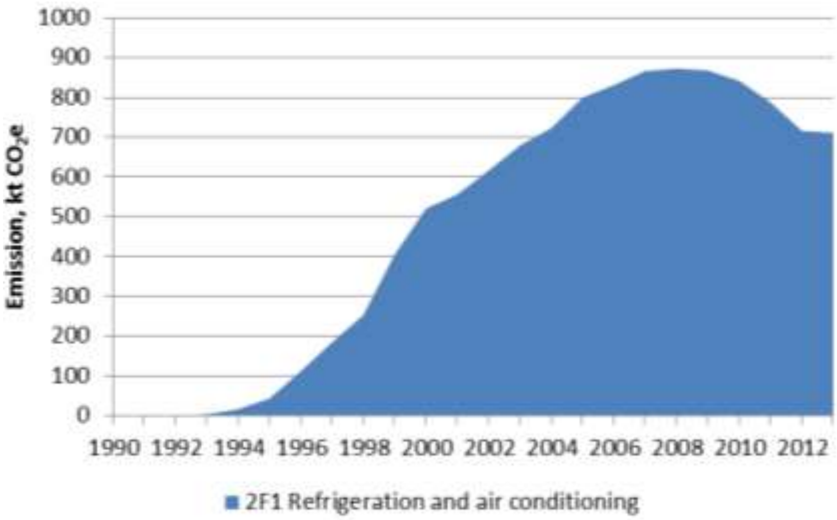

Figure 4.7.2 Emissions from refrigeration and air-conditioning from 1990 to 2013.

F-gas emissions from refrigeration and air-conditioning are dominating the overall emissions from this source. Hence the increasing trend from the early 1990'ties to 2009 and the subsequent decrease in emissions are explained in Chapter 4.7.2.

4.7.5 Foam blowing agents

2F2 Foam blowing agents consists of the following processes:

- Closed cells (hard foam)
- Open cells (soft foam)

In Denmark five specific processes have occurred during the time-series, i.e. foam in household fridges and freezers (closed cell), soft foam (open cell), joint filler (open cell), foaming of polyether for shoe soles (closed cell) and system foam for panels, insulation etc. (closed cell)

Methodology

The methodology used varies between the different processes. For all processes the methodology corresponds to the Tier 2 level of the 2006 IPCC guidelines. For some processes a bottom-up methodology is applied while for others a top-down approach or a combination of top-down and bottom-up is used. For more information on the details of the applied methodology, please refer to Poulsen (2015).

Activity data

The data collection is described in the Chapter 4.7.3 General methodology.

There is no longer production of HFC-based hard PUR insulation foam in Denmark. This production has been banned in statutory order since 1. January 2006 (MIM, 2002)

Emission factors

The applied EFs for foam blowing agents are presented in Table 4.7.4.

Table 4.7.4 Applied EFs for foam blowing agents (2F2) (Poulsen, 2015).

	Consumption	Stock	Lifetime
	%	%	years
Foam in household fridges and freezers (closed cell)	10	4.5	15
Soft foam (open cell)	100[1]		
Joint filler (open cell)	100[1]		
Foaming of polyether for shoe soles (closed cell)	15	4.5	3
System foam	0[2]	-[3]	

1. 100% emission during the first year after production.
2. HFC is used as a component in semi-manufactured goods and emissions first occur when the goods are put into use.
3. System foam is only produced for export.

System foam is produced in a closed environment and is only produced for export. Therefore, the consumption of HFCs does not contribute to the Danish stock.

The EFs for foam in fridges and freezers, soft foam and joint filler are default values from the 2006 IPCC guidelines (IPCC, 2006). The EFs for foaming of polyether is country-specific, please refer to Poulsen (2015).

The f-gases remaining in products at decommissioning (closed cell products) are destroyed by incineration and hence there is no f-gas emissions related to disposal of these products.

Emission trends

Figure 4.7.3 presents the emissions of f-gases from consumption of HFCs in foam blowing agents.

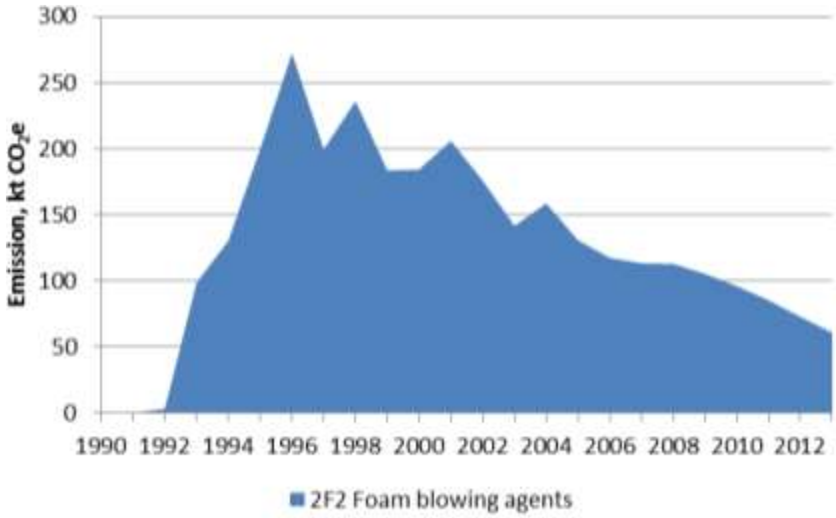

Figure 4.7.3 Emissions from foam blowing agents from 1990 to 2013.

The sharp fluctuations in the time-series are caused by fluctuations in the consumption of HFCs in production of soft foam, with an EF of a 100 % in the given year. For the later part of the time-series the trend reflects the limited use of HFCs consumed and reflects the emission from the stock of previous use of HFCs.

4.7.6 Fire protection

No HFCs or PFCs are used in fire protection in Denmark. The use of halogen substituted hydrocarbons has been banned since 1977 (MIM, 1977), this ban is still in place (MIM, 2009).

Halon-1301 has been used in planes, in the military, in server rooms and on ships. New fire protection systems use other technologies, e.g. early fire detection, inert gases or gas mixtures (argon, nitrogen and CO_2) or water vapour. For mobile systems halon-1211 has been replaced with CO_2 or foam fire extinguishers.

4.7.7 Aerosols

2F4 Aerosols consist of HFCs used for:

- Propellant in aerosols
- Metered dose inhalers

Methodology

For HFC use as propellant in aerosol cans the IPCC Tier 2a default methodology is used. A default emission factor of 50 % of the initial charge per year is used for aerosols while an emission factor of 100 % of the initial charge per year is used for metered dose inhalers.

Activity data

The general data collection process is described in the section 4.7.3.

Information on propellant consumption is derived from reports on consumption from the only major producers of HFC-containing aerosol sprays in Denmark. The import and export are estimated by the producer.

Emission factors
The applied EF is presented in Table 4.7.5.

Table 4.7.5 Applied EF for aerosols/medical dose inhalers (Poulsen, 2015).

	Consumption/filling	Stock	Lifetime
Aerosols	0 %	50 % first year 50 % second year	2 years
Medical dose inhalers	0 %	100 % in year of application	1 year

Emission trends
Figure 4.7.4 presents the emissions of f-gases from consumption of HFCs in aerosols.

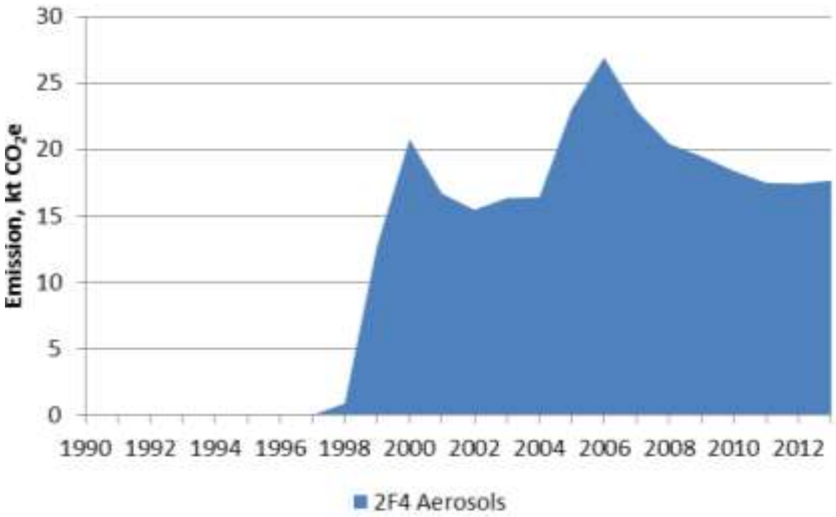

Figure 4.7.4 Emissions from aerosols from 1990 to 2013.

Due to the methodology used the fluctuations in the time-series are a result of changes in import, production and export. Baring these fluctuations the emission level has been rather constant at a level between 15 and 20 kt CO_2 equivalents.

4.7.8 Solvents

C_3F_8 was used as cleaner from 2000 to 2002 and the use then ceased following the ban in accordance with the Executive Order (MIM, 2002).

Methodology
The methodology used is the IPCC default and the fraction of chemical emitted from solvents in the year of initial use is assumed to be 50 % in line with good practice. The other 50 % is assumed to be emitted in the second year and hence there is no subtraction of any destruction of solvents.

Activity data
The general data collection process is described in the section 4.7.3.

Information on consumption of PFCs in liquid cleaners is derived from two importers' sales reports. This is representing 100% of the Danish consumption.

Emission factors

In accordance with the IPCC guidelines, the emission factor is 50 % in year 1 and 50 % in year 2.

Emission trends

Figure 4.7.5 presents the emissions of f-gases from consumption of PFCs used as solvents.

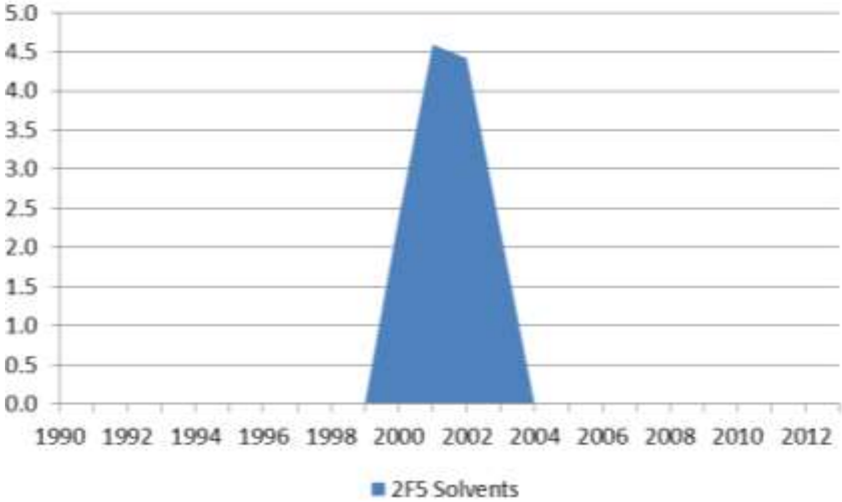

Figure 4.7.5 Emissions from PFCs used as solvents from 1990 to 2013.

As mentioned the use of PFCs as solvent only occurred from 2000 to 2002 and hence emissions only occurred from 2000 to 2003.

4.7.9 Source specific recalculations and improvements

Changes have been made in connection with implementation of the 2006 IPCC guidelines and the new UNFCCC reporting guidelines including the use of new GWP values.

4.7.10 Source specific planned improvements

There are no planned improvements.

4.8 Other Product Manufacture and Use

4.8.1 Source category description

The sector *Other Product Manufacture and Use* (CRF 2G) cover the following processes relevant for the Danish air emission inventory:

- 2G1 Electrical equipment (SNAP 060507); see section 4.8.3
- 2G2 SF_6 from other product uses (SNAP 060508); see section 4.8.4
- 2G3a Medical applications (SNAP 060501); see section 4.8.5
- 2G3b N_2O used as propellant for pressure and aerosol products (SNAP 060506); see section 4.8.6
- 2G4 Other product uses (SNAP 060601, 060602, 060605); see section 4.8.7

The SF_6 emission from other product use is identified as key categories for trend according to Approach 2.

4.8.2 Emissions

Total greenhouse gas emissions from the *Other Product Manufacture and Use* sector are available in the CRF Table 10. The emission time series for the source categories within *Other Product Manufacture and Use* (2G) are presented in Figure 4.8.1 and individually in the subsections below (Sections 4.8.3 – 4.8.7). The following figure gives an overview of which source categories that contribute the most throughout the time series.

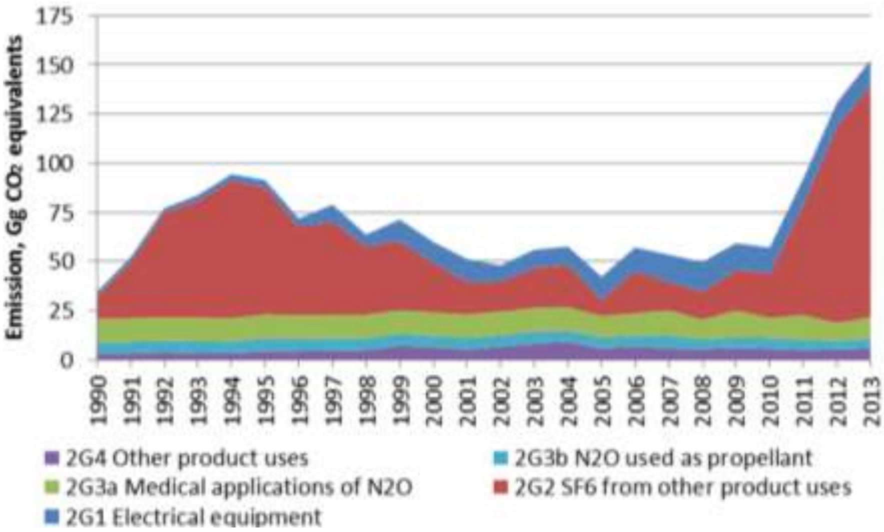

Figure 4.8.1 Emission of CO_2 equivalents from the individual source categories compiling *2G Other Product Manufacture and Use*, Gg.

4.8.3 Electrical equipment

Methodology

Power switches are filled or refilled with SF_6, either for new installation or during service and repair. Filling is usually carried out on new installations and a smaller proportion of the consumption of SF_6 is due to refilling.

The methodology uses annual data from importers statistics with detailed information on the use of the gas. This corresponds to the Tier 3 methodology in the 2006 IPCC guidelines.

No emissions are assumed to result from disposal since the used SF_6 is drawn off from the power switches and re-used internally by the concerned or appropriate disposed through waste collection scheme.

Activity data

The data collection is described in the Chapter 4.7.3 General methodology.

Information on consumption of SF_6 in high-voltage power switches is derived from importers' sales reports (gas or gas-containing products). The importers account for 100% of the Danish sales of SF_6.

The electricity sector also provides information on the installation of new plant and thus whether the stock is increasing.

Emission factors

The applied EFs are presented in Table 4.8.1. Special attention has been given to use of SF_6 as insolation in high-voltage plants (Poulsen, 2001; ELTRA, 2004).

Table 4.8.1 Applied EFs for other processes (Poulsen, 2015).

	Consumption	Stock	Lifetime
Insolation gas in high voltage switches	5 %	0.5 %	?[1]

1) Lifetime unknown.

Emission trends

Figure 4.8.2 presents the emissions of SF_6 from electrical equipment.

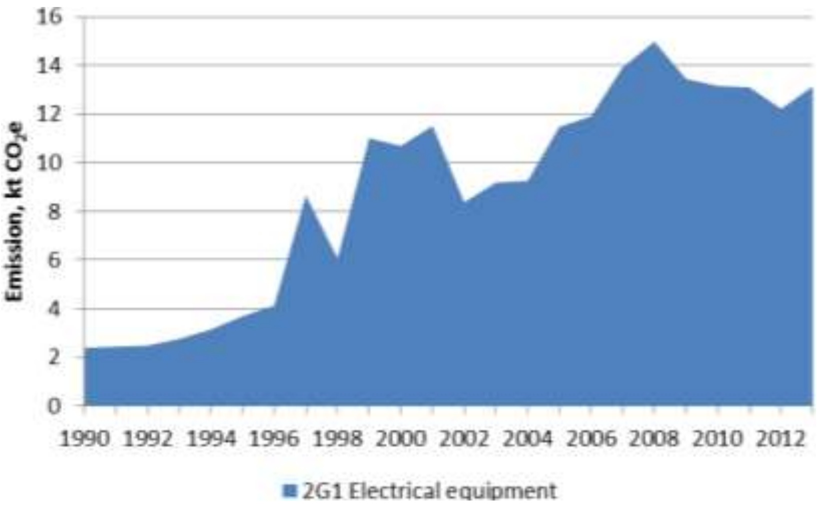

Figure 4.8.2 Emissions from SF_6 from electrical equipment from 1990 to 2013.

The trend in emissions from use of SF_6 in electrical equipment has been increasing. However, significant inter-annual variations occur depending on the specific activity level in a given year.

4.8.4 SF_6 from other product use

2G2 SF_6 from other product use consists of the following subcategories:

- Consumption of SF_6 in running shoes
- Consumption of SF_6 in laboratories
- Consumption of SF_6 in double glazed windows

Methodology

In general a mass balance approach is used for laboratory use of SF_6. For double glazed windows the default IPCC methodology is used with country-specific emission factor. For more information, please refer to Poulsen (2015).

Activity data

The data collection is described in the Chapter 4.7.3 General methodology.

Information on consumption of SF_6 in double glazing is derived from importers' sales reports to the application area. The importers account for 100% of the Danish sales of SF_6 for double glazing. In addition, the largest producer of windows in Denmark has provided consumption data, with which import information is compared.

Importer has estimated imports to Denmark of SF_6 in training footwear.

Emission factors

The applied EFs are presented in Table 4.8.2.

Table 4.8.2 Applied EFs for SF_6 from other product use (Poulsen, 2015).

	Consumption	Stock	Lifetime
Laboratories	100 %		
Insulation gas in double glazed windows	15 %	1 % annual	20 years
Shock-absorbing in Nike Air training footwear	-[1]	-[2]	5 years

[1]) No emission from production in Denmark.

[2]) Yearly emission has been estimated to 0.11 tonne (Poulsen, 2015).

Emission trends

Figure 4.8.3 presents the emissions of SF_6 from shoes, double glazed windows, laboratories and other use.

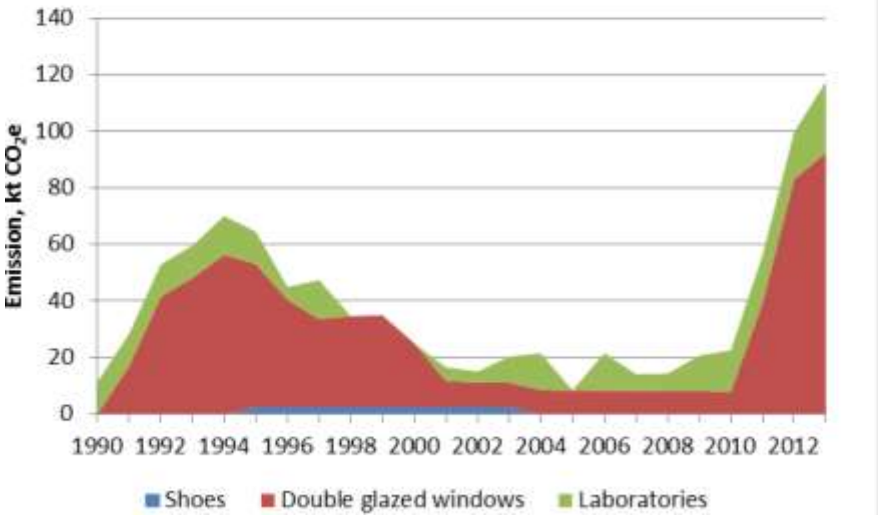

Figure 4.8.3 Emissions from SF_6 from other uses from 1990 to 2013.

The use of SF_6 in double glazed windows was banned in 2002 and the use had decreased in the prior years. The increase in SF_6 emission from 2010 onwards is due to the lifetime of 20 years, i.e. the gas remaining in the windows at this time is assumed to be fully emitted.

4.8.5 Medical applications of N_2O

The following SNAP-code is covered:

- 06 05 01 Anaesthesia

Methodology

N_2O has been used as anaesthetics for more than a hundred years but has in newer times also had other smaller applications. N_2O in this source category is predominantly used as anaesthesia and a small amount is used as fuel in race cars and in chemical laboratories.

In the mid 1990's, introduction of air quality limit values for N_2O together with requirements of expensive extraction systems reduced the application of N_2O for anaesthetics at smaller facilities like dentists.

Five companies sell N_2O in Denmark and only one company produces N_2O. N_2O is primarily used in anaesthesia by dentists, veterinarians and in hospitals and in minor use in laboratories, racing cars and in the production of electronics. Due to confidentiality no data on produced amount are available and thus the emissions related to N_2O production are unknown. Sold amounts are obtained from the respective distributors and the produced amount is estimated from communication with the company.

Activity data

Data on total sold and estimated produced N_2O for sale in Denmark is only reliable for the years 2005-2012, activity data for the years 1990-2004 and 2013 have therefore been estimated as the average value of the five following/previous years. Activity data for the time series are presented in Table 4.8.3.

Table 4.8.3 Activity data for N_2O mainly used for medical applications, Mg.

	1990-2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
N_2O consumption	40[1]	37	38	43	33	46	34	42	30	37[2]

[1)] Calculated: average 2005-2009.
[2)] Calculated: Average 2008-2012.

Emission factors

An emission factor of 1 is assumed for all uses.

Emission trends

The emission trend for the N_2O emission from medical applications is available in the CRF tables but is also presented in Figure 4.8.4 below.

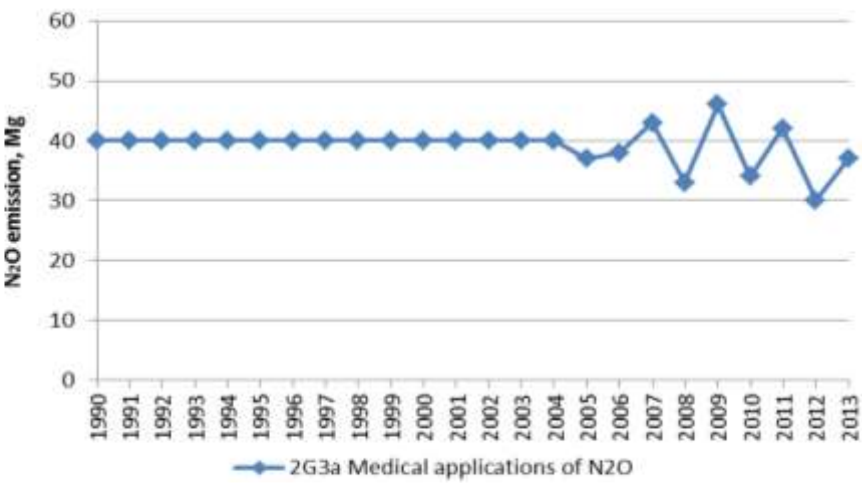

Figure 4.8.4 N_2O emissions from the use of anaesthetics.

Time series consistency and completeness

The methodology is consistent throughout the time series. It is not possible to obtain reliable data prior to 2005, but the source category is complete from 2005 onward.

4.8.6 N_2O used as propellant for pressure and aerosol products

The following SNAP-code is covered:

- 06 05 06 Aerosol cans

Methodology

There is a strong tradition of fresh dairy products in Danish culture and while canned whipped cream is popular for e.g. hot beverages in the winter months this product is not that widely used.

There are no statistics on production, import/export and/or sales of canned whipped cream in Denmark and the content of propellant is confidential. The consumption of canned whipped cream is therefore estimated as 1 % of the regular cream sale. Further assumptions made include 5 mass% propellant in a can, 250 ml (250 g) cream per can and 100 % release of N_2O.

Activity data

Data on total sold cream and the estimated sale of canned cream are presented in Table 4.8.4.

Table 4.8.4 Consumption of cream in Denmark, Mg.

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Cream[1]	37378	40622	39796	41387	40157	46279	42854	42401	40542	42488
Canned cream	374	406	398	414	402	463	429	424	405	425
	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Cream[1]	39380	39849	39525	42418	38306	102242	36876	45023	35019	34881
Canned cream	394	398	395	424	383	1022	369	450	350	349
	2010	2011	2012	2013						
Cream[1]	37201	35606	30408	31859						
Canned cream	372	356	304	319						

[1] Statistics Denmark (2014).

Emission factors

The applied emission factor is 0.05 Mg N_2O per Mg canned cream sold; 5 % propellant and 100 % release.

Emission trends

The emission trend for the N_2O emission from medical applications is available in the CRF tables but is also presented in Figure 4.8.5 below.

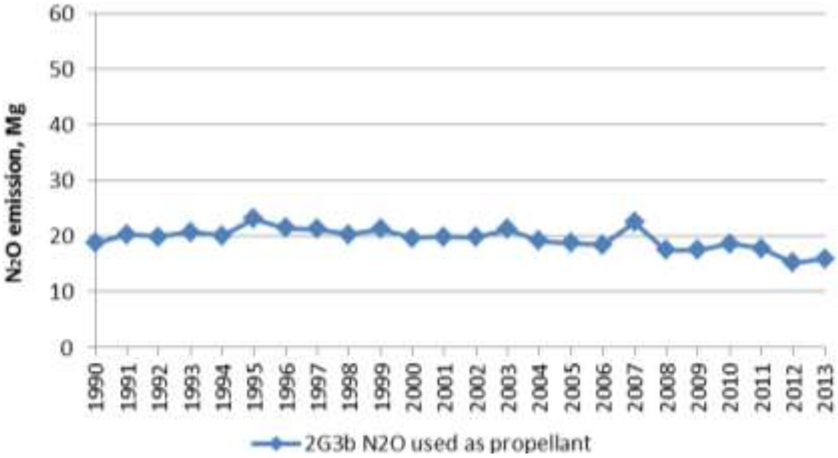

Figure 4.8.5 N_2O emissions from the use of canned whipped cream (Emission 2A from Figure 4.8.6).

Verification

In an attempt to verify the calculated N_2O emissions from canned whipped cream, the same emission is calculated using four assumptions in different combinations. Table 4.8.5 shows the calculated emission for 2012 using the four combinations of assumptions along with the overall assumptions that a con contains 250 ml (250 g) cream and 100 % release of the propellant.

Table 4.8.5 N_2O released as propellant (2012), Gg.

	Assumption 1	Assumption 2
	1 bottle used per household per year	1 % marked fraction of cream assumed to be canned
Assumption A		
5 % propellant	0.033	0.015
Assumption B		
5 g N_2O per bottle	0.013	0.005

Using the four assumptions presented in the table above, the time series are calculated; see Figure 4.8.6.

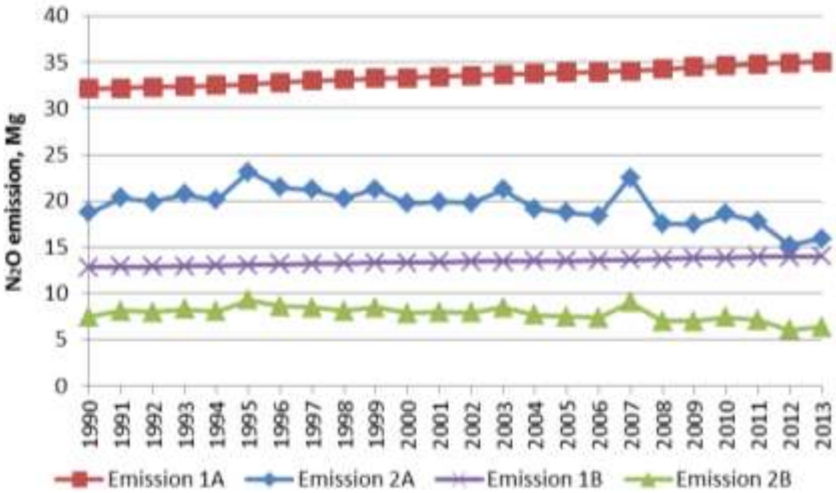

Figure 4.8.6 N_2O emissions from the use of canned whipped cream.

Although the calculated emissions vary over the four estimated the emission of N_2O from canned whipped cream can generally be said to lie between 5 Mg and 35 Mg. Emission 2A is chosen as the best estimate.

All four estimates are well below 0.05% of the national greenhouse gas emissions; in 2012 "Emission 1A" is 0.02 % of nationally emitted CO_2 equivalents (incl. LULUCF).

Time series consistency and completeness

The methodology is consistent throughout the time series.

4.8.7 Other product uses

The category *Other Product Uses* (CRF 2G4) covers the following SNAP-codes:

- CO_2, N_2O and CH_4 emissions from fireworks (SNAP 060601)
- N_2O and CH_4 emissions from tobacco combustion (SNAP 060602)
- N_2O and CH_4 emissions from charcoal in barbeques (SNAP 060605)

Methodology

Methane and nitrous oxide emissions are calculated for all three product uses but carbon dioxide is only calculated for fireworks since emissions from the two remaining product uses are considered to be biogenic.

Method 2) in EMEP/EEA (2013) is used for calculating pollutant emissions from fireworks, tobacco and charcoal for barbeques.

Activity data

Activity data are derived from import, export and production data from Statistics DK (2014). See Annex 3C-14.

Emission factors

Emission factors for use of fireworks, tobacco and charcoal are found from literature studies and are shown in Table 4.8.6.

Table 4.8.6 Emission factors for CRF 2G4 Other product uses.

Compound	Unit	Fireworks	Tobacco	BBQ
CO_2	kg/Mg	43.25[a)]	NA	NA
N_2O	kg/Mg	1.935[a)]	0.064 [b)]	0.030[c)]
CH_4	kg/Mg	0.825[a)]	3.187 [b)]	6.0[c)]

[a)] Netherlands National Water Board (2008).
[b)] EFs for wood (111A) in residential plants (1A4b i), SNAP 020200, the energy content used in the calculation is the average of wood pills and wood waste (16.1 GJ/Mg).
[c)] IPCC Guidelines (1997).

Emission trends

See Annex 3C-15 to 3C-17.

4.8.8 Source specific recalculations and improvements

For uses of SF_6 no recalculations have been made.

For "Medical applications of N_2O" emissions have been extrapolated back to 1990. A recalculation of the activity data for 2000-2004 has caused the emission for these years to increase drastically because last year's submission only included 1-2 distributors (out of four) for these years. Minor corrections were made for 2005-2012.

The category of "N_2O used as propellant for pressure and aerosol products" is new in this year's inventory.

CH_4 emissions have been included for use of fireworks, tobacco and charcoal for barbeques.

4.8.9 Source specific planned improvements

There are no planned improvements for the source categories in this subsector.

4.9 Uncertainty

4.9.1 Uncertainty input

The source specific uncertainties for industrial processes and product uses are presented in Table 4.9.1. The uncertainties are based on IPCC Guidelines (2006) combined with assessment of the individual processes.

Mineral Industry

The single Danish producer of cement has delivered the activity data for production as well as calculated the emission factor based on quality measurements. For activity data, there is a shift in methodology from 1997 to 1998. Prior to 1998 activity data are derived by the Tier 2 (1-2 % uncertainty) methodology for grey cement production and the Tier 1 (<35 % uncertainty) for white cement production (20-25 % of total production), the uncertainty for 1990-1998 it therefore assumed to be 8 %. Activity data have since 1998 fulfilled the Tier 3 methodology and is assumed to have an uncertainty of 1%. The estimation of emission factors fulfils the Tier 3 methodology for the entire time series and uncertainties are therefore assumed to be 2 %. Since uncertainties cannot vary over time in Approach 1, activity data uncertainties are assumed to be 1 % for the entire time series.

The activity data for production of lime, including non-marketed lime in the sugar production, are based on information compiled by Statistics Denmark. Due to the assumption of no lime kiln dust (LKD) the uncertainty for the entire time series is assumed to be 5 % for activity data. The emission factor for marketed lime production cover many producers and a variety of high calcium products, assumptions that influence the uncertainty includes the assumptions of no impurities, 100 % calcination and for sugar production also the assumptions on the lime consumption and sugar content in beets. Since 2006 and the introduction of EU-ETS data, the uncertainty decreased as many of the mentioned assumptions were no longer needed, the combined uncertainty for emission factors are estimated to be 8 % and 4 % for the periods 1990-2005 and 2006-2013 respectively. Since uncertainties cannot vary over time in Approach 1, the emission factor uncertainty is assumed to be 4 % for the entire time series.

The activity data uncertainty associated with glass production (including glass wool production) are low for recent years (EU-ETS data) but higher for historic years (carbonate data were not available for 1990-1996 and were therefore estimated for these years), activity data uncertainties are estimated to be 5 % for 1990 and 1 % for 2013. Since uncertainties cannot vary over time in Approach 1, activity data uncertainties are assumed to be 1 % for the entire time series. Uncertainties associated with the emission factors from glass production are low. Denmark uses the Tier 3 methodology and therefore stoichiometric CO_2 factors, some uncertainty is however connected to assuming a calcination factor of 1, and the overall emission factor uncertainty is therefore estimated to be 2 %.

The activity data for production of ceramics are based on information compiled by Statistics Denmark and EU-ETS. The uncertainty is assumed to be 5 % (Tier 2). The emission factor is based on stoichiometric relations and the assumption of full calcination; the uncertainty is assumed to be 2 %.

The CO_2 emission from other uses of soda ash is calculated based on national statistics (Statistics Denmark, 2014) and the stoichiometric emission factor for soda ash (Na_2CO_3) assuming the calcination factor of 1. Uncertainties are assumed to be 5 % and 2 % for activity data and emission factor respectively.

The category "Other Process Uses of Carbonates" in the Danish inventory includes flue gas desulphurisation and mineral wool production. The activity data uncertainty for flue gas desulphurisation is assumed to be 30 % (see "Verification" under Chapter 4.2.7). For mineral wool the activity data uncertainty is low for recent years (EU-ETS data) but higher for historic years (calculated/estimated), the uncertainties are assumed to be 2% and 30 % respectively. The overall activity data uncertainties for other process uses of carbonates are assumed to be 30 %. The uncertainty of the stoichiometric emission factors for both source categories is assumed to be 2 %

Chemical Industry

The producers have registered the production of nitric acid during many years and, therefore, the uncertainty is assumed to be 2 %. The measurement of N_2O is problematic and is only carried out for one year. Therefore, the uncertainty is assumed to be 25 %.

The uncertainty for the activity data as well as for the emission factor is assumed to be 5 % for production of catalysts/fertilisers.

Metal Industry

The uncertainty for the activity data and emission factor is assumed to be 5 % and 10 % respectively for production of secondary steel.

The uncertainty for the activity data and emission factor is assumed to be 10 % and 30 % respectively for production of magnesium and 10 % and 50 % respectively for lead production.

Non-Energy Products from Fuels and Solvent Use

Important uncertainty issues related to the mass-balance approach used for Non-energy products from fuels and solvent use (NFR 2D) are:

(i) Identification of pollutants that qualify as NMVOCs. Although a tentative list of 650 pollutants from NAEI (2000) has been used, it is possible that relevant pollutants are not included, e.g. pollutants that are not listed with their name in Statistics Denmark (**2014)** but as a product.

(ii) Collection of data for quantifying production, import and export of single pollutants and products where the pollutants are comprised. For some pollutants no data are available in Statistics Denmark (2014)**.** This can be due to confidentiality or that the amount of pollutants must be derived from products wherein they are comprised. For other pollutants the amount is the sum of the single pollutants *and* product(s) where they are included. The data available in Statistics Denmark (2014) is obtained from Danish Customs & Tax Authorities and they have not been verified in this assessment.

(iii) Distribution of pollutants on products, activities, sectors and households. The present approach is based on amounts of single pollutants. To differentiate the amounts into industrial sectors it is necessary to identify and quantify the associated products and activities and assign these to the industrial sectors and households. No direct link is available between the amounts of pollutants and products or activities. From the Nordic SPIN database it is possible to make a relative quantification of products and activities used in industry, and combined with estimates and expert judgement these products and activities are differentiated into sectors. The contribution from households is also based on estimates. If the household contribution is set too low, the emission from industrial sectors will be too high and vice versa. This is due to the fact that the total amount of pollutant is constant. A change in distribution of pollutants between industrial sectors and households will, however, affect the total emissions, as different emission factors are applied in industry and households, respectively.

A number of activities are assigned as "other", i.e. activities that cannot be related to the comprised source categories. This assignment is based on expert judgement but it is possible that the assigned amount of pollutants may more correctly be included in other sectors. More detailed information from the industrial sectors is continuously being implemented.

(iv) Rough estimates and assumed emission factors are used for some pollutants. For some pollutants more reliable information has been obtained from the literature and from communication with industrial sectors. In some cases it is more appropriate to define emission factors for sector specific activities rather than for the individual pollutants.

A quantitative measure of the uncertainty has not been assessed. Single values have been used for emission factors and activity distribution ratios etc.

Product Uses as Substitutes for Ozone depleting Substances

The emission of f-gases is dominated by emissions from refrigeration equipment and therefore, the uncertainties assumed for this sector will be used for all the f-gases. The IPCC propose an uncertainty at 30-40 % for regional estimates. However, Danish statistics have been developed over many years and, therefore the uncertainty on activity data is assumed to be 10 %. The uncertainty on the emission factor is, on the other hand, assumed to be 50 %. The base year for f-gases for Denmark is 1995.

Other Product Manufacture and Use

The uncertainty of N_2O used for medical applications is assumed to be 5-50 % for activity data and 20 % for the emission factor. The activity data uncertainty is highest for historic years and lower for recent years; since uncertainty cannot vary over time in Approach 1 the uncertainty input is here estimated to be 25 % for all years.

The uncertainty of N_2O used as propellant for pressure and aerosol products is estimated to be 100 % for activity data and 150 % for the emission factor.

The main issues leading to uncertainties for Other Product Use (NFR 2G) are:

(i) Collection of data for quantifying production, import and export of prod-ucts. Some data, like private import (cross-border shopping) of fireworks, are not available in Statistics Denmark (2014). Other missing data like the composition of mineral containing charcoal for barbequing are unobtainable due to confidentiality.

(ii) Reliable emission factors are difficult to obtain for other product use cat-egories. Some chosen emission factors apply to countries that are not directly comparable to Denmark, and hereby is introduced an increased uncertainty.

4.9.2 Approach 1 uncertainty

All uncertainty input values are discussed in Section 4.9.1 above. Table 4.9.1 presents the uncertainty inputs and the calculated total uncertainty for Approach 1 for the individual pollutants. The calculated Approach 1 uncertainty for the overall greenhouse gas emission for the IPPU sector in 2013 is 17.3% and the trend uncertainty is 15.6 %

Table 4.9.1 Uncertainties on activity data and emission factors as well as overall trend uncertainties for the different greenhouse gases.

CRF	Category	Activity data uncertainty %	Emission factor uncertainty CO_2 %	CH_4 %	N_2O %	HFCs[2] %	PFCs[2] %	SF_6[2] %
2A1	Cement production	1	2					
2A2	Lime production	5	4					
2A3	Glass production	1	2					
2A4a	Ceramics	5	2					
2A4b	Other uses of soda ash	5	2					
2A4d	Other process uses of carbonates	30	2					
2B2	Nitric acid production[1]	2			25			
2B10	Catalysts/fertiliser production	5	5					
2C1	Iron and steel production	5	10					
2C4	Magnesium production	10						30
2C5	Secondary lead production	10	50					
2D1	Lubricant use	10	20					
2D2	Paraffin wax use	15	60	60	60			
2D3	Paint application	10	15					
2D3	Degreasing, dry cleaning and electronics	10	15					
2D3	Chemical products manufacturing or processing	10	15					
2D3	Other use of solvents and related activities	10	20					
2D3	Road paving with asphalt	20	75	75				
2D3	Asphalt roofing	20	75					
2D3	Urea from fuel consumption	5	10					
2E	Electronics industry	10					50	
2F1	Refrigeration and air conditioning	10				50	50	
2F2	Foam blowing agents	10				50		
2F4	Aerosols	10				50		
2F5	Solvents[3]	-						
2G1	Electrical equipment	10						50
2G2	SF_6 from other product use	10						50
2G3a	Medical application	25			20			
2G3b	Propellant for pressure and aerosol products	100			150			
2G4	Fireworks	15	60	60	60			
2G4	Tobacco	15		60	60			
2G4	Barbeques	15		60	60			
Overall uncertainty in 2013			4.9	41.8	49.9	46.1	37.8	46.1
Trend 1990-2013 (1995-2013)			6.8	-38.7	98.2	-223.0	-1610.9	-27.5
Trend uncertainty			3.7	31.1	1.1	172.2	447.9	27.1

[1] The production closed down in the middle of 2004.
[2] The base year for f-gases is for Denmark 1995.
[3] Uncertainties are not calculated for solvents because this activity occurs in neither 1990 nor 2013.

4.9.3 Approach2 uncertainty

The Approach 2 uncertainties for CO_2 equivalent emission from Industrial Processes and Product Use is presented in Table 4.9.2. The uncertainty estimates are based on the individual uncertainties as discussed in Section 4.9.1 above.

Table 4.9.2 Approach 2 uncertainty for Industrial Processes and Product Use.

1990 (1995)			2013			1990-2013 (1995-2013)		
Median	Uncertainty		Median	Uncertainty		Median	Uncertainty	
Emission CO_2 eqv, Gg	Lower (-) %	Upper (+) %	Emission CO_2 eqv, Gg	Lower (-) %	Upper (+) %	Emission CO_2 eqv, Gg	Lower (-) %	Upper (+) %
2657	9	12	2144	14	21	512	91	81

4.10 Quality assurance/quality control (QA/QC)

4.10.1 Internal QA/QC

The approach used for quality assurance/quality control (QA/QC) is presented in Chapter 1.6; see also Nielsen et al. (2012). The present chapter presents QA/QC considerations for industrial processes and product use based on a series of Points of Measuring (PMs); see Chapter 1.6.

Data Storage level 1	1. Accuracy	DS.1.1.1	General level of uncertainty for every dataset including the reasoning for the specific values.

The uncertainty assessment has been performed on Approach 1 and Approach 2 level by using default and country specific uncertainty factors. The applied uncertainty factors are presented in Chapter 4.9.

Regarding Non-energy products from fuels and solvent use: The sources of data described in the methodology section and in DS.1.2.1 and DS.1.3.1 are used. It is the accuracy of these data that define the uncertainty of the inventory calculations. Any data value obtained from Statistics Denmark (2014) and SPIN are given as a single point estimate and no probability range or uncertainty is associated with this value. Information from reports is sometimes given in ranges. Uncertainties are therefore assessed from expert judgement and guidebook estimates.

Data Storage level 1	2.Comparability	DS.1.2.1	Comparability of the emission factors/calculation parameters with data from international guidelines, and evaluation of major discrepancies.

Comparability of the data has not been performed at "Data Storage level 1". However, investigation of comparability at CRF level is in progress.

The applied data sets are presented in Table 4.9.1.

Regarding Non-energy products from fuels and solvent use:

1) Production and import/export data from Statistics Denmark (2014) for single chemicals can be directly compared with data from Eurostat (2014) for other countries. This has been done for a few chosen chemicals and countries. Furthermore, chosen Danish data from Eurostat (2014) have been validated with data from Statistics Denmark (2014)

in order to check the consistency in data transfer from national to international databases.

2) Use categories for chemicals in products are found from the Nordic SPIN database. Data for all Nordic countries are available and reported uniformly. For chosen chemicals a comparison of chemical amounts and use has been made between countries.

3) A joint Nordic project funded by the Nordic Council of Ministers has been used on methodological issues and for emission factors (Fauser et al., 2009).

Data Storage level 1	3.Completeness	DS.1.3.1	Ensuring that the best possible national data for all sources are included, by setting down the reasoning behind the selection of datasets.

The data sources - in general - can be grouped as follows:

- Company specific environmental reports.
- Personal communication with individual companies.
- Company specific information compiled by Danish Energy Agency in relation to the EU-ETS.
- Industrial organisations.
- Statistics Denmark.
- Secondary literature.
- IPCC guidelines.

The environmental reports contribute with company-specific emission factors, technical information and, in some cases, activity data. The environmental reports are primarily used for large companies and, for some companies, are supplemented with information from personal contacts, especially for completion of the time series for the years before the legal requirement to prepare environmental reports (i.e. prior to 1996).

Statistics Denmark is used as source for activity data as they are able to provide consistent data for the period 1990-2013. In the cases where the statistics do not contain transparent data, statistics from industrial organisations are used to generate to required activity data.

For many of the processes, the default emission factors are based on chemical equations and are, therefore, the best choice. In some cases, the default EF has been modified in order to reflect local conditions.

Secondary literature may be used in the interpretation or in disaggregation of the public statistics.

Regarding Non-energy products from fuels and solvent use:

A number of external data sources form the basis for calculating emissions of single chemicals. The general methodology in the emission inventory is described above.

1) Statistics Denmark (2014) is used as the main database for collecting data on production, import and export of single chemicals, chemical groups and for some products. In order to obtain a uniform and unique set of data it is important that the data for e.g. production of single chemicals is in the same reporting format and from the same source. The amount of data is very comprehensive and is linked with the data present in Eurostat. The database covers all sectors and is regarded as complete on a national level.

2) Nordic SPIN database provides data on the use of chemicals in Norway, Sweden, Denmark and Finland. It is financed by the Nordic Council of Ministers, Chemical group, and the data is supplied by the product registries of the contributing countries. The Danish product register (PROBAS) is a joint register for the WEA and the EPA and comprises a large number of chemicals and products. The information is obtained from registration according to the EPA rules and from scientific studies and surveys and other relevant sources. The product register is the most comprehensive collection of chemical data in products for Denmark and with the availability of data from the other Nordic countries it enables an inter-country comparison. For each chemical the data is reported in a uniform way, which enhances comparability, transparency and consistency.

3) Reports from and personal contacts with industrial branches. It is fundamental to have information from the industrial branches that have direct contact with the activities, i.e. chemicals and products of interest. The information can be in the form of personal communication, but also reported surveys are of great importance. In contrast to the more generic approach of collecting information from large databases, the expert information from industrial branches may give valuable information on specific chemicals and/or products and industrial activities. By considering both sources a verification as well as optimum reliability and accuracy is obtained.

4) The present inventory procedure builds partly on information from the previous Danish solvent emission inventory, which is based on questionnaires to industrial branches. Furthermore a joint Nordic collaboration on solvent inventories has given important information on methods and data.

Data Storage level 1	4.Consistency	DS.1.4.1	The original external data has to be archived with proper reference.

The original data files are archived in the following folder:

U:\ST_ENVS-Luft-Emi\Inventory\2013\2_Industrial_Processes\Level_1a_Storage.

Regarding Non-energy products from fuels and solvent use: Data are predominantly extracted from the internet (Statistics Denmark and SPIN). These are saved as original copies in their original form. Specific information from industries and experts are saved as e-mails and reports.

Data Storage level 1	6.Robustness	DS.1.6.1	Explicit agreements between the external institution holding the data and NERI about the condition of delivery.

An agreement regarding inclusion of information - compiled by Danish Energy Agency for EU-ETS - in the Danish GHG-inventory has been signed. The implementation of this information has been introduced for production of cement, lime production, glass production, glass wool production, bricks, expanded clay products, flue gas desulphurisation and mineral wool production.

Data Storage level 1	7.Transparency	DS.1.7.1	Listing of all archived datasets and external contacts.

The datasets applied are presented in Table 4.10.1. For the reasoning behind their selection, see DS.1.3.1.

Table 4.10.1 Applied datasets (archived in: U:\ST_ENVS-Luft-Emi\Inventory\2013\2_Industrial _Processes\Level_1a_Storage)

\Groenne regnskaber\2013\	AalborgPortland_miljoeredegoerelse_2013
	Ardagh 2013
	Faxe Kalk Ovnanlæg Stubberup 2013
	HaldorTopsøe_GroentRegnskab2013
	NordicSugar 2013
	Rockwool 2013
	Saint Gobain Isover 2013
\CO2 kvote indberetninger\2013\	Kraftvaerker (folder)
	Industri (folder)
	CO2udledning_og_energiforbrug_2013
\Danmarks Statistik\2015\	Befolkningstal
	Bricks
	Cement
	Dinatriumcarbonat
	Dolomite and soda ash
	Expanded clay
	Floede
	Sugar production

Regarding Non-energy products from fuels and solvent use: Datasets are archived and external contacts are stored in e-mail and documents.

Data Processing level 1	1. Accuracy	DP.1.1.1	Uncertainty assessment for every data source not part of DS.1.1.1 as input to Data Storage level 2 in relation to type and scale of variability.

The uncertainty assessment has been performed on Approach 1 as well as Approach 2 level, assuming a normal distribution of activity data as well as emission data, by application of default uncertainty factors. Therefore, no considerations regarding distribution or type of variability have been performed.

Data Processing level 1	2.Comparability	DP.1.2.1	The methodologies have to follow the international guidelines suggested by UNFCCC and IPCC.

All methodologies follow UNFCCC and IPCC unless better national methodologies have been identified.

Data Processing level 1	3.Completeness	DP.1.3.1	Identification of data gaps with regard to data sources that could improve quantitative knowledge.

This is discussed for each source category individually in the "Time series consistency and completeness" chapters.

Regarding Non-energy products from fuels and solvent use: In "Uncertainties and time series consistency" important uncertainty issues related to missing quantitative knowledge is stated. To summarise; (i) identification and inclusion of all relevant chemicals (and products) Identification of chemicals that qualify as NMVOCs. The definition in the solvent directive (Directive 1999/13/EC) is used. Here VOCs are defined as follows: "Volatile organic compound shall mean any organic compound having at 293,15 K a vapour pressure of 0,01 kPa or more, or having a corresponding volatility under the particular condition of use". A tentative list of 650 chemicals from the "National Atmospheric Emission Inventory" (NAI 2000) has been used, it is possible that relevant chemicals are not included. (ii) Collection of data for quantifying production, import and export of single chemicals. For some chemicals no data are available in Statistics Denmark (2014). This can be due to confidentiality or that the amount of chemicals must be derived from products wherein they are comprised. (iii) Distribution of chemicals on products, activities, sectors and households. No direct link is available between the amounts of chemicals and products or activities. From the Nordic SPIN database it is possible to make a relative quantification of products and activities used in industry, and combined with estimates and expert judgement these products and activities are differentiated into sectors. More detailed information from the industrial sectors may still be required. (iv) Emission factors for single chemicals, products and industrial and household activities. For many industrial and household activities involving solvent containing products no estimates on emission factors are available. Large variations occur between industry and product groups. And given the large number of chemicals more specific knowledge regarding industrial processes and consumption is needed.

Data Processing level 1	4.Consistency	DP.1.4.1	Documentation and reasoning of methodological changes during the time series and the qualitative assessment of the impact on time series consistency.

Recalculations are described in the NIR. A manual log is included in the tool used for data processing at Data Processing level 2. This log also includes changes on Data Processing level 1.

Data Processing level 1	5.Correctness	DP.1.5.2	Verification of calculation results using time series.

The calculations are verified by checking the time series.

Data Processing level 1	5.Correctness	DP.1.5.3	Verification of calculation results using other measures.

The calculation of results is verified using other measures where other measurements are available.

Regarding Non-energy products from fuels and solvent use: Calculations performed by IIASA using RAINS codes, which are based on a different methodological approach gives total emission values that are similar to the emissions found in the present approach.

Data Processing level 1	7.Transparency	DP.1.7.1	The calculation principle, the equations used and the assumptions made must be described.

The calculation principles and equations are based on the methodology presented by the IPCC. A detailed description can be found in the sector report for industry (Hoffman et al., 2014).

Data Processing level 1	7.Transparency	DP.1.7.2	Clear reference to dataset at Data Storage level 1

The calculation files contain links to the original data files.

Data Processing level 1	7.Transparency	DP.1.7.3	A manual log to collect information about recalculations.

A log on information about recalculation is included in CollectER.

Data Processing level 2	5.Correctness	DS.2.5.1	Check if a correct data import to level 2 has been made

The sector report for industry (Hoffman et al., 2014) presents the connection between the datasets on Data Storage level 1 and Data Processing level 2. Individual calculations are used to check the output of the data processing tool used at Data Processing level 2.

Data Storage level 4	4. Consistency	DS.4.4.3	The IEFs from the CRF are checked both regarding level and trend. The level is compared to relevant emission factors to ensure correctness. Large dips/jumps in the time series are explained.

The IEFs are checked by using a tool developed especially for that purpose and outliers are explained.

Data Storage level 4	4. Correctness	DS.4.5.2	Check that additional information and information related to land-use changes has been correctly aggregated compared to the individual submissions of Denmark and Greenland.

The aggregated submission for Denmark and Greenland is checked against the individual submissions for Denmark and Greenland.

4.10.2 External QA/QC

External QA/QC is described for one source: cement production.

Cement production

Aalborg Portland has an environmental management system that meets the requirements in DS/ISO 14001, EMAS etc. (Aalborg Portland, 2013b). The environmental management system is part of an integrated process management system. The system is certified according to the standards by the accredited body: Danish Standards. Information on raw material consumption as well as internal recycling is compiled in an environmental database. Some pollutants (NO_x, SO_2, CO and TSP) are measured continuously. Emission of CO_2 is calculated based on (fuel and) raw material consumption and raw material flow according to an approved CO_2 emission plan (EU-ETS). The CO_2 emission plan has to fulfil the requirements in the guidelines developed by EU (EU Commission, 2007).

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5 Agriculture

The data presented in Chapter 5 relates to Denmark only, whereas information for Greenland is included in Chapter 16 and for the Faroe Islands in Annex 8.

The emission of greenhouse gases from agricultural activities includes:

- CH_4 emission from enteric fermentation and manure management.
- N_2O emission from manure management and agricultural soils.
- Emission of CH_4 and N_2O from burning of straw on field.
- CO_2 emission from liming, urea and other carbon-containing fertilizers
- For emission of NVMOC, CO and NO_x see the Danish Informative Inventory Report (Nielsen et al, 2014)

Emissions from rice production and burning of savannahs do not occur in Denmark and consequently these categories have been reported as Not Occurring.

5.1 Overview of sector

In CO_2 equivalents, the agricultural sector contributes with 19 % of the overall greenhouse gas emission (GHG) in 2013 excl. LULUCF. Next to the energy sector, the agricultural sector is the largest source of GHG emission in Denmark. The majority of agricultural greenhouse gas emissions are covered by N_2O and CH_4, which contributes in 2013 with 88 % and 78 % respectively of the total Danish emissions of N_2O and CH_4.

From 1990 to 2013, the emissions decreased from 12.5 million tonnes CO_2 equivalent to 10.1 million tonnes CO_2 equivalent, which corresponds to a 19 % reduction (Table 5.1). CH_4 is the largest contributor to the overall agricultural greenhouse gas emission, in 2013 accounting for 53 % in CO_2 equivalents. The decrease in the agricultural emission is caused by a decrease in N_2O emission, while the CH_4 emission is nearly unaltered.

Table 5.1 Emission of GHG in the agricultural sector in Denmark 1990 – 2013.

	1990	1995	2000	2005	2010	2011	2012	2012
CH_4, kt CO_2 eqv.	5 530	5 708	5 481	5 425	5 398	5 361	5 409	5 387
N_2O, kt CO_2 eqv.	6 340	5 647	5 148	4 805	4 528	4 554	4 433	4 514
CO_2, kt CO_2-eqv	619	537	268	222	156	165	192	246
Total, kt CO_2 eqv.	12 489	11 892	10 897	10 452	10 082	10 080	10 035	10 148

The major part of the emission is related to livestock production, which in Denmark is dominated by the production of cattle and swine.

Figure 5.1 shows the distribution of the greenhouse gas emission across the main agricultural sources. The total N_2O emission from 1990-2013 has decreased by 29 % and can largely be attributed to the decrease in N_2O emissions from agricultural soils. This reduction is due to a proactive national environmental policy over the last twenty five years to prevent loss of nitrogen from agricultural soil to the aquatic environment. These measures includes among other things a ban on manure application during autumn and winter, strict requirements to storage and application of manure, increasing area with winter-green fields to catch nitrogen, a maximum number of animals per hectare (ha) and maximum nitrogen application rates for agricultural crops. A combination of these increasing environmental requirements and the efforts to obtain economic advantage, the farmers has been forced to improve the utilisation of nitrogen in manure. An improvement of feed efficiency has been one of the most important drivers to reach the objectives. This has led to a halving of nitrogen use in inorganic fertilizer and a decrease of emission per produced kg meat, which all has reduced the overall GHG emission.

The CH_4 emissions from 1990 to 2013 shown in Figure 5.1 indicate a decrease in emission from enteric fermentation, which is mainly due to a decrease in the number of cattle. A contrasting development has taken place in emission from manure management. Structural changes in the sector have led to a move towards the use of slurry-based housing systems, which have a higher emission factor than systems with solid manure. By coincidence, the decrease and the increase almost balance each other out and the total CH_4 emission from 1990 to 2013 has decreased by 3 %.

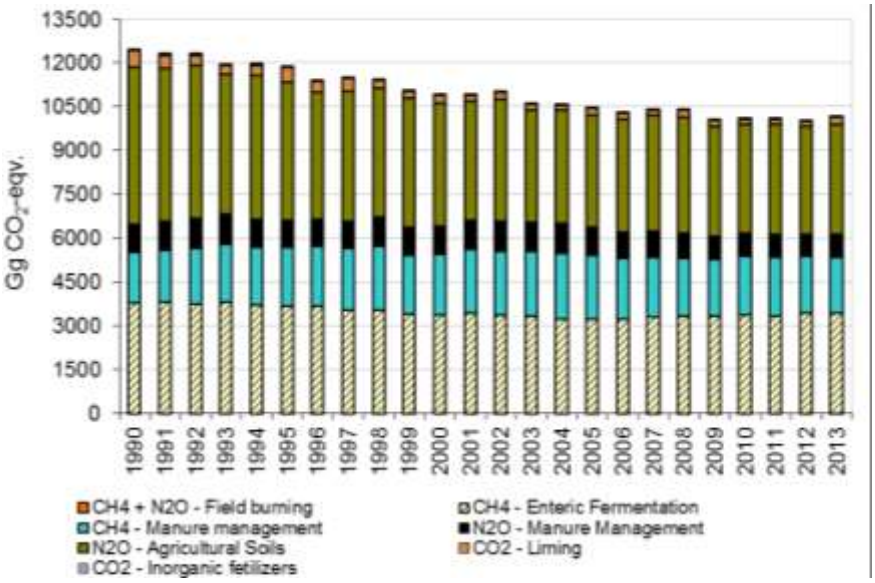

Figure 5.1 Danish greenhouse gas emissions 1990 – 2013.

5.1.1 Key category identification

The key category analysis (KCA) divides the agriculture emissions into 19 subcategories, refer Annex 1. In Table 5.2 is listed KCA covering Approach 1 and Approach 2. Approach 1 only gives key source identification based on the quantitative emission, while the Approach 2 analyse also include information on uncertainties estimates (refer to Chapter 1.5). In 1990, 11 of the 19 agricultural sources are registered as key categories and 13 sources are key categories if uncertainties are taken into account (Approach 2). In 2013, 6 of the sources are listed as key categories according to level and trend for Approach 1 and 12 sources in Approach 2. For the methodological choice Denmark uses the key categories identified using both Approach 1 and Approach 2 for the latest year as well as key categories identified for the trend from 1990 to the latest year.

The three most important agriculture key categories are CH_4 from enteric fermentation and N_2O emissions from nitrogen leaching and run-off and inorganic N fertilizers.

Table 5.2 Key category identification Tie1 and Tier 2 from the agricultural sector 1990 and 2013.

CRF table	Compounds	Emission source	Key category identification	
2013			Approach 1	Approach 2
3.A	CH_4	Enteric fermentation	Level/trend	Level/trend
3.B	CH_4	Manure management	Level/trend	Level/trend
3.F	CH_4	Field burning of agri. residues	-	-
3.B	N_2O	Manure management	Level	Level/trend
3.B.5	N_2O	Atmospheric deposition		Level
3.Da.1	N_2O	Inorganic N fertilizers	Level/trend	Level/trend
3.Da.2a	N_2O	Animal manure applied to soils	Level/trend	Level/trend
3.Da.2b	N_2O	Sewage sludge applied to soils	-	-
3.Da.2c	N_2O	Other organic fertilizer applied to soils	-	-
3.Da.3	N_2O	Urine and dung deposited by grazing animals	Level	Level/trend
3.Da.4	N_2O	Crop residue	Level/trend	Level/trend
3.Da.5	N_2O	Mineralization	Level	Level/trend
3.Da.6	N_2O	Cultivation of organic soils	Level	Level/trend
3.Db.1	N_2O	Atmospheric deposition	Level	Level/trend
3.Db.2	N_2O	Nitrogen leaching and run-off	Level	Level/trend
3.F	N_2O	Field burning of agri. residues	-	-
3.G	CO_2	Liming	Level/trend	Level/trend
3.H	CO_2	Urea application	-	-
3.I	CO_2	Other carbon-containing fertilizers	-	Trend
1990				
3.A	CH_4	Enteric fermentation	Level	Level
3.B	CH_4	Manure management	Level	Level
3.F	CH_4	Field burning of agri. residues	-	-
3.B	N_2O	Manure management	Level	Level
3.B.5	N_2O	Atmospheric deposition	-	Level
3.Da.1	N_2O	Inorganic N fertilizers	Level	Level
3.Da.2a	N_2O	Animal manure applied to soils	Level	Level
3.Da.2b	N_2O	Sewage sludge applied to soils	-	-
3.Da.2c	N_2O	Other organic fertilizer applied to soils	-	-
3.Da.3	N_2O	Urine and dung deposited by grazing animals	Level	Level
3.Da.4	N_2O	Crop residue	Level	Level
3.Da.5	N_2O	Mineralization	-	Level
3.Da.6	N_2O	Cultivation of organic soils	Level	Level
3.Db.1	N_2O	Atmospheric deposition	Level	Level
3.Db.2	N_2O	Nitrogen leaching and run-off	Level	Level
3.F	N_2O	Field burning of agri. residues	-	-
3.G	CO_2	Liming	Level	Level
3.H	CO_2	Urea application	-	-
3.I	CO_2	Other carbon-containing fertilizers	-	-

5.2 Data references

The calculated emissions are based on methods described in the IPCC Guidelines for National Greenhouse Gas Inventories (IPCC, 2006).

Activity data and emission factors are collected and discussed in cooperation with specialists and researchers in various institutes with agricultural expertise, such as the DCA - Danish Centre for Food and Agriculture – Aarhus University, Statistics Denmark, the Danish Agricultural Advisory Service, the Danish AgriFish Agency, the Danish Environmental Protection Agency and the Danish Energy Agency. In this way, both data and methods will be evaluated continually, according to the latest knowledge and information. DCE - Danish Centre for Environment and Energy, Aarhus University has established data agreements with the institutes and organisations to assure that the necessary data are available to prepare the emission inventory on time.

Table 5.3 List of institutes involved in the emission inventory for the agricultural sector.

References	Link	Abbreviation	Data/information
Statistics Denmark – Agricultural Statistics	www.dst.dk	DSt	- livestock production - milk yield - slaughtering data - export of live animal - poultry - land use - crop production - crop yield
Danish Centre for Food and Agriculture, Aarhus University		DCA	- N-excretion - feeding situation - animal growth - use of straw for bedding - N-content in crops - modelling of data regarding N-leaching/runoff - NH_3 emissions factor
SEGES	www.geses.dk	SEGES	- housing type (until 2004) - grazing situation - manure application time and methods - estimation of extent of field burning of agricultural residue
Danish Environmental Protection Agency	www.mst.dk	EPA	- sewage sludge used as fertilizer (until 2004) - industrial waste used as fertilizer
The Danish AgriFish Agency	http://naturerhverv.fvm.dk	DAFA	- inorganic N fertilizer (consumption and type) - housing type (from 2005) - sewage sludge used as fertilizer (from 2005 based on the register for fertilization) - number of animals from the Central Husbandry Register
The Danish Energy Agency	www.ens.dk	DEA	- manure used in biogas plants

The emissions from the agricultural sector are calculated in a comprehensive agricultural model complex called IDA (Integrated Database model for Agricultural emissions). The model complex is designed in a relational database system (MS Access). Input data are stored in tables in one database called IDA_Backend and the calculations are carried out as queries in another linked database called IDA. This model complex, as shown in Figure 5.2, is implemented in great detail and is used to cover emissions of air pollutants and greenhouse gases. Thus, there is a direct coherence between the NH_3 emission and the emission of N_2O.

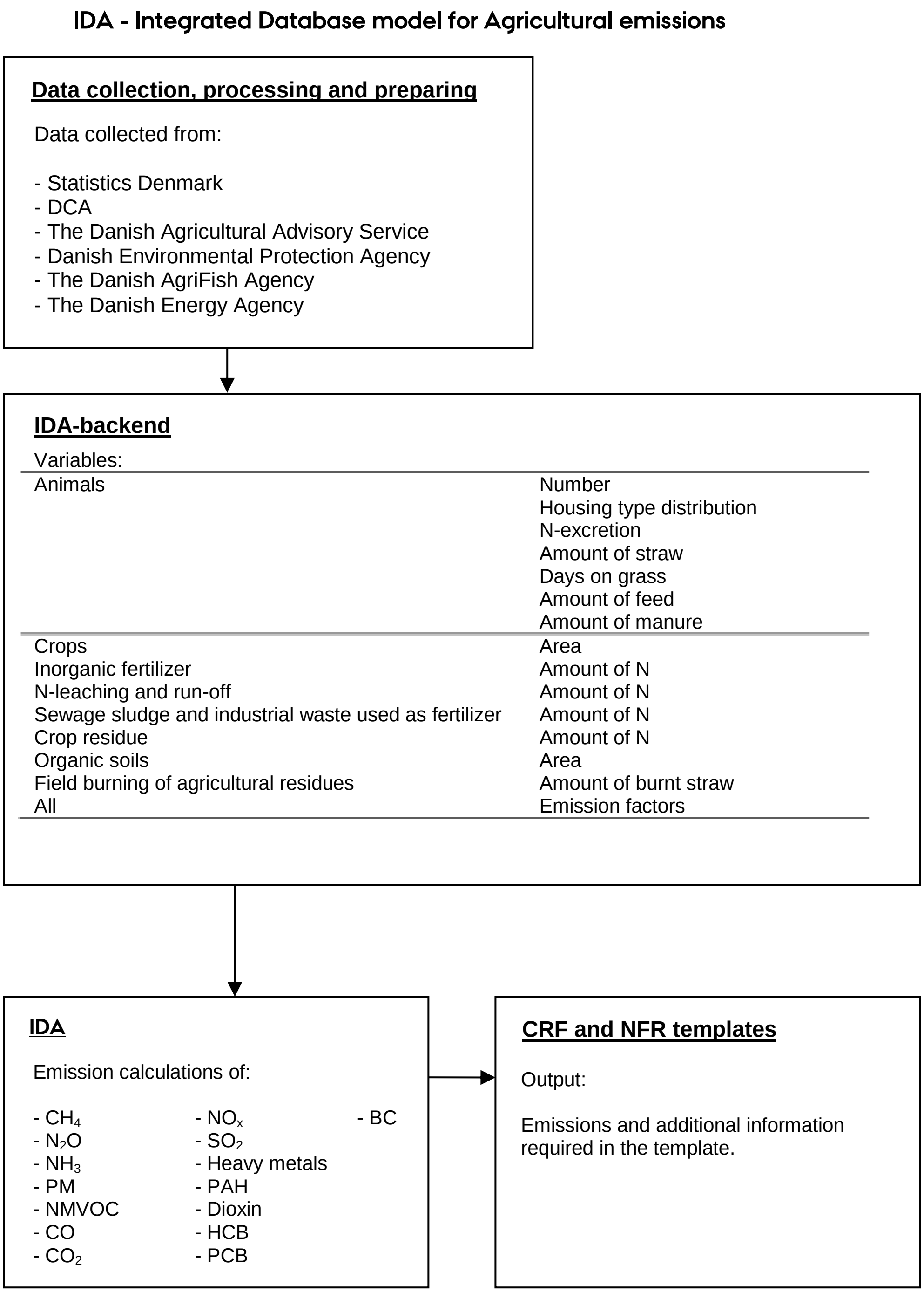

Figure 5.2 IDA - Integrated Database model for Agricultural emissions.

Most emissions relate to livestock production, which basically is based on information on the number of animals, the distribution of animals according to housing type and, finally, information on feed consumption and excretion.

IDA operates with 39 different livestock categories, according to livestock type, weight class and age. These categories are subdivided into housing type and manure type, which results in 266 different combinations of livestock subcategories and housing types (see Annex 3D Table 3D-1). For each of these combinations, information on e.g. feed intake, digestibility, excretion and grazing days is included. The emission is calculated from each of these subcategories and then aggregated in accordance with the IPCC livestock categories given in the CRF.

Table 5.4 Livestock categories and subcategories.

CRF 3B	Aggregated livestock categories as given in IPCC	Includes	No. of subcategories in IDA, animal type/housing system
3B 1a	Dairy Cattle[1]	Dairy Cattle	35
3B 1b	Non-dairy Cattle[1]	Calves (<½ yr), heifers, bulls, suckling cattle	129
3B 2	Sheep	Sheep and lambs	2
3B 3	Swine	Sows, weaners, fattening pigs	37
3B 4	Deer		1
	Goats	Including kids (meet, dairy and mohair)	3
	Horses	<300 kg, 300 - 500 kg, 500 - 700 kg, >700 kg	4
	Poultry	Hens, pullets, broilers, turkeys, geese, ducks, ostriches, pheasant	47
	Fur-bearing animals	Mink and foxes	8

1) For all subcategories, large breed and jersey cattle are distinguished from each other.

It is important to point out that changes over the years, both to the national emission and the implied emission factor, are not only a result of changes in the numbers of animals, but also depend on changes in the allocation of subcategories, changes in feed consumption and changes in housing type.

5.2.1 Number of animals

Livestock production is primarily based on the agricultural census from Statistics Denmark (DSt). For many animal categories the number given in the annual Agricultural Statistics can be used directly. However, for weaners, fattening pigs, bulls and poultry the number is based on slaughter data also collected from the Agricultural Statistics. This is because the production cycle for these animals is under one year and the normative figures are based on produced animals.

Only farms larger than five hectares are included in the annual census from Statistics Denmark. Especially horses, goats and sheep are placed on small farms, which mean that the number of animals given in the Agricultural Statistics is not representative. Therefore, the number of sheep and goats is based on the Central Husbandry Register (CHR) which is the central register of farms and animals managed by the Ministry of Food, Agriculture and Fisheries. From 2010 the annual census includes farms with more than 20 goats and sheep, but the CHR is considered as more reliable because the register include all animal independent on farm size.

The number of deer and ostriches is also based on CHR because these are not included in the Agricultural Statistics published by Statistics Denmark. The number of horses is based on data from The Danish Agricultural Advisory Service. The number of pheasants is based on expert judgement from Department of Bioscience, Aarhus University and the Danish pheasant breeding association.

The agricultural annual census in present form goes back to 1977 (Statistics Denmark, 2010). The survey has taken place every year as a questionnaire based survey where the farmer has received a questionnaire in a letter with an obligation to complete it. The questionnaire has varied from year to year depending on EU requirements and national needs. From 1977 to 1983 the survey was based on total censuses where all farms where included, which also is the case for the years; 1985, 1987, 1989, 1999 and 2010. The remaining surveys is based on sample surveys; 1984, 1986, 1988, 1990-98, 2000-09 and

2011-13 and include around 20-35 % of all farms and around 50 % of the farms in 2003, 2005 and 2007.

As soon as the data from the questionnaires are processed, tested and quality assured the data is annually published at the Statistics Denmark's homepage; http://www.statistikbanken.dk and is available in both English and Danish.

In Annex 3D Table 3D-2 is provided number of animals allocated on all livestock subcategories.

5.2.2 Housing type

From 2005, all farmers have to report to the Danish AgriFish Agency (DAFA) information concerning the use of housing type. Annex 3D Table 3D-1 shows the housing type for each livestock category for the years 1990 – 2013.

Before 2005 there exist no official statistics which cover the distribution of animals according to housing type. The distribution is, therefore, based on an expert judgement from SEGES and DCA. Approximately 90-95 % of Danish farmers are members of SEGES, which regularly collects statistical data from the farmers on different issues, as well as making recommendations with regard to farm buildings. Hence, SEGES has a good understanding of which housing types that are currently in use and also the changes over time.

5.2.3 Feed consumption and excretion

The DCA provide Danish standards related to feed consumption, excreted volumes, nutrient content of nitrogen, phosphor and potassium, dry matter in manure and contribution of different manure type. These standards are all a part of the "Danish Normative System", which is used for fertilizer planning and control by the Danish farmers and authorities (Poulsen et al., 2001, Poulsen, 2014). The complexity and dynamics of the system has increased during the years to secure the development of accurate values. Furthermore, the normative system includes emission factors for NH_3, which is based on a combination of measurements and model calculations. Emission factors for NH_3 from the housing unit and storage are given in Annex 3D Table 3D-3 (a-d) and 3D-4.

The Danish normative standards are based on practical farming and thus reflect the actual Danish agricultural production conditions. DCA receive data from SEGES, which is the central office for all Danish agricultural advisory services. SEGES carries out a considerable amount of research itself, as well as collecting efficacy reports from the Danish farmers for dairy production, meat production, pig production, etc., to optimise productivity in Danish agriculture. Feeding plans are used to provide values to the Danish Normative System and for dairy cows the values are based on approximately 800 feeding plans. In total the normative standards covers feed plans from 15-18 % of the Danish dairy production, 25-30 % of the pig production, 80-90 % of the poultry production and approximately 100 % of the fur production. A high fraction of the pig production is represented, which is caused by the intensive focus on the possibilities to optimize the feed intake to increase the feed efficiency. The values covering the cattle production can be considered as reliable, even though only 15-18 % of the productions are represented.

These values include mainly feeding plans from the farmers with a production efficiency corresponding to a middle level. The farmers with a high productivity level are often not users of the Danish Agricultural Advisory Service, which also is the case for farmers with a low productivity level.

Previously, the normative standards were updated and published every third or fourth year (Laursen, 1987; Laursen, 1994; Poulsen and Kristensen, 1997). From 2001 these standards are updated annually and available to download at the homepage of DCA:
http://anis.au.dk/forskning/sektioner/husdyrernaering-og-miljoe/normtal/ (Dec. 2014).

One of the reports concerning the normative data is published in English in Poulsen and Kristensen (1998) and is available at the homepage of DCA, see list of references. The normative data is adjusted over time but the methodology is the same.

5.3 CH_4 emission from enteric fermentation

5.3.1 Description

The major part of the agricultural CH_4 emission originates from digestive processes. In 2013, this source accounts for 34 % of the total GHG emission from agriculture. The emission is primarily related to ruminants and, in Denmark, particularly to cattle, which, in 2013, contributed with 87 % of the emission from enteric fermentation. The emission from pig production is the second largest source and covers 10 % of the emission from enteric fermentation, followed by horses (2 %) and sheep, goats, deer and poultry (1 %).

From 1990 to 2013, the emission from enteric fermentation has overall decreased by 9 %, which is primarily related to a decrease in the number of cattle. The number of swine has increased from 9.5 million in 1990 to 12.1 million in 2013, but this increase is only of minor importance in relation to the total CH_4 emission from enteric fermentation. The emission where lowest in 2005 but have increased slightly until 2013, mainly due to a slightly increase in number of cattle.

5.3.2 Methodological issues

The methodology for estimating emissions from enteric fermentation is based on IPCC Guidelines for National Greenhouse Gas Inventories (IPCC, 2006). The methodology for poultry, ostrich and pheasants is based on Tier 1, while the remaining animal categories are based on a Tier 2/Country Specific (CS) approach. CH_4 emission from enteric fermentation from fur farming is considered to be not applicable based on country-specific information (Hansen, 2010). Feed consumption for all animal categories is based on the Danish normative figures. Default values for the methane conversion rate (Y_m) given by the IPCC are used for all livestock categories, except for dairy cattle and heifers, where a national Y_m is used for all years.

Tier 1

Emission factors used for poultry, ostrich and pheasants are based on the emission factors given by Wang & Huang (2005). EF for broilers with a life cycle of 30-56 days is scaled in proportion to 42 days for broilers given by Wang & Huang (2005). Organic broilers with a life cycle of 81 days are scaled in proportion to the Taiwan country chicken with 91 days of life cycle and pullets with a life cycle of 112-119 days are scaled in proportion to the 140 days given for pullets by Wang & Huang (2005). EF for ducks, geese, turkeys, ostrich chickens and pheasant chickens is scaled by weight in proportion to a Danish broiler with 40 days of life cycle. For laying hens, the EF for laying hens given by Wang & Huang (2005) is used and for ostrich hens and pheasant hens the EF is scaled by weight in proportion to a laying hen. All EF for CH_4 from enteric fermentation for poultry are shown in Annex 3D Table 3D-5.

Tier 2

The Tier 2/CS equation for EF of enteric fermentation is the sum of the feeding situation in winter and summer. The EF is based on actual feeding plans, which is provided from data for feed units (FU) for each livestock category – see below. Feeding with sugar beets is taken into account because sugar beet feeding gives a higher methane production rate compared to grass and maize due to the high content of easily convertible sugar. However, it is only dairy cattle and heifers which have sugar beets in the feed. The parts of the equation concerning sugar beet will be left out for the remaining animal categories.

$$EF = EF_{winter} + EF_{summer}$$

$$EF_{winter} = FU \cdot ((\frac{GE_{FU\,winter}}{55.65}) \cdot Y_{m\,excl\,sugarbeet} \cdot (1 - \frac{grazing\ days}{365} - \frac{days\ with\ sugar\ beet}{365}) + (\frac{GE_{FU\,winter}}{55.65}) \cdot Y_{m\,incl\,sugarbeet} \cdot \frac{days\ with\ sugar\ beet}{365})$$

$$EF_{summer} = FU \cdot (\frac{GE_{FU\,summer}}{55.65}) \cdot Y_{m\,grazing} \cdot \frac{grazing\ days}{365}$$

Where:

FU = feeding units

$GE_{FU,winter}$ = gross energy per feeding unit, MJ per FU in winter

$GE_{FU,\ summer}$ = gross energy per feeding unit, MJ per FU in summer

Y_m= methane conversion factor, per cent of gross energy in feed converted to methane

Thus, to calculate the total gross energy (GE) intake, the GE per feed unit – defined as GE_{FU} – needs to be estimated. A feed unit in Denmark is defined as the feed value in 1.00 kg barley with a dry matter content of 85 % (Statistics Denmark, yearbook 2010). For other cereals e.g. wheat and rye one feed unit is 0.97 kg and 1.05 kg, respectively.

Gross energy intake

The calculation of $GE_{FU,\ winter}$ and $GE_{FU,\ summer}$ is based on the composition of feed intake and the energy content in proteins, fats and carbohydrates based on actual efficacy feeding controls or actual feeding plans at farm level, collected by SEGES or DCA. The data are given in Danish feed units or kg feedstuff and these values are converted to mega joule (MJ). The calculation is shown in the equation below:

The principle for estimation of $GE_{FU, winter}$ and $GE_{FU, summer}$ is the same, why the following equation only is defined as GE_{FU}.

$$GE_{FU} = \frac{MJ/day}{FU/day}$$

$$FU/day = \frac{kg\ dm}{day} \cdot \frac{FU}{kg\ dm}$$

$$MJ/day = \frac{kg\ dm}{day} \cdot \frac{MJ}{kg\ dm}$$

$$MJ/kg\,dm = \%_{Crudeprotein} \cdot E_{Crudeprotein} + \%_{Raw\ fat} \cdot E_{Raw\ fat} + \%_{Carbonhydrates} \cdot E_{Carbonhydrates}$$

$$\%_{Carbonhydrates} = 100 - (\%_{Crudeprotein} + \%_{Raw\ fat} + \%_{Raw\ ashes})$$

In Annex 3D Table 3D-6 and 3D-7 are listed all parameters for winter feeding plans covering the amount of proteins, fats and carbohydrates in the feed, FU per kg, kg dry matter per day and MJ per day. Annex 3D Table 3D-8 and 3D-9 provides additional information about feed intake given in FU and grazing days for each livestock category.

As seen in Annex 3D Table 3D-8, GE for heifer from 2005 to 2007. In 2007 new estimations and measurements received from DCA shows that the GE for heifers differs from the previous estimates. This development is not caused by a single year change in feed intake but due to changes in feed practice during some years. Therefore, interpolation of GE for heifer was chosen from year 2004 to 2007 to avoid a significant jump from 2006 to 2007. The GE for non-dairy cattle is an average of GE for calves, heifers, bulls and suckling cattle. However, heifer is the most important subcategory and thus affects the weighed GE average for non-dairy cattle, which also increases from 2004 to 2007.

Estimation of $GE_{FU, summer}$ covers the time where animals are grazing.

For dairy cows, the energy intake comes out at 18.3 MJ pr. FU in a standard winter feed regardless of whether the animal grazes or not, which is based on information from DCA. For bull calves (< ½ year), as well as bulls older than ½ year, the same energy content value is used, as for dairy cows.

For horses, heifers, suckling cattle, sheep and goats an average winter feed plan is provided based on information from DCA and SEGES on which the calculation of the GE content is based. Feeding conditions for deer is comparable with goats, why the GE for deer is based on feed plans for goats.

Table 5.5 GE per feeding unit, MJ per FU.

	GFU_{winter}	GFU_{summer}
Dairy cattle	18.3	18.3
Calves and bulls	18.3	18.8
Heifers	25.8	18.8
Suckling cattle	34.0	18.8
Sows	17.5	17.5
Weaners	16.5	16.5
Fattening pigs	17.3	17.3
Horses, sheep, goats and deer	30.0	18.8

In Annex 3D Table 3D-10, the annual average feed intake given in GE as MJ per day is shown, from 1990 to 2013, for each livestock category.

The Tier2/CS for enteric fermentation differs from the IPCC Tier 2 in the calculation of GE. A comparison between these two methods is shown in Chapter 5.13.1.

Methane conversion rate (Y_m)

Investigations from DCA have shown a change in fodder practice from use of sugar beet to maize (whole cereal). Sugar beet feeding gives a higher methane production rate compared to grass and maize due to the high content of easily convertible sugar. The development in fodder practice reflects the change in the average Y_m for dairy cattle and heifer from 6.38 in 1990 to 6.00 in 2002 and onwards.

The estimation of the national values of Y_m is based on model "Karoline" developed by DCA based on average feeding plans for 20 % of all dairy cows in Denmark obtained from SEGES (Olesen et al.; 2005). DCA have estimated the CH_4 emission for a winter feeding plan for two years, 1991 (Y_m=6.7) and 2002 (Y_m=6.0). Y_m for the years between 1991 and 2002 are estimated by interpolation. Sugar beets are only included in the winter feeding plan and the Y_m is therefore also adjusted for days on winter and summer feeding plan. It is assumed that winter feeding plan covers 200 days.

New measurements (Hellwing et al, 2014) have shown an Y_m value between 5.98 and 6.13. Based on this information the Y_m value for dairy cattle and heifers are kept at 6.00 from 2002 to 2013 (Lund, 2014).

Table 5.6 CH_4 conversion rate (Y_m) – national factor used for dairy cattle and heifers > ½ year 1990 – 2013, %.

Dairy cattle + Heifers > ½ year	1990	1991	1995	2000	2002-2013
$Y_{m\ \text{incl. sugar beet}}$	6.70	6.70	6.45	6.13	6,00
$Y_{m\ \text{excl. sugar beet}}$	6.00	6.00	6.00	6.00	6.00
$Y_{m\ \text{grazing}}$	6.00	6.00	6.00	6.00	6.00
Average Y_m	6.38	6.38	6.24	6.07	6.00

5.3.3 Emission factor

IEFs vary across the years for dairy cattle, non-dairy cattle, swine, goats and poultry due to changes for feed intake, distribution of animals in subcategories and number of grazing days. For goats new subcategories are introduced in 2005 and therefore the IEF differs from the other years. For sheep, horses, deer, ostrich and pheasants the IEF is constant. The emission from fur farming is considered to be not applicable (Hansen, 2010).

The IEF for dairy cattle has increased from 117 kg CH_4 per cow per year in 1990 to 136 kg CH_4 in 2013. The IEF depends on milk yield and feed intake – see Figure 5.3. From 1990 to 2000 the IEF is almost unchanged but increased significant from 2000 to 2013. The development in feed intake follows the same development as the IEF, while the milk yields in percentage increases even more and especially from year 2000. This is caused by increased feed efficiency; an improvements of the feed utilization.

The milk yield has in average increased from 6 000 litre per cow in 1990 to approximately 8 700 litre per cow in 2013 (Statistics Denmark).

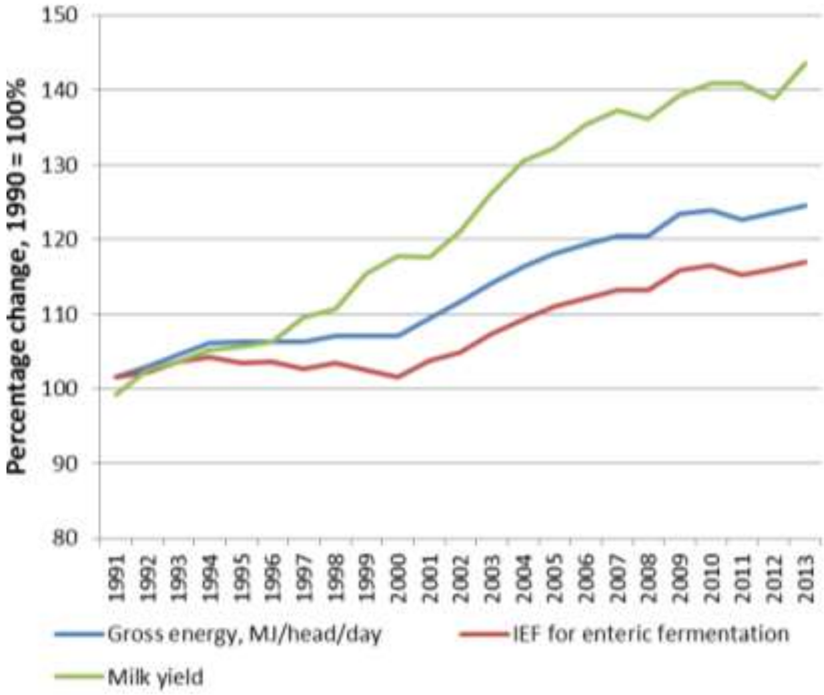

Figure 5.3 Comparison of feed intake, milk yield and IEF for dairy cattle (1990 = 100 %).

A comparison with IPCC Tier 2 calculation in Chapter 5.13.1 shows that the IEFs for the Danish inventory are lower. However, the national IEF reflects the Danish agricultural conditions and the lower level can be explained by the lower Y_m value which is based on national measurements.

The category "Non-Dairy Cattle" includes calves, heifers, bulls and suckling cattle and the IEF is a weighted average of these different subcategories. Changes in allocation of animals in subcategories can be reflected in the IEF. The development 1990 - 2008 shows a slight increase due to a higher feed consumption for heifers. From 2008 – 2013 the IEF seems stabile.

The Danish IEF for non-dairy cattle is lower than the Tier 1 default value given in the IPCC 2006. This is due to a combination of lower Y_m value for heifers and lower weight/lower feed intake (Table 5.7). In Chapter 5.13.1 the national IEF is compared with IPCC Tier 2 calculation and the result shows a good correlation, which indicates the Danish estimate is correct.

Table 5.7 Subcategories for Non-Dairy Cattle 2013 – enteric fermentation.

Non Dairy Cattle – subcategories		Number of animals (DSt)	Energy intake, MJ per day	Methane conversion rate (Y_m), %	IEF, kg CH_4 per head per yr
Calves, bull (0-6 month)	200 kg	124 964	61.70	3.0[a]	12.14
Calves, heifer (0-6 month)	150 kg	160 086	51.14	6.0	40.25
Bulls (6 month to slaughter)	large breed: 440 kg sl. weight jersey: 330 kg sl. weight	133 318	113.59	3.0[a]	22.35
Heifers (6 month to calving)	325 kg	516 954	130.17	6.0	51.23
Suckling cattle	Up to 800 kg	96 981	163.55	6.0	64.36
Average - Non-Dairy Cattle			104.6		39.39
IPCC – default value				6.5	57

[a] Default IPCC 2006 feedlot fed cattle.

The annual variations for swine primarily reflect the changes in the distribution of animals in subcategories (sows, weaners and fattening pigs). The feed intake for sows and weaners has overall increased while the feed intake for fattening pigs has decreased as a result of improved fodder efficiency (Annex 3D Table 3D-8 and 3D-10).

In Table 5.8 the IEFs for swine subcategories are shown. The Danish IEF for swine is lower than the IPCC default value. The energy intake for fattening pigs is nearly the same as the default value, while the energy intake for weaners is significantly lower. The lower Danish IEF can be explained by the relatively high share of weaners.

Table 5.8 Subcategories for Swine 2013 – enteric fermentation.

Swine – subcategories	Number of animals (DSt)	Energy intake, MJ per day	Methane conversion rate (Y_m), %	IEF, kg CH_4 per head per year
Sows (incl. piglets until 7.4 kg)	1 010 516	79.06	0.60	3.08
Weaners (7.4 – 32 kg)	5 847 458	10.63	0.60	0.42
Fattening pigs (32 – 107 kg)	5 472 905	38.60	0.60	1.52
Average - Swine		23.0		1.12
IPCC – default value			0.60	1.5

It is important to point out that the IEF for goats includes emission from kids due to the Danish normative data. This explains why the Danish IEFs are nearly twice as high as the IPCC default values.

5.3.4 Activity data

Activity data are the number of animals from the agricultural statistics (Statistics Denmark), SEGES and CHR (see Chapter 5.2.1). For numbers see Annex 3D Table 3D-2.

Since 1990, the number of swine and poultry has increased, in contrast to the number of cattle, which has decreased. The number of cattle has decreased because the milk yield has increased while the total production of milk has been fixed by the EU milk quota. Buffalos, camels & llamas and mules & asses are not occurring in Denmark.

5.3.5 Time series consistency

The main part of emission of CH_4 from enteric fermentation comes from cattle. The development in the milk production has been a high increase in milk per cow and which has increased the feed per cow and thereby increased the implied emission factor. But due to fixing of the total production of milk by the EU milk quota, the number of dairy cattle has decreased. The emission of CH_4 from enteric fermentation from dairy cattle has decreased from 1990 to 2007, from 2008 to 2013 the emission from dairy cattle has increased due increase in number of animals.

The emission from non-dairy cattle follows the trend of dairy cattle due to the high share of heifers and the production of heifers is closely connected to the dairy cattle production.

Emission from swine increases due to increase in number of animals.

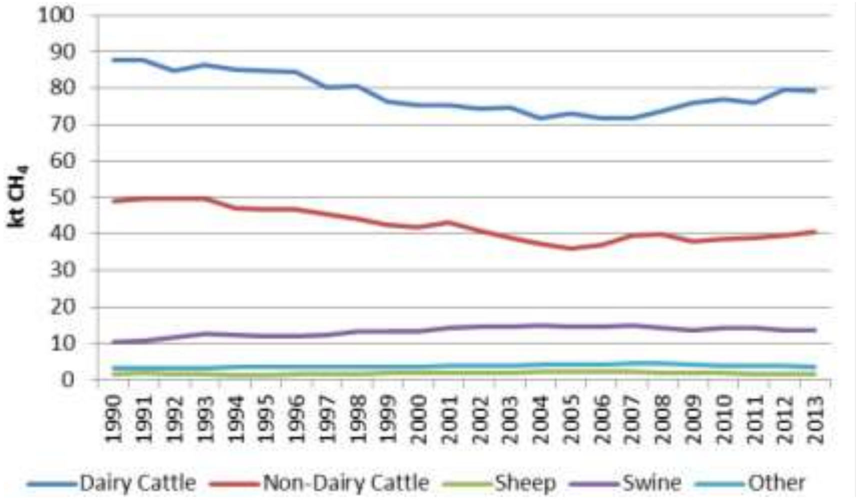

Figure 5.4: Emission of CH_4 from enteric fermentation, 1990-2013.

5.4 CH_4 emission from manure management

5.4.1 Description

This source contributes with 20 % of the total greenhouse gas emission from the agricultural sector in 2013. The major part of the emission originates from the production of cattle (48 %) followed by swine production (45 %). The remaining part is mainly from poultry and fur bearing animals (7 %).

5.4.2 Methodological issues

The IPCC Tier 2/CS methodology is used for the estimation of the CH_4 emission from manure management. The calculation is based on manure excretion instead of feed intake as described in IPCC Guidelines for National Greenhouse Gas Inventories (IPCC, 2006). Default values for maximum methane producing capacity (B_0) and methane conversion factor (MCF) given by the IPCC are used. The calculation of volatile solids (VS) is based on national data.

Table 5.9 CH_4 – Manure management – use of national parameters and IPCC default values.

CH_4 – Manure management	National parameters	IPCC default value
Volatile solids, VS	Based on amount of manure (Annex 3D Table 3D-11)	
Maximum methane producing capacity, B_0		IPCC 2006
Methane conversion factor, MCF		IPCC 2006

The amount of manure is calculated for each combination of livestock subcategory and housing type and then aggregated to the IPCC livestock categories. In the calculation grazing days and use of straw in the housing are taken into account. Equation for CH_4 calculation:

$$CH_{4\,manure} = CH_{4\,housing} + CH_{4\,grazing}$$

$$CH_{4\,housing} = VS_{housing} \cdot MCF \cdot 0.67 \cdot B_0$$

$$CH_{4\,grazing} = VS_{grazing} \cdot MCF \cdot 0.67 \cdot B_0$$

Estimation of VS

VS is calculated from data concerning amount of manure, dry matter content, share of VS in dry matter, amount of bedding and grazing days. Except from grazing days for dairy cattle and heifers, all these parameters are based on Danish Normative data.

The determination of VS is country-specific, given that it is based on the amount of manure excreted.

$$VS_{housing} = \frac{m}{365} \cdot DM_M \cdot VS_{DM} \cdot (365 - g_1) + s \cdot DM_S \cdot (1 - \frac{\% \, ash}{100}) \cdot (365 - g_2)$$

$$VS_{grazing} = \frac{m}{365} \cdot DM_M \cdot VS_{DM} \cdot g_1$$

Where:	VS	= volatile solids, kg animal^{-1} yr^{-1}
	m	= amount of manure excreted, kg animal^{-1} yr^{-1}
	DM	= dry matter of M manure or S straw, pct.
	VS_{DM}	= volatile solids of dry matter, pct.
	g_1	= feeding days on grass, days yr^{-1} [1]
	g_2	= actual days on grass, days yr^{-1}
	s	= amount of straw, kg animal^{-1} yr^{-1}
	% ash	= ash content in straw

The ash content in straw is set to 4.5 % (SEGES, 2005). VS of dry matter are 80 % for all livestock categories. The number of days on grass is shown in Annex 3D Table 3D-9. The amount of manure excreted and straw used depends on housing type and is given in the normative figures table (Poulsen, 2014).

The VS daily excretion in average for all main livestock categories and cattle subcategories is shown in Annex 3D Table 3D-11.

MCF - Methane conversion factor

Default values provided in the IPCC guidelines for the methane conversion factor are used. For liquid systems the MCF is a weighted value depended on the situation for covered and uncovered slurry tanks in Denmark. Also for swine on deep bedding housing system is used a weighted value due to the residence time of manure in the barn. In Annex 3D Table 3D-12 is given a survey of all national manure management systems and the MCF related to each system.

Slurry

Due to legislation from 2003 all slurry tanks have to be fully covered or have established a floating cover. However, it is difficult to achieve full floating cover all day of the year some emission can take place during filling and mixing of manure in the tank. Therefore, it is assumed that floating/fixed covers are absent on 5 % of slurry tanks in swine production and on 2 % in cattle and fur production. This results in a MCF of 10.4 for swine slurry and 10.1cattle and fur slurry.

[1] Actual days on grass are the number of days that heifers are outside. Feeding days on grass is higher than actual days on grass due to a higher feed intake during grazing compared to the period in housing. Feeding days on grass is a conversion of this higher feed intake on grass. This is only relevant for heifers.

Table 5.10 MCF factor for cattle, fur and swine slurry.

MCF, slurry	MCF, DK	% covered DK	MCF, IPCC 2006	
			Covered	Uncovered
Liquid/slurry cattle + fur	10.1 %	98	10 %	17 %
Liquid/slurry swine	10.4 %	95	10 %	17 %

Deep bedding

The MCF for swine deep bedding depends on how long time the manure is stored in the barn and the emission is particularly higher for bedding store more than one month. The bedding situation is based on information from SEGES and is different for the three swine subcategories. The lowest MCF at 7.2 % is seen for weaners because 70% of the bedding material is removed during the first month. The situation is opposite for sows where only 20 % of the bedding is removed during the first month, which lead to a higher MCF at 14.7 %.

Table 5.11 MCF factor for swine, deep bedding.

MCF, swine deep bedding	MCF, DK	DK condition, pct of yr		IPCC, 2006	
		> 1 month	< 1 month	> 1 month	< 1 month
Deep bedding weaners	7.2 %	30	70	17 %	3 %
Deep bedding fattening	11.4 %	60	40	17 %	3 %
Deep bedding sows	14.7 %	80	20	17 %	3 %

5.4.3 Emission factor

The implied emission factor depends on the VS content in manure, the use of straw, the number of days on grass and the manure type. The changes of IEFs during the years thus reflect changes in the variable mentioned above. For some livestock categories which include subcategories, the IEF can also be affected by changes in allocation of animal on the different subcategories.

The IEF for poultry, ostriches, pheasants and deer are unaltered from 1990 – 2013 because of very few changes in feed intake and grazing days. A more detailed division in subcategories for goats and horses is implemented from 2007 and 2003, respectively, and explains the small changes in IEFs.

IEF for dairy cattle has increased as a result of increasing milk yield, but also because of changes in housing types (Annex 3D Table 3D-1). Old-style tethering systems with solid manure have been replaced by loose-housing with slurry-based systems, which has a higher MCF. Same pattern is seen for non-dairy cattle, but here the reason for increasing IEF mainly caused by a higher proportion of bull-calves are raised in housings with deep litter, where the MCF also is high. The decrease of IEF for non-dairy cattle from 2012 to 2013 is caused by new data for use of straw to bulls, which is lower than previous estimations.

Due to the movement from solid manure to slurry-based systems the IEF for swine and fur bearing animal increases from 1990 to 2013.

5.4.4 Activity data

Activity data includes both the number of animals and the allocation of animal on different housing types, which determines the manure type. The livestock production is based on the agricultural statistics (Statistics Denmark), SEGES and CHR (see Chapter 5.2.1) and the numbers are given in Annex 3D Table 3D-2. The allocation of housing types is based on registration from the Danish AgriFish Agency (see Chapter 5.2.2 and Annex 3D Table 3D-1).

5.4.5 Biogas treated slurry

In previous emission inventory a reduced emission as a consequence of biogas treated slurry has been included. The IPCC 2006 now includes guidelines for estimation of emission from biogas treatment of manure and this is not consistence with the methodology Denmark until now has used to estimate the reduced emission of CH_4 and N_2O. Guidelines use a specific methane conversions factor (MCF) for the biogas treated slurry. Following the IPCC 2006 Guidelines Denmark use a MCF of 10.4 % for dairy cattle slurry. This is a weighted value depending on covering of slurry tanks and the temperature zone. Logically, the MCF has to be lower for biogas treated slurry compared to non-treated slurry, but it is difficult to quantify how much lower. Currently very few data is available to estimate a MCF corresponding to the Danish agricultural conditions. Because of the lack of data the reduction of CH_4 emission is not included in this year inventory. However, some research activities are ongoing during this year and hopefully the result of these activities can be used to estimate a MCF for biogas treated slurry.

Current inventor thus only includes activity data on biogas treated slurry. The same MCF is used for both biogas treated and non-treated slurry, which mean a MFC at 10.4 % for e.g. dairy cattle slurry.

The Danish Energy Agency (DEA) provides annually the Danish energy statistics, which for 2013 shows that the produced energy from biogas corresponds to 4642 TJ (DEA, 2014). The majority of this production (3256 TJ) takes place on biogas plants and uses agricultural products which mainly are animal manure (slurry). In Denmark exist around 80 biogas plants and the largest ones which produce more than 100 TJ per year account for around 50 % of total production.

Table 5.12 Number of biogas plants and production of energy.

Production size, TJ per year	No. of biogas plants	Energy production, TJ
<10	26	112
10-50	33	761
50-100	10	808
100-250	11	1574
Total	80	2969

The energy potential very much depends on the type of biomass input; the combination of manure and other agricultural biomasses, the storage time and the technology on the different biogas DEA assume an average energy potential where 0.83 million tonnes of slurry produce 1 PJ biogas. This means that in 2013 around 2.7 million tonnes of slurry has been treated in biogas plants, which is equivalent to approximately 7 % of total slurry excreted. It is assumed that of the total amount of biogas treated slurry, cattle slurry makes up 45 % and pig slurry 55 % (Tafdrup, 2010).

5.4.6 Time series consistency

The overall CH_4 emission from manure management is increased by 11% from 1990 to 2013 and this is from both the cattle and swine production. The emission from swine has increase from 1990 to 2004 and hereafter decreased until 2013. The emission is mainly determined by the production of fattening pigs and the emission development follows the same trend as the number of produced fattening pigs.

The emission from dairy cattle is also increased from 1990 to 2013, despite a decrease in number of dairy cattle, but is related to higher milk yield and thus higher feed intake.

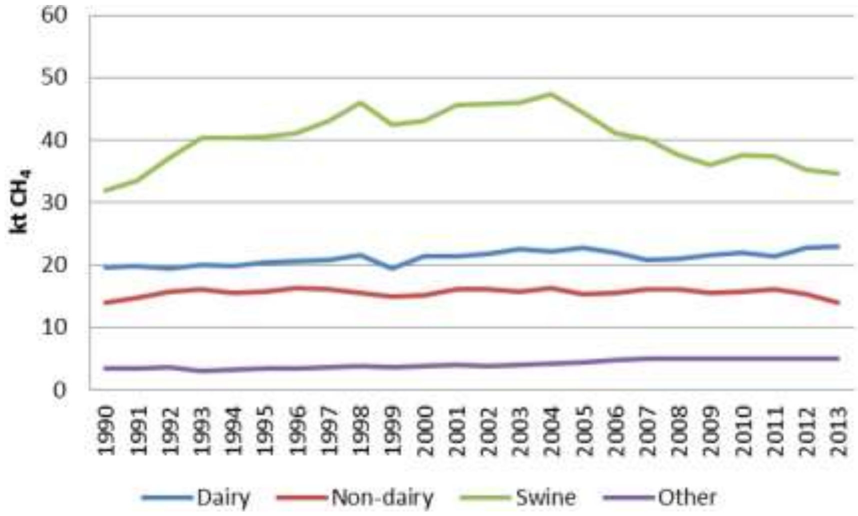

Figure 5.5 CH_4 emission from manure management, 1990 - 2013.

5.5 N_2O emission from manure management

5.5.1 Description

The N_2O emission related to CRF category 3B covers a direct and an indirect emission source. The direct emission includes emission from handling of manure in housing and storage and the indirect emission includes the N_2O emission estimated on the emission of NH_3 and NO_x which take place in housing and storage.

The N_2O emission from manure management represents 8 % of the total greenhouse gas emission from the agricultural sector in 2013 and the major part origins from the direct emission. The cattle- and pig production account for the largest contribution.

The emission only includes the emission from housing and storage, while the emission from manure deposited on grass is included in CRF category 3D.3 Urine and dung deposited by grazing animals.

5.5.2 Methodological issues

The emission is based on IPCC 2006 Guidelines Tier 2 approach. The emission depends on the N-content in manure and national data is used for N-excretion for all livestock categories.

5.5.3 Emission factor

For the direct emission the IPCC default N_2O emission factors are applied for all livestock categories. In following table is shown the Danish housing system compared to the housing system given in IPCC 2006 Guidelines Table 10.21 and the respective default emission factors.

Table 5.13 Manure management system (MMS) - emission factors.

DK MMS	IPCC MMS	Emission factor, kg N_2O-N pr kg Nex
Cattle		
Liquid/Slurry	Liquid/Slurry, with natural crust cover	0.005
Solid	Solid storage	0.005
Deep bedding	Cattle and Swine deep bedding, no mixing	0.01
Biogas treated slurry	Anaerobic digester	0
Swine		
Liquid/Slurry	Liquid/Slurry, with natural crust cover	0.005
Solid	Solid storage	0.005
Deep bedding	Cattle and Swine deep bedding, Active mixing	0.07
Biogas treated slurry	Anaerobic digester	0
Poultry		
Housing with or without litter	Poultry manure with or without litter	0.001
Fur-bearing animals		
Slurry	Liquid/Slurry, with natural crust cover	0.005
Solid	Cattle and Swine deep bedding, no mixing	0.01
Sheep and goats		
Deep bedding	Cattle and Swine deep bedding, no mixing	0.01
Horses and ostrich		
Deep bedding	Cattle and Swine deep bedding, no mixing	0.01

N_2O emission factor for indirect emission is based on the IPCC default at 0.01 kg N_2O-N per kg NH_3-N and NO_x-N volatilized.

5.5.4 Activity data

Besides number of animal the activity data for direct emission also covers allocation of housing types and the N-excretion for each animal category.

The livestock production is based on the agricultural statistics (Statistics Den-mark), SEGES and CHR (see Chapter 5.2.1) and the numbers are given in Annex 3D Table 3D-2. The allocation of housing types is based on registration from the Danish AgriFish Agency (see Chapter 5.2.2 and Annex 3D Table 3D-1).

The total amount of nitrogen in manure for each animal category is based on the standards given in the "Danish Normative System", which builds on data from the farmers fertilizers plans – see chapter 5.2.3 for further details. It is important to point out that the N-excretion rates shown in Table 5.14 are values weighted for the subcategories and thus reflects the nitrogen excreted per AAP. The variations in N-excretion during 1990 and onwards reflect changes in feed intake, feed efficiency and allocation of animal in subcategories. The N-ex increases for dairy cattle as a result of higher milk yield. It also has to be noted that the average N-ex for swine has decreased significant due to improvement of feed efficiency.

Table 5.14 Nitrogen excretion, annual average 1990 – 2013, kg N per head per year (AAP).

CRF Table 3.B(b)	1990	1995	2000	2005	2010	2011	2012	2013
Livestock category								
Dairy cattle	129.49	125.23	125.31	133.30	138.63	138.47	138.03	138.82
Non-dairy	35.59	36.26	36.39	40.88	43.15	44.11	43.39	44.03
Sheep	7.84	8.11	6.64	6.64	6.64	6.64	6.64	6.64
Goats	21.18	21.90	16.95	15.83	16.40	16.43	16.55	16.54
Swine	11.84	9.70	9.61	9.19	7.81	7.98	8.01	8.00
Poultry	0.63	0.62	0.55	0.73	0.60	0.56	0.54	0.50
Horses	44.15	39.56	39.56	39.56	39.56	39.56	39.56	39.56
Fur farming	4.90	4.65	4.62	5.38	5.82	5.65	5.44	5.35
Deer	16.00	16.00	16.00	16.00	16.00	16.00	16.00	16.00
Ostrich	0.00	15.61	15.60	15.60	15.60	15.60	15.60	15.60
Pheasant	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
N-excretion, total, kt N per year	292	274	270	277	261	260	258	257
N-excretion, housing, kt N per year	258	239	235	251	239	239	237	235

Activity data for the indirect emission covers the volatilisation of NH_3 and NO_x which takes place in housing and during storage of the manure. These are based on national data.

Table 5.15 Volatilization of NH_3-N and NO_x-N in housing and during storage, 1990-2013

CRF Table 3.B(b)	1990	1995	2000	2005	2010	2011	2012	2013
NO_X-N, housing and storage	41 960	38 515	38 586	38 836	32 959	32 918	32 356	29 906
NH_3-N, housing and storage	146	132	114	95	73	68	66	66
Sum, tons N	42 106	38 648	38 699	38 931	33 032	32 985	32 422	29 972

5.5.5 Biogas treated slurry

In previous emission inventory Denmark has included a reduced N_2O emission for biogas treated slurry based on research from Sommer et al., 2001 and Sommer et al., 2004. However, the IPCC 2006 now includes guidelines for estimation of anaerobic digested manure and has assumed an emission factor of zero for biogas treated manure (IPCCC 2006 Table 10.21), which DK has chosen to use in the national inventory.

The Danish Energy Agency (DEA) provides annually the Danish energy statistics, which for 2013 shows that the produced energy from biogas production based on manure corresponds to 3.26PJ (DEA, 2014). Converted to amount of slurry, this corresponds to 2.7 million tons slurry, which corresponds to 7 % of the total amount of slurry. Refer to more details in chapter 5.4.5.

5.5.6 Time series consistency

The N_2O emission from manure management is estimated to 2.5 kt in 2013 of which only 0.5 is related to the indirect emission. The overall emission has decreased with 0.7 kt N_2O from 1990 – 2013 corresponding to 23 %. This decrease is mainly caused by a decreased emission from swine, which is driven by improvement of feed efficiency. The average N-ex per swine has decreased dramatically (see Table 5.14) from 1990 due to the farmers economic benefit of increased feed efficiency and due to environmental requirements.

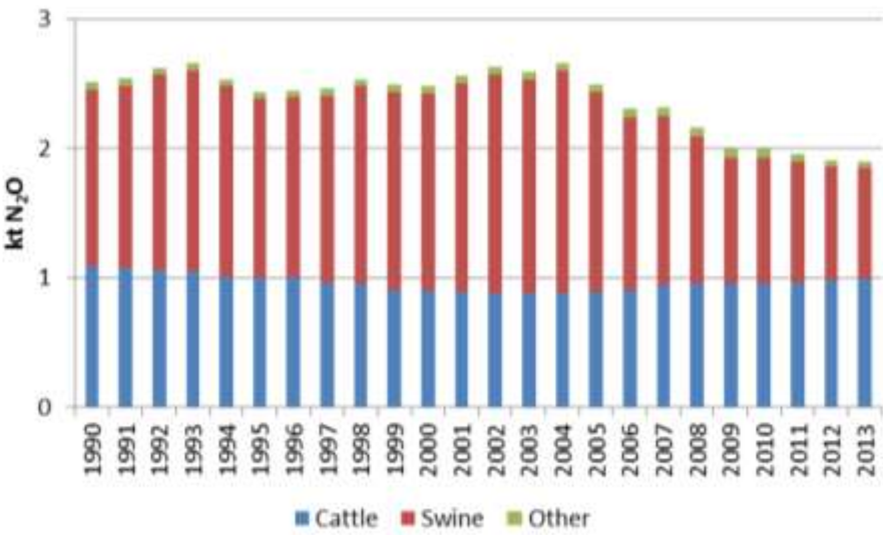

Figure 5.6 N_2O direct emission from manure management, 1990 - 2013.

5.6 N_2O emission from agricultural soils – direct emissions

5.6.1 Description

The emissions from agricultural soils – direct emissions, is emissions from inorganic N fertilizer, animal manure applied to soils, sewage sludge, industrial waste applied to soils, urine and dung deposited by grazing animals, crop residues, mineralization/immobilization and organic soils. Emission from agricultural soils – direct emissions contribute, in 2013 with 72 % of the N_2O emission from the agricultural sector. The largest sources are manure and inorganic N fertilizer applied on agricultural soils. The emission has overall decreased 27 %.

5.6.2 Methodological issues

To calculate the N_2O emission the IPCC Tier 1 methodology is used.

Emissions of N_2O are closely related to the nitrogen balance and all data concerning the evaporation of NH_3 and data for manure condition is applied from the national NH_3 emission inventory. This is described in great detail in Mikkelsen et al. (2014) and Denmark's annual inventory report to the UNECE Convention on Long-Range Transboundary Air Pollution (Nielsen et al., 2014).

5.6.3 Activity data

Area of agricultural land is shown in Annex 3D Table 3D-13.

Inorganic N fertilizer applied to soils

The amount of nitrogen (N) applied to soil by use of inorganic N fertilizer is estimated from sales estimates from the Danish AgriFish Agency, the source for the FAO database. Table 5.16 shows the consumption of each fertilizer type. Furthermore, the NH_3 emission factor for each fertilizer is given, based on the values from the EMEP/EEA Guidebook, which has been updated in 2013. The NH_3 emission depends on fertilizer type and the major part of the Danish emission is related to the use of calcium ammonium nitrate and NPK fertilizer, where the emission factor is 0.02 and 0.04 kg NH_3-N per kg N, respectively. The Danish $Frac_{GASF}$ is low compared to the IPCC default value.

This is due to the small consumption of urea (<1%), which has a high emission factor.

Table 5.16 Inorganic N fertilizer consumption 2013 and the NH_3 emission factors.

	NH_3 Emission factor[1] kg NH_3-N per kg N	Consumption[2] 1000 t N
Fertilizer type		
Calcium and boron calcium nitrate	0.11	0.1
Ammonium sulphate	0.01	5.5
Calcium ammonium nitrate and other nitrate types	0.02	97.6
Ammonium nitrate	0.04	5.7
Liquid ammonia	0.01	6.7
Urea	0.24	0.4
Other nitrogen fertilizer	0.04	19.3
Magnesium fertilizer	0.11	0.0
NPK-fertilizer	0.04	49.5
Diammonphosphate	0.11	1.2
Other NP fertilizer types	0.11	5.6
NK fertilizer	0.04	1.8
Total consumption of N in inorganic N fertilizer		193.6
National emission of NH_3-N, kt	6.00	
Average NH_3-N emission ($Frac_{GASF}$)	0.04	

1) EMEP/EEA (2013).

2) The Danish AgriFish Agency (2014).

The use of inorganic N fertilizer includes fertilizer used in parks, golf courses and private gardens. 1 % of the inorganic N fertilizer can be related to these uses outside the agricultural area.

As a result of increasing requirements for improved use of nitrogen in livestock manure and reduce the nitrogen loss to the environment, the consumption of nitrogen in inorganic N fertilizer has more than halved from 1990 to 2013 (Table 5.17).

Table 5.17 Nitrogen applied as fertilizer to agricultural soils 1990 – 2013.

	1990	1995	2000	2005	2010	2011	2012	2013
N content in inorganic N fertilizer, kt N	400	316	251	206	190	197	187	194
NH_3-N emission, kt NH_3-N	14	13	8	6	6	6	6	6
N in fertilizer applied on soil, kt N	387	303	243	200	184	191	181	188
N_2O emission, kt N_2O	6.07	4.77	3.82	3.14	2.89	3.00	2.85	2.95

Animal manure applied to soils

The amount of nitrogen applied to soil is estimated as the N-excretion in housings. The total N-excretion in housings from 1990 to 2013 has decreased by 7 %.

Table 5.18 Nitrogen applied as manure to agricultural soils 1990 – 2013.

	1990	1995	2000	2005	2010	2011	2012	2013
N-excretion, housing, kt N	258	239	235	251	246	237	239	239
N in manure applied on soil, kt N	214	200	197	212	213	206	208	208
N_2O emission, kt N_2O	3.36	3.15	3.09	3.34	3.34	3.24	3.27	3.27

Sewage sludge applied to soils

Information about sewage sludge applied on agricultural soil and the content of nitrogen is obtained from a series of reports published by the Danish Environmental Protection Agency. From 2005 the amount of sewage sludge and N content is based on the information registered in the fertilizer accounts controlled by The Danish AgriFish Agency.

Table 5.19 Emission from sewage sludge applied on agricultural soils 1990 – 2013.

	1990	1995	2000	2005	2010	2011	2012	2013
Nitrogen in sewage sludge, t N	3 115	4 635	3 625	2 173	2 692	2 592	2 470	2 457
N_2O emission, kt N_2O	0.05	0.07	0.06	0.03	0.04	0.04	0.04	0.04

Other organic fertilizers applied to soils

The category, "Other", includes emission sludge from industries applied to agricultural soils as fertilizer. Information about industrial waste applied on agricultural soil and the content of nitrogen is obtained from a series of reports published by the Danish Environmental Protection Agency. The recent official figures regarding the amount of sludge from the industrial waste are data covering year 2001 (Petersen & Kielland, 2003). From 2005 the amount of sludge from industries is based on the information registered in the fertilizer accounts controlled by The Danish AgriFish Agency. Amounts in 2002-2004 are interpolated.

Table 5.20 Emission from sludge from industries applied on agricultural soils 1990 – 2013.

	1990	1995	2000	2005	2010	2011	2012	2013
Nitrogen in industrial waste, t N	1 529	4 500	5 147	5 509	3 401	3 474	4 356	4 596
N_2O emission, kt N_2O	0.02	0.07	0.08	0.04	0.05	0.05	0.07	0.07

Urine and dung deposited by grazing animals

The amount of nitrogen deposited on grass is based on estimations from the NH_3 inventory. Grazing days is based on expert judgement from the Danish Agricultural Advisory Service. N-excretion on grass has decreased due to a reduction in the number of dairy cattle and days on grass.

Table 5.21 Nitrogen excreted on grass 1990 – 2013.

	1990	1995	2000	2005	2010	2011	2012	2013
N-excretion, grass, kt N	34	36	34	26	23	22	22	21
N_2O emission, kt	1.00	1.05	1.01	0.73	0.65	0.62	0.61	0.60

$Frac_{GASM}$

The $Frac_{GASM}$ express the fraction of N applied from all organic N fertilizers and dung and urine deposited by grazing animals volatilised as NH_3 and NO_x emission. Emission factors for NH_3 from the housing unit and storage are given in Annex 3D Table 3D-3 and 3D-4. The $Frac_{GASM}$ has decreased from 0.14 in 1990 to 0.08 in 2013 (Table 5.22). This is the result of an active strategy to improve the utilisation of the nitrogen in manure.

Table 5.22 $Frac_{GASM}$ 1990 – 2013.

	1990	1995	2000	2005	2010	2011	2012	2013
N applied, kt N	253	245	240	243	242	236	236	236
NH_3-N and NO_x- N emission, kt N	35	29	25	21	21	21	21	20
$Frac_{GASM}$	0.14	0.12	0.11	0.09	0.09	0.09	0.09	0.08

Crop residues

The emission from crop residues is based on the IPCC methodology 2006. Default values for all parameters given in IPCCC 2006 Table 11.2 are used except from dry matter values which are based on national values. The default N_2O emission factor at 0.01 kg N_2O-N per kg N in crop residues is used.

The dry matter fraction in crops is based on feed stuff table produced by SEGES, which has information for content of dry matter, fatty acid, protein, starch, sugar and energy for each crop type. The total amount of dry matter in harvest product used to estimate the "Above-ground residue dry matter $AG_{DM(T)}$" is based on data from Statistic Denmark. The $AG_{DM(T)}$ varies from year to year depending on the climate conditions – refer to Annex 3D Table 3D-14.

The amount of straw harvest used for feeding, bedding and bio fuel in power plants is taken into account because this quantity of removed nitrogen returns to the soil via manure. The amount of harvest straw is given in the annual census prepared by Statistic Denmark.

The total amount of nitrogen in crop residues is calculated and then the N-content in harvested straw is deducted. The N content in crop residues has increased from 122 million kg N in 1990 to 137 million kg N in 2013, which is mainly a result of a lower amount of N in harvest straw.

Table 5.23 N-content in crop residue, 1990-2013.

Million kg N	1990	1995	2000	2005	2010	2011	2012	2013
Total N in crop residue	145.8	132.5	134.1	140.2	148.0	154.1	157.4	151.0
N-content in harvest straw	24.2	20.1	17.4	14.6	14.8	14.7	16.5	14.2
CRF Table 3.D.4								
N in crop residue	121.6	112.4	116.7	125.6	133.1	139.4	140.9	136.8

The N_2O emission is depended on the N-amount in crop residues. Figure 5.7 shows the total N-content in crop residues allocated on the main crop types. Increase in N-content for maize and grass-clover mixtures in rotation is a result of increase of cultivated area. Some variations is seen from one year to another due to the annual climate conditions e.g. in 1992 the spring and summer was extremely dry.

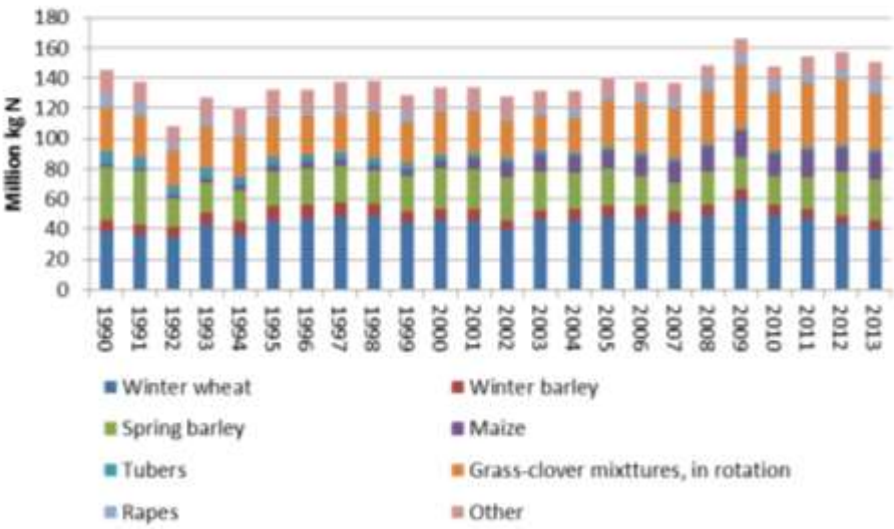

Figure 5.7 Total N in crop residue, 1990 – 2013.

Mineralization/immobilization associated with loss/gain of soil organic matter

The N mineralization from mineral soils associated with loss/gain of soil organic matter is estimated with a dynamical modelling tool - C-TOOL, which is used to estimate long-term changes in carbon from mineral soils. For a further description see LULUCF, Section 6.4.1. cropland and cropland management, mineral soils. C-TOOL is a 3-pooled dynamic model, where the approximate average half-live times for the three different pools, Fresh organic matter (FOM), Humified organic matter (HUM) and ROM (Resilient Organic Matter) are 0.6-0.7 years, 50 years and 600-800 years, respectively. The main part of biomass returned to soil each year is in the first and easiest degradable FOM pool. This pool consists of mainly fresh straw, fresh manure, root residues, fungi and small animals and fluctuates very much between years depending on the harvest yield and climatic conditions. The annual input to the FOM-pool is very close to the estimated annual amount of crop residues.

The estimated release of N_2O follow eq. equation 11.8, page 11.16 in IPCC 2006 Guidelines. The N_2O formation is estimated from the annual changes in the HUM and ROM pool. Changes in the FOM pool is considered as being the same as crop residues incorporated in the soil and to avoid double-counting changes in the FOM is not included.

C-TOOL is subdivided into 44 combinations of regions and soil types. Within each subdivision are only losses included in the estimate. Only losses in soil carbon are included in the estimate. If a subdivision one year has an increase in the HUM and ROM pool the release of N_2O by default are zero as only losses are included, cf. eq. 11.8. A C:N-ratio of 10, which are common in the fertilized Danish agricultural soils are used for all soil types. The recommended default value in the IPCC 2006 Guidelines is 15.

Cultivation of organic soils

N_2O emissions from cultivation of organic soils are based on the area of cropland and grassland with organic soils multiplied by the default emission factor given by the IPCC, 13 kg per ha cropland and 8.2 kg per ha grassland. EF is constant for all years 1990-2013. The area of organic soils is shown in Table 5.24. The area of organic soils has decreased from 1990 to 2013, see more in Chapter 6.4.1.

Table 5.24 Area of organic soils in ha, 1990-2013.

Year	1990	1995	2000	2005	2010	2011	2012	2013
Cropland	74 473	69 282	64 092	58 901	53 710	52 687	50 886	49 760
Grassland	23 254	21 633	20 013	18 392	16 771	16 771	17 171	16 810

5.6.4 Emission factors

In the calculation of N_2O from agricultural soils the N_2O emission factors for all sources are based on the default values given by the IPCC (IPCC, 2006). A NH_3 and N_2O emission factor overview is presented in Table 5.25.

Table 5.25 Emission factors – NH_3 and N_2O from agricultural soils – direct emissions.

	NH_3 emission factor (national data) Kg NH_3-N per kg N	N_2O emission factor (IPCC default value) kg N_2O -N per kg N
Inorganic N fertilizers	0.02	0.01
Animal manure applied to soils	0.20*	0.01
Sewage sludge applied to soils	0.02	0.01
Other organic fertilizers applied to soils		0.01
Urine and dung deposited by grazing animals	0.07	0.01-0.02
Crop residues		0.01
Mineralization/immobilization associated with loss/gain of soil organic matter		0.01
Cultivation of organic soils		8.2-13**

*Varies from year to year, has decreased from 0.28 in 1990.
**Unit: kg N_2O-N pr ha.

5.6.5 Time series consistency

Figure 5.8 shows the distribution and the development from 1990 to 2013 according to different N_2O sources. The increase from 2007 to 2008 was due to a rise in the use of inorganic N fertilizer, which can mainly be explained by stockpiling due to expectations of rising prices. In 2009 the emission has decreased again and since then nearly no changes have taken place. The overall decrease is mainly due to decrease in emission from inorganic N fertilizer, due to increasing requirements for improved use of nitrogen in livestock manure and reduction of nitrogen loss to the environment.

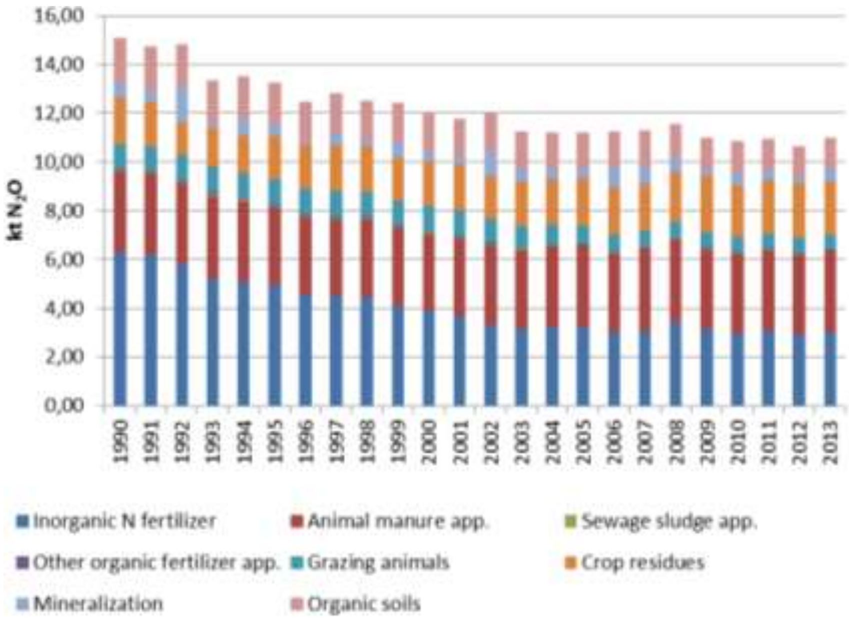

Figure 5.8 N_2O emissions from agricultural soils – direct emissions 1990 - 2013.

5.7 N_2O emission from agricultural soils – indirect emissions

5.7.1 Description

The emissions from agricultural soils – indirect emissions, are emissions from atmospheric deposition and from leaching and run-off. Agricultural soils – indirect emissions contribute, in 2013 with 11 % of the N_2O emission from the agricultural sector. The largest source is nitrogen leaching and run-off. The emission has overall decreased 51 % from 1990 to 2013.

5.7.2 Methodological issues

To estimate the emission of N_2O from atmospheric deposition, IPCC Tier 1 is applied.

Nitrogen, which is transported through the soil, can be transformed to N_2O. The IPCC recommends an N_2O emission factor of 0.0075 used, of which 0.0025 is for leaching to groundwater, 0.0025 for transport to watercourses (in IPCC definition called rivers) and 0.0025 for transport out to sea (in IPCC definition called estuaries). The N_2O emission from nitrogen leaching is a sum of the emission for all three parts calculated as:

$$N_2O_{leaching} = (N_{leach\text{-}ground} \cdot EF_{ground} + N_{leach\text{-}rivers} \cdot EF_{rivers} + N_{leach\text{-}estuatires} \cdot EF_{estuatires}) \cdot \frac{44}{28}$$

The calculation of the N_2O emission from nitrogen leaching and runoff is based on IPCC model and a national model. In the Action Plans for the Aquatic Environment, nitrogen leaching to groundwater, rivers and estuaries has been estimated, see Table 5.27. The calculation of N to the groundwater is based on two different models– SKEP/Daisy and N-LES (Børgesen & Grant, 2003) carried out by DCA and DCE, Aarhus University (see overview of model in Annex 3D Figure 3D-1). SKEP/DAISY is a dynamical crop growth model taking into account the growth factors, whereas N-LES is an empirical leaching model based on more than 1500 leaching studies performed in Denmark during the last 15 years. The models produce rather similar results for nitrogen leaching on a national basis (Waagepetersen et al., 2008). The SKEP/Daisy model has estimated the total N leached from 2003-2007 to be 172-159 thousand tonnes N, whereas N-LES model has estimated the total N leached to be 163-154 thousand tonnes in the same period. An average of the results from the two models is used in the emission inventory.

5.7.3 Activity data

Atmospheric deposition

Atmospheric deposition includes all agricultural NH_3 and NO_x emission sources included in the Danish NH_3 emission inventory (Nielsen et al., 2014). Emission from atmospheric deposition from livestock manure, housing and storage, is reported in Sector 3B. Atmospheric deposition reported in Sector 3D includes the emission from livestock manure applied to soils and deposited during grazing, inorganic N fertilizer, growing crops, NH_3-treated straw used as feed, field burning of crop residues and sewage sludge plus sludge from industrial production applied to agricultural soils.

The emission from atmospheric deposition has decreased from 1990 – 2013 as a result of the reduction in the total NH_3 emission, from 66 727 tonnes of N in 1990 to 32 461 in 2013.

Table 5.26 NH_3 and NO_x emission 2013.

	t NH_3-N	T NO_x-N
Manure	17 612	1 849
Inorganic N fertilizers	6 001	2 348
Crops	4 426	
NH_3 treated straw	0	
Burning of agricultural residues	92	
Sewage sludge and industrial sludge	46	86
Emission total	28 178	4 283
N_2O emission, kt		0.51

Nitrogen leaching and Run-off

Data concerning the N-leaching to rivers and estuaries are based on data from NOVANA (National Monitoring program of the Water Environment and Nature) received from the department of Bioscience, Aarhus University (Windorf et al., 2011). NOVANA is a monitoring program which includes monitoring of the ecologic, physic and chemical condition of water areas and transport of water and a range of substances, including N, to lakes and the sea (Wiberg-Larsen et al., 2010). These studies include measurements from 223 monitoring stations in all parts of Denmark and have been going on from the early 1990's.

Table 5.27 N leaching to groundwater, rivers and estuaries in kt, 1990-2013.

	1990	1995	2000	2005	2010	2011	2012	2013
Groundwater	267	235	179	160	168	165	159	161
Rivers	102	104	95	67	68	73	74	65
Estuaries	100	91	81	56	55	59	59	54

Figure 5.9 shows leaching from groundwater estimated in relation to the nitrogen applied to agricultural soils as livestock manure, inorganic N fertilizer and sludge. The average proportion of nitrogen leaching from groundwater has decreased from around 39 % in the middle of the nineties to around 35 % in 2013. The decline is due to implementation of measures to avoid the nitrogen surplus in the agricultural production by improved nitrogen in manure, to use catch crops during winter and ban application of manure in winter. The reduction in nitrogen applied is particularly due to the fall in the use of inorganic N fertilizer, which has been reduced by 50 % from 1990 to 2013.

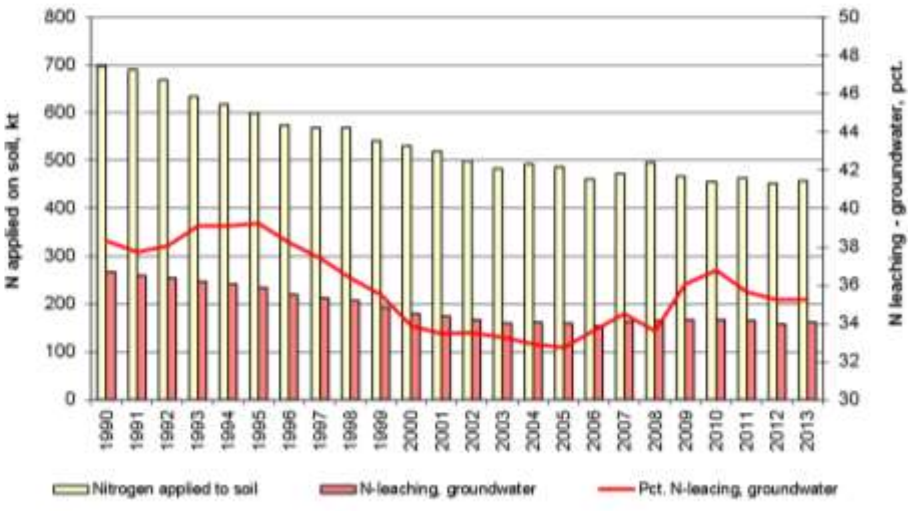

Figure 5.9 Nitrogen applied to agricultural soils and N-leaching, groundwater 1990-2013.

$Frac_{LEACH}$

The proportion of N input to soils lost through leaching and runoff ($Frac_{LEACH}$) used in the Danish emission inventory is in 2013 27 %, the default value of the IPCC is 30 %. $Frac_{LEACH}$ has decreased from 1990 and onwards. At the beginning of 1990s, manure was often applied in autumn. Now the main part of manure application takes place in the spring and early summer, where there is nearly no downward movement of soil water. The decrease in $Frac_{LEACH}$ over time is due to increasing environmental requirements and banning manure application after harvest. The data based on model estimates from DCA and DCE reflect the Danish conditions and are considered the best estimate.

5.7.4 Emission factors

In the calculation of N_2O from agricultural soils the N_2O emission factors for all sources are based on the default values given by the IPCC (IPCC, 2006). See Table 5.28.

Table 5.28 Emission factors – N_2O from agricultural soils – indirect emissions.

	N2O emission factor (IPCC default value) kg N2O -N per kg N
Atmospheric Deposition	0.01
Nitrogen Leaching and Run-off	0.0075*

*Groundwater = 0.0025, rivers = 0.0025 and estuaries = 0.0025.

5.7.5 Time series consistency

In Figure 5.10 is shown the emission of N_2O from agricultural soils – indirect emissions. Both emissions from atmospheric deposition and leaching ad run-off have decreased from 1990 to 2013. The dips and jumps are mainly due to change in emission from leaching and run-off.

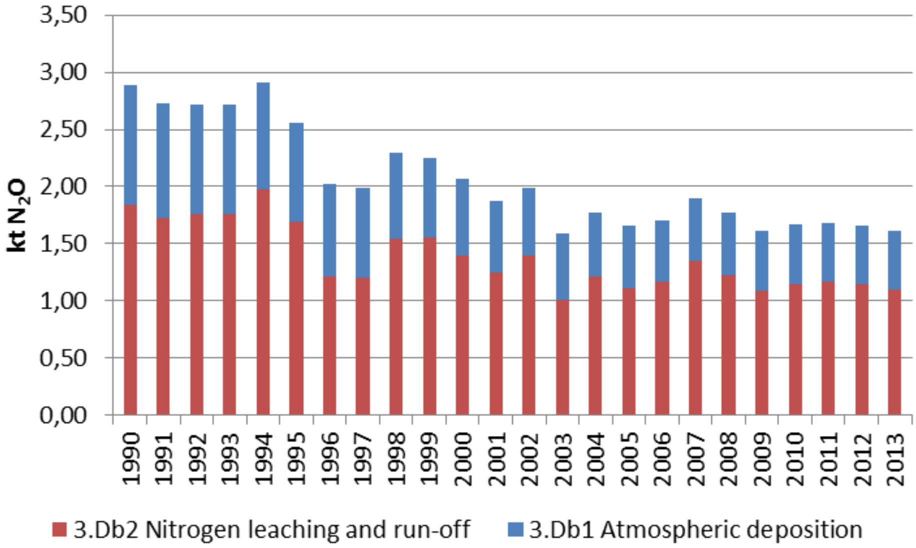

Figure 5.10 N_2O emissions from agricultural soils – indirect emissions 1990 – 2013.

5.8 Field burning of agricultural residues

5.8.1 Description

Field burning of agricultural residues has in Denmark been prohibited since 1990 and may only take place in connection with production of grass seeds on fields with repeated production and in cases of wet or broken bales of straw. From field burning is seen emissions of a series of different compounds and related to GHG emissions of the following compounds are estimated CH_4, N_2O, NO_x, CO, CO_2, SO_2 and NMVOC. For emission of NO_x, CO, CO_2, SO_x and NMVOC see the Danish Informative Inventory Report (Nielsen et al, 2014).

5.8.2 Methodological issues

Equation for calculating emission of various compounds:

$$E = BB \cdot \frac{EF}{1\,000\,000} \cdot FO$$

$$BB = CP \cdot FB \cdot FR_{dm}$$

Where:
E = emission of compounds, kt
BB = total burned biomass, kt dm
CP = crop production, t
FB = fraction burned in fields
FR_{dm} = dry matter fraction of residue
EF = emission factor, g per kg dm
FO = fraction oxidized

5.8.3 Activity data

The amount of burnt straw from the grass seed production is estimated as 15 % of the total amount produced. The amount of burnt bales of broken or wet bales of straw is estimated as 0.1 % of total amount of straw. Both estimates are based on an expert judgement by the Danish Agricultural Advisory Service. The total amounts are based on data from Statistics Denmark.

5.8.4 Emission factor

In Table 5.29 is shown the emission factors used to estimate emissions of CH_4 and N_2O.

Table 5.29 Factors for estimating emissions of CH_4 and N_2O, 2013.

		Crop production	Fraction burned in fields	Dry matter (dm) fraction of residue	Total Biomass burned	EF	Fraction oxidized	Emission
		t			kt dm	g per kg dm		kt
CH_4	Mixed cereals	5 805 500	0.001	0.85	4 935	2.7	0.90	0.012
CH_4	Straw from seeds of grass	368 500	0.15	0.85	46 984	2.7	0.90	0.114
N_2O	Mixed cereals	5 805 500	0.001	0.85	4 935	0.07	0.90	0.0003
N_2O	Straw from seeds of grass	368 500	0.15	0.85	46 984	0.07	0.90	0.003
Total CO_2 eqv								3.66

5.8.5 Time series consistency

The emission of CH_4, N_2O, NO_x, CO, CO_2, SO_2 and NMVOC from field burning contributes with less than 1 % of the national emission.

5.9 CO_2 from liming

5.9.1 Description

The emission of CO_2 from liming in Denmark occurs during liming with limestone. The emission of CO_2 from liming contributes with 99 % of the CO_2 emission from the agricultural sector.

5.9.2 Methodological issues

A Tier 1 method as given in IPCC 2006 is used.

5.9.3 Activity data

The amount of limestone used is based on the sales statistics. The amount used on the agricultural soils is collected by SEGES (Vestergaard, 2014). The amount of limestone used in private gardens is based on expert judgement (Andersen, 2004).

5.9.4 Emission factors

The emission factor is 4.4 kt CO_2 per kt limestone and the same for all years 1990 to 2013. It is based on the molecular weight for $CaCO_3$, CO_2 and C.

$$EF = M_{CaCO_3} \cdot M_C \cdot \frac{M_{CO_2}}{M_C}$$

Where:

EF Emission factor for CO_2 from liming

M_i Molecular weight for *i* molecule

5.9.5 Time series consistency

The emission of CO_2 from liming has overall decreased by 57 % from 1990 to 2013. As shown in Figure 5.11 the main decrease is occurring from 1990 to 1997 and is due to decrease in the amount of sold limestone.

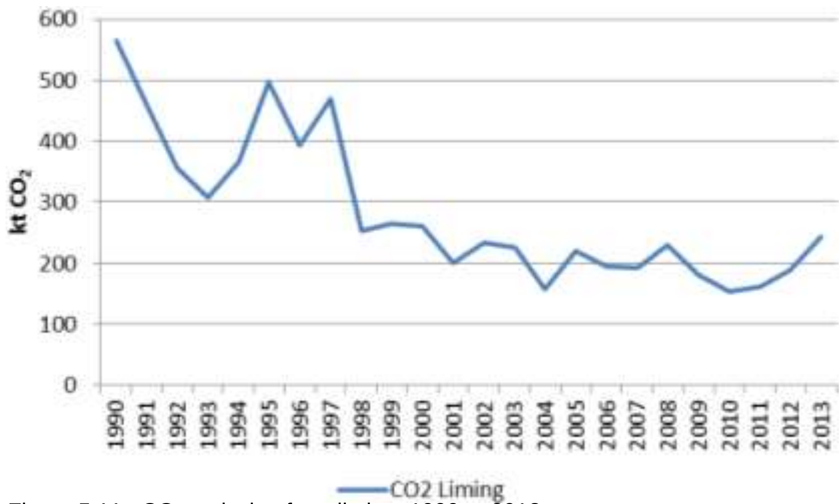

Figure 5.11 CO_2 emission from liming, 1990 to 2013.

5.10 CO_2 from urea

5.10.1 Description

Emission of CO_2 from use of urea contributes with less than 1 % of the CO_2 emission from the agricultural sector.

5.10.2 Methodological issues

A Tier 1 method as given in IPCC 2006 is used.

5.10.3 Activity data

The amount of urea used on agricultural soils is based on sales estimates from the Danish AgriFish Agency (Danish AgriFish Agency, 2014).

5.10.4 Emission factors

The default emission factor of 0.20 given in IPCC 2006 is used.

5.10.5 Time series consistency

In Figure 5.12 are shown the emission of CO_2 form use of urea. The emission has decreased with 96 % from 1990 to 2013, but the main decrease is occurring from 1990 to 2002. From 2003 to 2013 the emission is almost unaltered. The decrease is due to decrease in the use of urea.

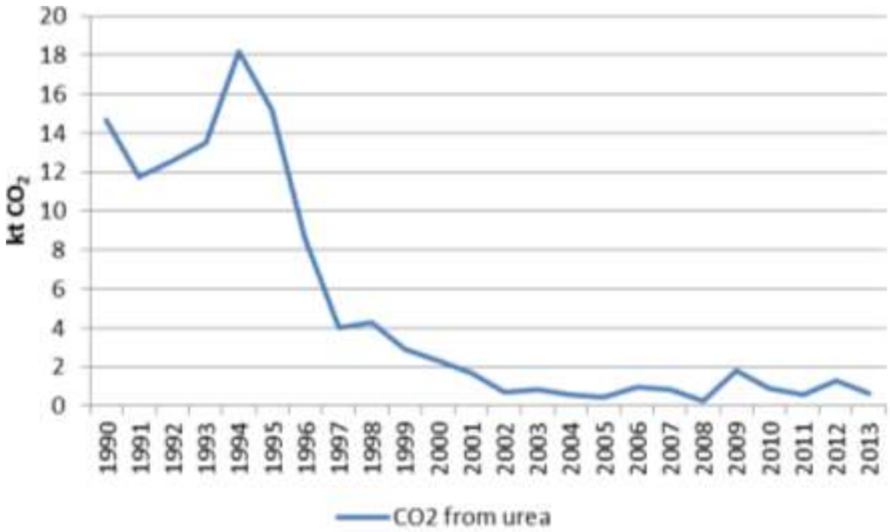

Figure 5.12 Emission of CO_2 from use of urea, 1990 to 2013.

5.11 CO_2 from other carbon-containing fertilizers

5.11.1 Description

Use of other carbon-containing fertilizers is in Denmark the use of calcium ammonium nitrate (CAN). The emission of CO_2 from CAN contributes with less than 1 % of the CO_2 emission from the agricultural sector.

5.11.2 Methodological issues

A Tier 1 method as given in IPCC 2006 is used.

5.11.3 Activity data

The amount of CAN used on agricultural soils is based on sales estimates from the Danish AgriFish Agency (Danish AgriFish Agency, 2014).

5.11.4 Emission factors

The emission factor is 0.026 kg CO_2 per kg CAN and the same for all years 1990 to 2013. It is based on the molecular weight:

$$EF = \left(\frac{\text{kg CaCO}_3}{\text{kg CAN}}/100\right) \cdot M_{CaCO_3} \cdot M_C \cdot \frac{M_{CO_2}}{M_C}$$

$$\frac{\text{kg CaCO}_3}{\text{kg CAN}} = \left(100 - M_{NH_4NO_3}\right)/M_{CaMg(CO_3)_2} \cdot M_{CaCO_3} \cdot 2$$

Where:

EF Emission factor for CO_2 from CAN

M_i Molecular weight for *i* molecule

5.11.5 Time series consistency

In Figure 5.13 are shown the emission of CO_2 form use of CAN. The emission has decreased with 96 % from 1990 to 2013, but the main decrease is occurring from 1990 to 1999. From 2000 to 2013 the emission is almost unaltered. The decrease is due to decrease in the use of CAN.

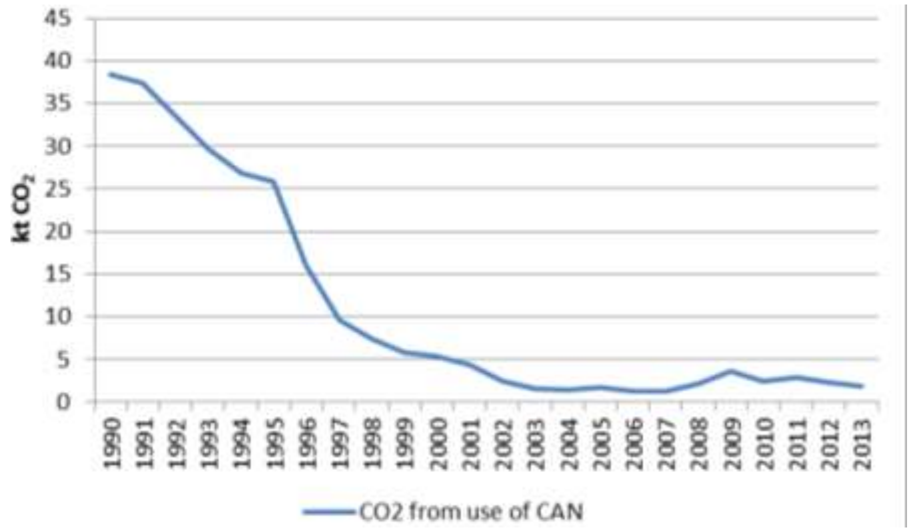

Figure 5.13 Emission of CO_2 from use of CAN, 1990 to 2013.

5.12 Uncertainties

Uncertainties are calculated using both Approach 1 and Approach 2; see Chapter 1.7 for a description of Approach 2 methodology. The same uncertainty values for activity data and emission factors are used for both Approach 1 and Approach 2.

5.12.1 Uncertainty values

Uncertainties regarding animal production, such as number of animals, feeding consumption, normative figures etc., are very small. The number of animals is estimated by Statistics Denmark and all cattle, sheep and goats have their own ID-number (ear tags) and, hence, uncertainty with regard to their numbers is almost non-existing. Statistics Denmark has estimated the uncertainty in the number of swine to be less than 1 %.

The Danish Normative System for animal excretions is based on data from the SEGES, which is the central office for all Danish agricultural advisory services. SEGES engages in a great deal of research as well as the collection of efficacy reports from Danish farmers for dairy production, meat production, swine production, etc. to optimise productivity in Danish agriculture. In total, feeding plans from 15-18 % of Danish dairy production, 25-30 % of swine production, 80-90 % of poultry production and approximately 100 %

of fur production are collected annually. These basic feeding plans are used to develop the standard values of the "Danish Normative System".

The normative figures (Poulsen et al. 2001) are comprised of arithmetic means. Based on feeding plans, the standard deviation in N-excretion rates between farms can be estimated to ±20 % for all animal types (Poulsen, DCA). However, due to the large number of farms included in the norm figures the arithmetic mean can be assumed as a very good estimate with a low uncertainty.

Data for hectares under cultivation is estimated by Statistics Denmark and the uncertainties are based on their estimates. For the most common crops the uncertainties are below 5 %.

For this submission the uncertainty estimates for both activity data and emission factors were re-evaluated and some adjustments were made. For CH_4 emission from enteric fermentation the uncertainty for activity data is the uncertainty for numbers of animals and the uncertainty for the emission factor is based on IPCC 2006. For the emission of CH_4 from manure management the uncertainty for the activity data is the uncertainty for number of animals and the distribution of housing types. The uncertainty for the emission factor is based on uncertainty given in IPCC 2006.

For the N_2O emission uncertainties, the activity data uncertainty is based on the uncertainties for NH_3 emission due to the high correlation between the NH_3 and N_2O emission (Nielsen et al, 2014). Uncertainties related to the N_2O emission factor are based on the IPCC 2006. See Table 5.30 for uncertainty values for the agricultural sector.

Table 5.30 Uncertainties values for activity data and emission factors for CH_4, N_2O and CO_2.

CRF category	Emission factor	Uncertainties value for activity data, %	Uncertainties value for emission factor, %
3A Enteric Fermentation	CH_4	2	20
3B Manure Management	CH_4	5	20
	N_2O	25	100
3B5 Atmospheric Deposition	N_2O	16	100
3D Agricultural Soils			
3Da Direct soil emissions			
3Da1 Inorganic N fertilizer	N_2O	3	100
3Da2a Animal manure applied to soils	N_2O	25	100
3Da2b Sewage sludge applied to soils	N_2O	15	100
3Da2c Other organic fertilizer applied to soils	N_2O	20	100
3Da3 Urine and dung deposited by grazing animals	N_2O	10	100
3Da4 Crop Residues	N_2O	25	100
3Da5 Mineralization	N_2O	50	100
3Da6 Cultivation of organic soils		20	100
3Db Indirect soil emissions			
3Db1 Atmospheric deposition	N_2O	16	100
3Db2 Leaching	N_2O	20	100
3F Field Burning of Agricultural Residue			
	CH_4	25	50
	N_2O	25	50
3G Liming	CO_2	5	100
3H Urea applicaton	CO_2	3	100
3I Other carbon-containing fertilizers	CO_2	3	100

5.12.2 Result of the uncertainty calculation

Table 5.31 shows the result of Approach 1 and Approach 2 uncertainty calculation for 2013. A calculation of 1990 gives nearly the same uncertainty values as for 2013, for all emission sources. The overall uncertainty calculation for the agricultural sector based on Approach 1 is estimated to ±19 %. Approach 2 calculation shows an uncertainty interval from -15 % to +21.

For most of the emission sources the uncertainty level based on Approach 2 are nearly at the same level as for Approach 1, see Figure 5.14. The two calculations can be considered as consistent. The lowest uncertainties are seen for CH_4 emission from enteric fermentation and manure management and the highest for emission form mineralization and this pattern is reflected in both calculations.

The biggest difference between Approach 1 and Approach 2 uncertainty calculations is seen for N_2O from manure management and CO_2 from liming and use of inorganic fertilizer.

Table 5.31 Comparison between Approach 1 and Approach 2 uncertainty calculation, 2013.

Uncertainty		Approach 1		Approach 2		
		Emission, kt CO_2 eqv	Uncertainty, %	Median emission, kt CO_2 eqv	Uncertainty, %	
			Lower and upper (±)		Lower (-)	Upper (+)
3 Agriculture total	CH_4 and N_2O	10 148	19	10 612	15	21
3A Enteric Fermentation	CH_4	3 467	20	3 475	12	14
3B Manure Management	CH_4 and N_2O					
	CH_4	1 918	21	1 926	11	12
	N_2O	615	103	664	40	74
3B5 Atmospheric deposition	N_2O	140	101	94	61	154
3D Agricultural Soils	N_2O					
3Da Direct soil emissions	N_2O					
3Da1 Inorganic N fertilizer	N_2O	906	100	904	60	152
3Da2a Animal manure applied to soils	N_2O	976	103	975	61	171
3Da2b Sewage sludge applied to soils	N_2O	12	101	11	61	153
3Da2c Other organic fertilizer applied to soils	N_2O	22	102	21	60	157
3Da3 Urine and dung deposited by grazing animals	N_2O	185	100	185	60	155
3Da4 Crop Residues	N_2O	640	103	640	62	164
3Da5 Mineralization	N_2O	169	112	170	65	185
3Da6 Cultivation of organic soils	N_2O	367	102	370	61	155
3Db Indirect soil emissions	N_2O					
3Db1 Atmospheric deposition	N_2O	152	101	133	61	155
3Db2 Leaching	N_2O	329	102	324	61	156
3F Field Burning of Agricultural Residues	CH_4 and N_2O					
	CH_4	3	56	3	42	73
	N_2O	1	56	1	42	72
3G Liming	CO_2	244	100	244	60	150
3H Urea application	CO_2	1	100	1	61	156
3I Other carbon-containing fertilizers	CO_2	2	100	2	61	147

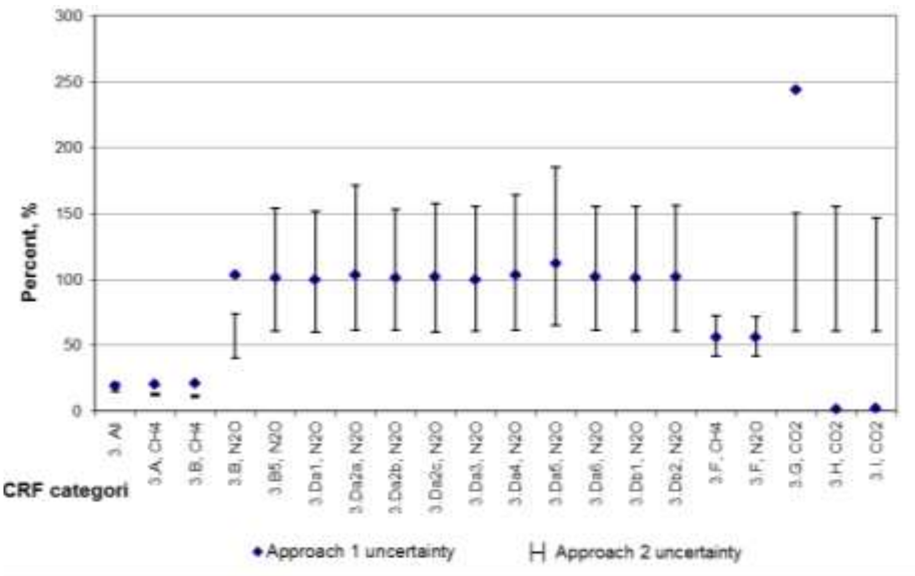

Figure 5.14 Approach 1 and Approach 2 uncertainties for the agricultural sector, 2013.

5.13 Quality assurance and quality control (QA/QC)

5.13.1 Verification

Enteric fermentation

Tier 2/Country Specific compared to IPCC Tier 2 method

A comparison between IPCC Tier 2 and Denmark's Tier2/Country Specific (CS) calculation method for enteric fermentation is made. In the IPCC Guidelines default values are given for dairy cattle and non-dairy cattle, therefore a comparison is made for these groups.

Calculations of IEFs are made by IPCC Tier 2, with both default and national values for Y_m, and Denmark's Tier 2/CS method. A comparison between IEFs (Table 5.32) shows that the Danish method gives a value for dairy cattle there is 4 % lower than the IPCC Tier 2 method and for non-dairy cattle the Danish method gives a value there is 3 % lower than the IPCC Tier 2.

Table 5.32 IEFs for enteric fermentation calculated by different methods, 2013.

kg CH_4 per animal per year	Tier 2 (IPCC Y_m)	Tier 2 (DK Y_m)	Tier 2/CS
Dairy cattle	142.6	131.7	136.6
Non-dairy cattle	40.8	38.3	39.4

The three different Tier 2 calculations for non-dairy cattle all show an IEF between 38.3-40.8 kg per head per year, which indicates that the Tier 2/CS used in the Danish inventory is reasonable. However, these values are lower compared to the Tier 1 default value at 57 kg per head per year given in the IPCC 2006, Table 10.11, which can be explained by a combination of lower Y_m for heifers and lower animal weight/lower feed intake.

The lower value for the IEF for dairy cattle is mainly due to a lower Y_m because GE is higher in the Danish method (Table 5.33). The Danish values for feed consumption are based on the Danish normative figures and the normative data are based on actual efficacy feeding controls or actual feeding plans at farm level, more info on GE calculations and Y_m is included in Chapter 5.3.2.

Table 5.33 GE for dairy cattle calculated by different methods, 2013.

MJ per animal per day	Tier 2 (IPCC Y_m and DK Y_m)	Tier 2/CS
Dairy cattle	334.6	346.3

Manure management

Nex compared to IPCC default

For non-dairy cattle, horses, poultry and fur-bearing animals Nex given by IPCC 2006 and the Danish Nex are at the same level. For dairy cattle Denmark has a higher Nex than given in IPCC 2006, this is probably due to the high milk production per cow at Danish dairy cattle. Nex for swine is for Denmark an average for the subcategories sows, weaners and fattening pigs. The Danish Nex is lower than the Nex for swine given in IPCC 2006, this is due to the high feed efficiency in Danish swine and the high share of weaners.

Table 5.34 Nex from IPCC and for Denmark.

IPCC	kg N per 1000 kg animal per day	Weight kg (DK)	kg N per animal per year	Denmark	kg N per animal per year
Dairy cattle	0.48	580	101.6	Dairy cattle	138.8
Other cattle	0.33	320	38.5	Non-dairy cattle	44.0
Swine - market	0.51	107	19.9	Swine	8.0
Swine - breeding	0.42	140	21.5		
Sheep	0.85	48.5	15.0	Sheep - mother	12.8
				Sheep - lamb	2.5
Goats	1.28	38.5	18.0	Goats	16.5
Horses	0.26	438	41.6	Horses	39.6
Hens	0.96	2	0.7	Poultry	0.5
Pullets	0.55	1.4	0.3		
Broilers	1.1	2	0.8		
Turkeys	0.74	14	3.8		
Ducks	0.83	3.7	1.1		
Mink			4.59	Fur-bearing animals	5.4
Fox			12.09		

MCF compared to IPCC default

See Annex 3D Table 3D-12 for the comparison of MCF given in IPCC 2006 and the MCF used in the Danish inventory. The MCF used in the Danish inventory is based on MCF given in IPCC 2006 but for systems with liquid and slurry manure an average MCF is estimated based on occurrence of natural crust cover.

Distribution of animals on housing types

Table 5.35 shows the distribution of animals on different housing types given in IPCC 2006 and the Danish national distribution. The main part of Danish dairy cattle are housed in systems with liquid/slurry manure whereas the distribution given by IPCC has a great part is housed in systems with solid manure. For non-dairy cattle the percentage of animal in systems with liquid/slurry and pasture, range and paddock are almost the same in IPCC and in Denmark. IPCC has a great part of non-dairy cattle on systems with solid manure, whereas this part of non-dairy cattle in the Denmark is in systems with deep litter that is the manure management system other. For swine the main part of the animals in Denmark is housed in systems with liquid/slurry, whereas the main part in IPCC is in systems with pit > 1 month.

Table 5.35 Distribution of animals on housing types IPCC 2006 vs. national.

	IPCC 2006			DK 2013		
	Dairy cattle	Other cattle	Swine	Dairy cattle	Non-dairy cattle	Swine
Lagoon	0	0	8.7	0	0	0
Liquid/slurry	35.7	25.2	0	82.3	31.3	89.1
Solid storage	36.8	39	13.7	1.7	0.7	0.2
Drylot	0	0	0	0	0	0
Pasture, range and paddock	20	32	-	5	29.4	0.1
Daily spread	7	1.8	2	0	0	0
Digester	0	0	0	5.9	0	8.4
Burned for fuel	0	0	-	0	0	0
Other	0.5	2	3	5.1	38.6	2.2
Pit < 1 month	-	-	2.8	0	0	0
Pit > 1 month	-	-	69.8	0	0	0

Calculation of VS based on GE and DM

In Figure 5.15, 5.16 and 5.17 are shown a comparison of the calculation of VS based on gross energy (GE) and manure. In the Danish inventory the calculation of VS is based on manure. For dairy cattle the two calculations follow the same trend, but the VS based on manure are higher than the one based on GE. This is mainly due to the inclusion of bedding.

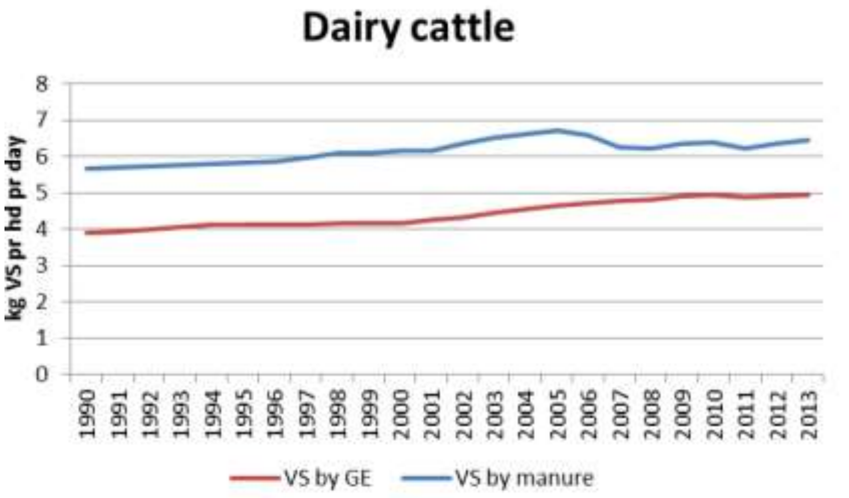

Figure 5.15 VS for dairy cattle based on GE and on manure.

For all non-dairy cattle VS based on manure are higher than the one based on GE and this is also mainly due to the inclusion of bedding. For bulls, VS based on manure, increase in 2001-2011 due to increase in the share of animals in housings with deep litter. From 2012 to 2013 the VS for bulls decrease due to reduction of bedding per animal per day given in the normative figures. VS based on manure for suckling cattle change due to increase in amount of manure per animal and decrease in dry matter (DM) in the manure for animals on some housing types. The decrease from 2006 to 2007 is due to division of suckling cattle in three wait classes with different amount of bedding per animal per day.

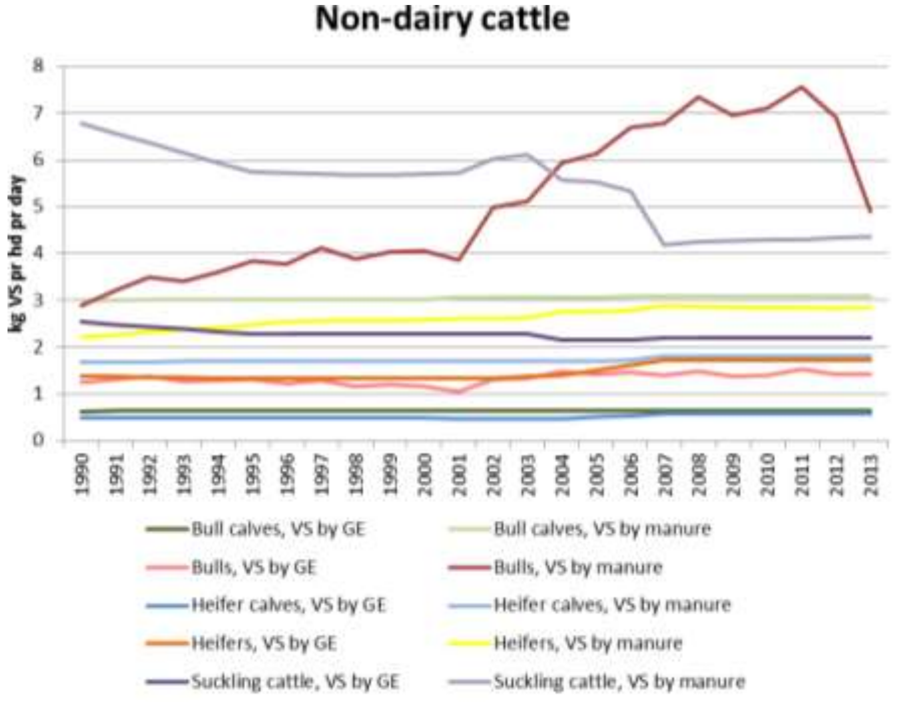

Figure 5.16 VS for non-dairy cattle based on GE and manure.

VS for weaners and fattening pigs based on both GE and manure follow the same trend, but the VS based on GE are a bit higher than VS based on manure. This is mainly due to high feed efficiency in Danish swine. The decrease in VS based on manure for sows in 2004-2007 is due to decrease in the share of animals in housings with bedding.

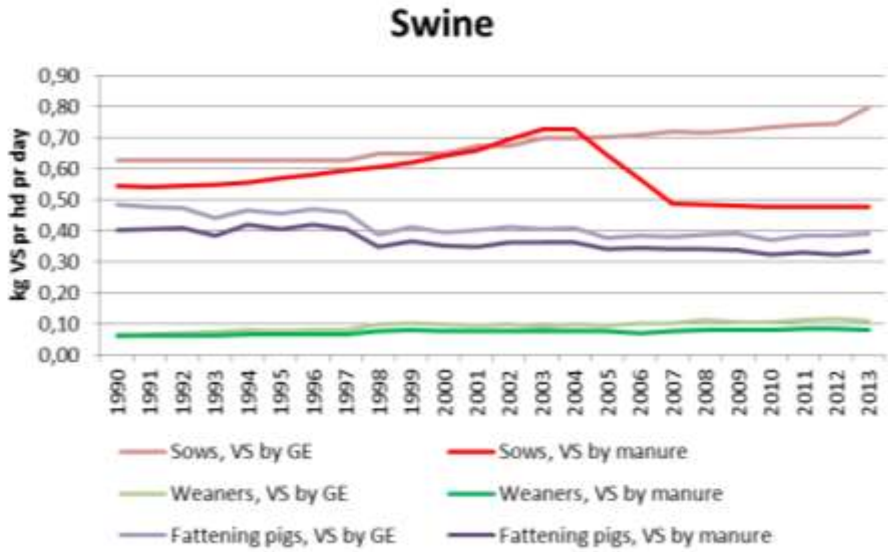

Figure 5.17 VS for swine based on GE and manure.

5.13.2 QA/QC plan

A first step of development and implementation of a general QA/QC plan for all sectors started in 2004 which is described in a publicised manual (Sørensen et al., 2005). The manual describes the concepts of quality work and how to handle quality management by using Critical Control Points and a list of Point of Measurements (Nielsen et al, 2013). For more detailed information of the structure in the general QA/QC plan refers to Chapter 1.6 for QA/QC.

A complete list Points of Measures (PM) are given in Table 1.2. PM related to the agricultural inventory is listed below in Chapter 5.13.3 and are primarily connected to data storage and data processing level 1. For PM not mentioned below please refer to Chapter 1.6.

The QA/QC work specific for the agricultural sector is still improved. The overall framework regarding a QA/QC plan for agriculture are constructed in form of six stages and each stage focus on quality assurance and quality check in different part of the inventory process. A more detailed set up for stage I, II and III are developed – refer to Annex 3D Table 3D-15.

The QA/QC procedure is divided in six stages as listed below:

Table 5.36 Stages of QA/QC procedure.

Stage I	**Check of input data** - check of data input in IDA are consistent with data from external data suppliers
Stage II	**Check of IDA data – overall** - check of recalculations for total emissions compared with the latest submission (2012) - check of total emissions for the total CO_2 eqv. and for each compound
Stage III	**Check of IDA data – specific** - check of annual changes of activity data, emission factors, IEF and other important variables as GE, Nex, housing system distribution, grazing days
Stage IV	**Check by comparing calculation with estimates from other institutions** - the total Nex for all livestock production estimated by DCA - the Register for fertilization controlled by the Danish AgriFish Agency
Stage V	**Check of data registered in CRF** - compare data in CRF with data from IDA
Stage VI	**Check of the inventory in general (external review)** - check that data is used correctly - check the methodology and the calculations

Stage I: Check of input data

At stage I, it is checked that all input data in IDA are consistent with data from the external data suppliers. Data from the Statistics Denmark have to be checked for the livestock production, slaughter data for poultry and pigs, check of land use and crop yield. Data input from the DCA have to be checked for feed intake, N-excretion, manure production, dry matter content and grazing days. Data from the Danish AgriFish Agency: distribution of housing systems and the use of nitrogen in inorganic N fertilizer.

Stage II: Check of IDA data - overall

Stage II includes check of the overall calculations in IDA, where the first step is to compare the inventory with the last reported emission inventory - submission 2014. In the case where an error covers the whole time series, it can be difficult to identify this error by checking the changes in inter-annual values. Therefore, a check of recalculations is needed.

Next step in stage II is a check of total emissions of CH_4, N_2O, NMVOC and the other compounds, which are related to the field burning of agricultural residues. For each compound a check of trends of time series 1990-2013 and inter-annual changes is provided. Significant jumps or dips from one year to another could indicate an error - otherwise it has to be explained.

Stage III: Check of IDA data - specific

At stage III, a check of specific variables in IDA is provided for both inter-annual changes and trends for the entire time series. Variables includes activity data, emission factors, IEFs and other important key variables such as feed intake, GE, Nex and housing system distribution.

Stage IV: Check by comparing calculation with estimates from other institutions

The purpose of stage IV is to verify the calculations in IDA, as far as external data estimations are available. For other purposes DCA for some years calculate the overall N excretion from the total livestock production in DK, which could be compared with the survey given in the emission inventory. Another possibility to check some of the IDA estimations is the information in the fertilizer accounts controlled by The Danish AgriFish Agency. Farmers with more than 10 animal units have to be registered and have to keep accounts of the N content in manure, received manure or other organic fertilizer. These comparisons will properly show some differences, which not necessarily indicate an error, but the most important cause of the difference has to be identified.

Stage V: Check of data registered in CRF

Stage V primarily focuses on the last reported year 2013 and the base year (1990), where all activity data, emissions and IEFs are checked. Furthermore, CRF sum emissions are checked with sum emissions in IDA. If an error is detected a more detailed check is done to find the reason for the error.

Stage VI: Check of the inventory in general

A detailed description of the methodology used to calculate the Danish agricultural emissions is published as a sectorial report for agriculture (Mikkelsen et al., 2014). General checks of the inventory include considerations of which data input is used, how they are used in the calculations and whether more accurate data are available. The review of the sectorial report addresses these issues and is a most valuable part of the QA of the agricultural sector.

Status for the QA/QC plan

The framework for working out a specific QA/QC plan for the agricultural sector is complete. Stage I-III is done as part of the process of inventory preparation, which has reduced the number of errors in the CRF and in this way meet the ERT recommendations. A more detailed list showing the checked variables of stage I – III is provided in Annex 3D Table 3D-15.

Concerning the stage IV we have provide some random checks but need to provide a more systematic check. We are aware of some external calculations which can be compared with the estimations in IDA – e.g. total N-excretion in manure calculated of DCA. Furthermore, some comparisons with the Register of Fertilisation administrated by the Danish AgriFish Agency can be provided.

Stage VI is implemented. Three reports describing the methodology in calculation of agricultural emissions in details are published (Mikkelsen et al., 2006, Mikkelsen et al., 2011 and Mikkelsen et al., 2014). All reports have been reviewed by experts not involved with the preparation of the emission inventory. The 2014 report was reviewed by: MST. The reviewers have reviewed all sections of the report. An updated version of the methodology report is planned to take place in 2015/2016.

5.13.3 QA/QC plan expressed in Critical Control Points and Point of Measurements

Data storage level 1

Data Storage level 1	3. Completeness	DS.1.3.1	Documentation showing that all possible national data sources are included by setting down the reasoning behind the selection of datasets.

The following external data are in used in the agricultural sector, in more details see Table 5.2:

- Data from the annual agricultural census made by Statistics Denmark.
- DCA, Aarhus University.
- The Danish AgriFish Agency.
- SEGES
- The Danish Energy Agency.
- Danish Environmental Protection Agency.

The emission factors come from various sources:

- IPCC guidelines.
- DCA, Aarhus University: NH_3 emission, CH_4 emission from enteric fermentation and manure management.

Statistics Denmark

The agricultural census made by Statistics Denmark is the main supply of basic agricultural data. In Denmark, all cattle, sheep and goats have to be registered individually and hence the uncertainty in the data is negligible. For all other animal types, farms having more than 10 animal units are registered.

DCA

The DCA is responsible for the delivery of N-excretion data for all animal and housing types. Data on feeding consumption on commercial farms are collected annually by SEGES from on-farm efficacy controls. For dairy cattle, data is collected from 15-20 % of all farms, for pigs, 25-30 % and for poultry and mink, 90-100 % of all farms. The farm data are used to calculate average N-excretion from different animal and housing types. Due to the large amount of farm data involved in the dataset, N-excretion is seen as a very good estimate for average N-excretion at the Danish livestock production.

Danish AgriFish Agency

Total area with the various agricultural crops is provided to the Danish AgriFish Agency via the agricultural subsidy system. For every parcel of land (via a vector-based field map with a resolution of >0.01 ha), the area planted with different crops is reported. If the total crop area within a parcel is larger than the parcel area, a manual control of the information is performed by the Agency. The area with different crops, therefore, represents a very precise estimate.

All farmers are obligated to do N-mineral accounting on a farm and field level with the N-excretion data from DCA. Data at farm level is reported annually to the Danish AgriFish Agency. The N figures also include the quantities of inorganic N fertilizers bought and sold. Suppliers of inorganic N fertilizers are required to report all N sales to commercial farmers to the Agency.

The total sold to farmers is very close to the amount imported by the suppliers, corrected for storage. The total amount of inorganic N fertilizer in Denmark is, therefore, a very precise estimate for the inorganic N fertilizer consumed. This is also valid for N-excretion in animal manure.

The Danish AgriFish Agency, as the controlling authority, performs analysis of feed sold to farmers. On average, 1600 to 2000 samples are analysed every year. Uncertainty in the data is seen as negligible. The data are used when estimating average energy in feedstuffs for pigs, poultry, fur animals, etc.

From 2005 the Danish AgriFish Agency provides data for distribution of housing type.

SEGES
SEGES is the central office for all Danish agricultural advisory services. SEGES carries out a considerable amount of research itself, as well as collecting efficacy reports from the Danish farmers for dairy production, meat production, pig production, etc., to optimise productivity in Danish agriculture. From SEGES data on housing type until 2004, grazing situation and information on application of manure is received.

The Danish Energy Agency
The amount of slurry treated in biogas plants is received from the Danish Energy Agency.

Danish Environmental Protection Agency
Information on the sludge from waste water treatment and the manufacturing industry and the amount applied on agricultural soil is obtained from the Danish Environmental Protection Agency.

Data Storage level 1	1. Accuracy	DS.1.1.1	General level of uncertainty for every dataset including the reasoning for the specific values

The most important emission source is related to the animal production. Uncertainty for the animal data is very low due to the very strict environmental laws in Denmark. Standard deviation regarding the numbers of cattle and pigs has been estimated to <0.7 %. For poultry the standard deviation is <2.1 %. For all years, 25-35 % of all holdings are included in the census. The standard deviation for N-excretion between farms is reported as 25 % for dairy cattle and pigs, but due to the large numbers involved in the estimation of the average N-excretion, the average is assumed to be a precise estimate for the Danish agricultural efficacy level.

Regarding uncertainties for the remaining emission sources see Chapter 5.12.

Data Storage level 1	1. Accuracy	DS.1.1.2	Quantification of the uncertainty level of every single data value including the reasoning for the specific values.

Please, refer to Chapter 5.12 and Table 5.30.

Data Storage level 1	1. Comparability	DS.1.2.1	Comparability of the data values with similar data from other countries, which are comparable with Denmark, and evaluation of discrepancy.

The Danish N-excretion levels are generally lower than IPCC default values. This is due to the highly skilled, professional and trained farmers in Denmark, with access to a highly competent advisory system.

The feed consumption per animal is in line with similar data from Sweden, although they are not quite comparable because Denmark is using feeding units (FE) which cannot easily be converted to energy content. Earlier, one feeding unit was defined as one kg of barley. Today, the calculations are more complicated and depend on animal type.

Data Storage level 1	4. Consistency	DS.1.4.1	The origin of external data has to be preserved whenever possible without explicit arguments (referring to other PMs).

External data received are stored in the original format in quality management database system.

Data Storage level 1	6. Robustness	DS.1.6.1	Explicit agreements between the external institution holding the data and DCE about the conditions of delivery.

DCE has established formal data agreements with all institutes and organisations which deliver data, to assure that the necessary data is available to prepare the inventory on time.

Data Storage level 1	6. Robustness	DS.1.6.2	At least two employees must have a detailed insight into the gathering of every external data set.

Please refer to Chapter 1.7.

Data Storage level 1	7. Transparency	DS.1.7.1	Summary of each dataset including the reasoning for selecting the specific dataset.

Please refer to DS 1.1.1.

Data Storage level 1	7. Transparency	DS.1.7.2	The archiving of data sets needs to be easy accessible for any person in the emission inventory.

Please refer to Chapter 1.7.

Data Storage level 1	7. Transparency	DS.1.7.3	References for citation for any external data set have to be available for any single value in any dataset.

A great deal of documentation already exists in the literature list, and also achieved in the quality management database system.

Data Storage level 1	7. Transparency	DS.1.7.4	Listing of external contacts for every dataset.

Statistics Denmark:

Mrs. Mona Larsen (mla@dst.dk)

Mr. Karsten K. Larsen (kkl@dst.dk)

DCA (Aarhus University):

Mrs. Hanne Damgaard Poulsen (hdp@anis.au.dk)

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Danish AgriFish Agency:

Mr. Troels Knudsen (tkn@naturerhverv.dk)

Mrs. Mette Thomsen (mth@naturerhverv.dk)

The Danish Energy Agency:

Mr. Søren Tafdrup (st@ens.dk)

The Danish Environmental Protection Agency:

Mrs. Linda Bagge (bagge@mst.dk)

Data processing level 1

Data Processing level 1	1. Accuracy	DP.1.1.1	Uncertainty assessment for every data source as input to Data Storage level 2 in relation to type of variability. (Distribution as: normal, log normal or other type of variability).

The Approach 1 methodology is used to calculate the uncertainties for the agricultural sector. The uncertainties are based on a combination of IPCC guidelines and expert judgement (Olesen et al., 2001, Poulsen et al., 2001) and a normal distribution is assumed. Approach 2 calculations is provided, please refer to Chapter 5.12.

Data Processing level 1	1. Accuracy	DP.1.1.2	Uncertainty assessment for every data source as input to Data Storage level 2 in relation to scale of variability (size of variation intervals).

Please refer to DP 1.1.1.

Data Processing level 1	1. Accuracy	DP.1.1.3	Evaluation of the methodological approach using international guidelines.

Denmark has worked out a report with a more detailed description of the methodological inventory approach in Mikkelsen et al. (2006), Mikkelsen et al. (2011) and an updated version in Mikkelsen et al. (2014). The first report has been reviewed by the Statistics Sweden, who is responsible for the Swedish agricultural inventory, the second was reviewed of qualified persons with comprehensive agricultural knowledge; Nicholas J. Hutchings from the DCA, Aarhus University and Johnny M. Andersen from the Faculty of Life Sciences, University of Copenhagen. The updated report has been reviewed by MST. None of the reviewers is involved in the preparation of the annual inventory.

Furthermore, data sources and calculation methodology developments are continuously discussed in cooperation with specialists and researchers in different institutes and research sections. As a consequence, both the data and methods are evaluated continually according to the latest knowledge and information.

Data Processing level 1	1. Accuracy	DP.1.1.4	Verification of calculation results using guideline values

The methodological approach is consistent with the IPCC 2006 Guidelines. See Chapter 5.13.1.

Data Processing level 1	2. Comparability	DP.1.2.1	The inventory calculation has to follow the international guidelines suggested by UNFCCC and IPCC.

The methodological approach is consistent with the IPCC 2006 Guidelines.

Data Processing level 1	3. Completeness	DP.1.3.1	Assessment of the most important quantitative knowledge which is lacking.

Regarding the reduction potential for biogas treated slurry, more information and investigation would be preferred. There is on-going work to increase the accuracy of this emission source.

Data Processing level 1	3. Completeness	DP.1.3.2	Assessment of the most important missing accessibility to critical data sources

All known major sources are included in the inventory. In Denmark, only very few data are restricted. Accessibility is not a key issue; it is more lack of data.

Data Processing level 1	4. Consistency	DP.1.4.1	In order to keep consistency at a high level, an explicit description of the activities needs to accompany any change in the calculation procedure

The calculation procedure is consistent for all years.

Data Processing level 1	4. Consistency	DP.1.4.2	Identification of parameters (e.g. activity data, constants) that are common to multiple source categories and confirmation that there is consistency in the values used for these parameters in the emission calculations

Please refer to Chapter 1.7.

Data Processing level 1	5. Correctness	DP.1.5.1	Show at least once, by independent calculation, the correctness of every data manipulation.

During the development of the model, thorough checks have been made by all persons involved in preparation of the agricultural section.

Data Processing level 1	5. Correctness	DP.1.5.2	Verification of calculation results using time series.

Time series for activity data, emission factors and national emission are performed to check consistency in the methodology, to avoid errors, to identify and explain considerable year to year variations.

Data Processing level 1	5. Correctness	DP.1.5.3	Verification of calculation results using other measures.

A comparison between IPCC Tier 2 method for enteric fermentation and Denmark's Tier 2/CS is made, see Chapter 5.13.1.

Data Processing level 1	5. Correctness	DP.1.5.4	Show one-to-one correctness between external data sources and the databases at Data Storage level 2

In the database key ids is used to identify the unique data. The data on DS level 1 is linked to the key id used in the database so a clear reference from DS level 1 to higher levels of both DP and DS is secured.

Data Processing level 1	6. Robustness	DP.1.6.1	Any calculation must be anchored to two responsible persons that can replace each other in the technical issue of performing the calculations.

Please refer to Chapter 1.7.

Data Processing level 1	7. Transparency	DP.1.7.1	The calculation principle and equations used must be described.

All calculation principles are described in the NIR and the documentation report (Mikkelsen et al., 2014).

Data Processing level 1	7. Transparency	DP.1.7.2	The theoretical reasoning for all methods must be described.

All theoretical reasoning is described in the NIR and the documentation report (Mikkelsen et al., 2014).

Data Processing level 1	7. Transparency	DP.1.7.3	Explicit listing of assumptions behind methods.

All theoretical reasoning is described in the NIR and the documentation report (Mikkelsen et al., 2014).

Data Processing level 1	7. Transparency	DP.1.7.4	Clear reference to dataset at Data Storage level 1.

In the database key ids is used to identify the unique data. The data on DS level 1 is linked to the key id used in the database so a clear reference from DS level 1 to higher levels of both DP and DS is secured.

Data Processing level 1	7. Transparency	DP.1.7.5	A manual log to collect information about recalculations.

Changes compared with the last emissions report are described in the NIR and the national emission changes is given in a table under the section, "Recalculation". The text describes whether the change is caused by changes in the dataset or changes in the methodology used. Furthermore a log table is filled in when data are updated or adjusted continuously.

Data storage and processing level 2

For point of measurements not mentioned below please refer to Chapter 1.7.

Data Storage level 2	5. Correctness	DS.2.5.1	Documentation of a correct connection between all data types at level 2 to data at level 1.

A manual check-list is under development for correct connection between all data types at level 1 and 2.

Data Processing level 2	5. Correctness	DS.2.5.2	Check if a correct data import to level 2 has been made.

A manual check-list is under development for correctness of data import to level 2.

5.14 Recalculation

Below follows an overview of improvements and recalculations implemented since the 2014 submission.

A range of changes in calculation of agricultural emissions 1990-2012 have taken place. The recalculation has contributed to a increase in the total agricultural emissions for the years 1990-2012 of up to 8 % (2003) given in CO_2 equivalent (Table 5.35).

Table 5.37 Changes in GHG emission in the agricultural sector compared with the CRF reported last year.

	1990	1995	2000	2005	2010	2011	2012
Previous inventory							
4.A Enteric Fermentation, CH_4	154.6	149.2	136.2	130.3	136.3	135.2	138.3
4.B Manure Management, CH_4	46.9	52.0	55.8	62.1	61.9	62.3	61.8
4.B Manure Management, N_2O	1.9	1.8	1.7	1.7	1.4	1.3	1.3
4.D Agricultural Soils, N_2O	24.8	21.9	19.0	17.1	16.2	16.5	16.1
4.F Field Burning of Agricultural Residues, CH_4	0.1	0.1	0.1	0.1	0.1	0.1	0.1
4.F Field Burning of Agricultural Residues, N_2O	0.002	0.003	0.003	0.004	0.003	0.003	0.003
Total in CO2-eqv., Mio. t	12.53	11.57	10.45	9.85	9.61	9.67	9.60
Recalculated							
3.A Enteric Fermentation	152.0	148.1	135.5	129.7	135.7	134.5	137.7
3.B Manure Management, CH_4	69.2	80.1	83.6	87.2	80.1	79.8	78.5
3.B Manure Management, N_2O	3.3	3.1	3.2	3.2	2.7	2.6	2.6
3.D Agricultural Soils, N_2O	18.0	15.8	14.1	12.9	12.5	12.7	12.3
3.F Field Burning of Agricultural Residues, CH_4	0.1	0.1	0.1	0.1	0.1	0.1	0.1
3.F Field Burning of Agricultural Residues, N_2O	0.002	0.003	0.003	0.004	0.003	0.003	0.003
Total in CO2-eqv., Mio. t	12.49	11.89	10.90	10.45	10.08	10.08	10.03
Change							
3.A Enteric Fermentation	-2.7	-1.1	-0.7	-0.6	-0.6	-0.7	-0.5
3.B Manure Management, CH_4	22.2	28.2	27.8	25.1	18.3	17.6	16.8
3.B Manure Management, N_2O	1.3	1.3	1.5	1.6	1.3	1.3	1.3
3.D Agricultural Soils, N_2O	-6.8	-6.1	-4.9	-4.2	-3.7	-3.8	-3.8
3.F Field Burning of Agricultural Residues, CH_4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3.F Field Burning of Agricultural Residues, N_2O	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total in CO2-eqv., Mio. t	-0.04	0.3	0.4	0.6	0.5	0.4	0.4
Change in pct.							
3.A Enteric Fermentation	-1.7	-0.7	-0.5	-0.5	-0.4	-0.6	-0.4
3.B Manure Management, CH_4	47.4	54.2	49.7	40.4	29.5	28.2	27.1
3.B Manure Management, N_2O	69.6	71.8	84.1	96.0	94.9	101.6	103.5
3.D Agricultural Soils, N_2O	-27.5	-27.7	-25.8	-24.5	-22.6	-23.3	-23.7
3.F Field Burning of Agricultural Residues, CH_4	0.0	0.0	0.0	0.0	0.0	0.0	-2.1
3.F Field Burning of Agricultural Residues, N_2O	0.0	0.0	0.0	0.0	0.0	0.0	-2.1
Total in pct.	-0.3	2.8	4.2	6.1	4.9	4.3	4.5

The most significant inventory changes are mentioned below:

The most important changes there have been made are change in the calculations so they follow IPCC 2006 Guidelines, which give rise to changes in a range of methods and change of Global Warming Potential (GWP).

Change in CH_4 from enteric fermentation is due to change in Y_m for non-dairy cattle, dairy cattle and sheep.

The main reason for the increase in CH_4 from manure management is due to new definitions of manure management systems and associated MCF.

The increase in N_2O from manure management is mainly due to two changes; change in definition of manure management systems and associated emission factors and that emission of N_2O from atmospheric deposition occurring in manure management systems are now reported in Sector 3B and not Sector 3D.

The decrease in N_2O from agricultural soils is due to a range of changes. First of all the emission factors has changed for almost all sources. NH_3-N is no longer subtracted from the amount of N used for calculation of N_2O. New method is used to calculate emissions for crop residues, emission from mineralization has been implemented and emission from N-fixing is no longer estimated.

Furthermore has some changes been made in the number of animals due to updated numbers in the statistics. These changes are minor important compared to the changes mentioned above.

Emission of CO_2 from liming and use of inorganic fertilizers in now reported in the agricultural sector, last submission this were reported in LULUCF.

5.15 Planned improvements

First step is taken to improve the documentation of the biogas treated slurry. The Energy Statistics got information of the total produced biogas production in Denmark and from another statistic; Energy production census it is possible to get plant specific information regarding the energy production. We still got the challenge with the energy potential in manure – how many tonnes of slurry are used to produce the total energy as given in the Energy Statistics. We still investigate the opportunity to use the register for fertilization where all farmers have to register the amount of nitrogen, but it requires a calculation from amount of nitrogen to amount of manure, which differ significant between the different animal types. Data revived from the Danish Biogas Plant Association could also be helpful to check the information of the amount of biogas treated slurry for the largest biogas plants.

Another issue which has to be investigated are improvements of the documentation regarding the emission reduction potential. This is planned to be done by a literature study. Other countries e.g. Germany also use biogas treated slurry and could have some available interesting data. Based on this knowledge it is hopefully possible to do some improvements in near future.

Besides the biogas issue, further work to document the comprehensive QC procedures is planned. Further focus will in particular be addressed to compare the calculations from our database IDA with estimates from other institutions as far as available data makes it possible (refer to "Stage V" in the QA/QC plan – see Chapter 5.13.2).

It is planned to provide a comparison of activity data for inorganic N fertilizer given by Statistics Denmark and given in FAO.

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6 LULUCF

6.1 Overview of the sector

This chapter covers only the territory of Denmark without the Faroe Islands and Greenland. Greenland is submitting a separate NIR and the corresponding CRF tables for the Greenlandic territory to UNFCCC. This can be found as Chapter 16 in this NIR.

The current submission is based on the IPCC 2006 GL combine emission factors from the 2013 Wetlands Supplement (IPCC 2014) Chapter 2 and 3 for CO_2, N_2O and CH_4 combined with national derived emission factors. No CH_4 emission from forest soils has been estimated as well as CO_2 and CH_4 from drained ditches on organic soils due to lack of data.

Denmark (Capital: Copenhagen) is situated around 56°N and 13°E and covers 43,098 km^2. No permanent ice is occurring and only very small insignificant areas with rocks. The climate is according to IPCC GPG 2003 cold and wet. Denmark is an intensive agricultural country where most of the area is affected by agriculture. The average temperature in the standard 30 year, 1961-1990 was 7.7°C with a minimum temperature in February of 0.3°C and a maximum in July of 17.0°C. Year 2013 had an average mean temperature of only 8.4°C which is 0.7°C above the average. (www.dmi.dk).

All land is classified into Forest, Cropland, Grassland, Wetlands, Settlements or Other Land.

6.1.1 Abbreviations

The following abbreviations are used in accordance with definitions in the IPCC guidelines:

A: Afforestation, areas with forest established after 1990 under article 3.3.
R: Reforestation, areas which have temporarily been unstocked for less than 10 years - included under article 3.4.
D: Deforestation, areas where forests are permanently removed to allow for other land use, included under article 3.3.
FF: Forest remaining Forest, areas remaining forest after 1990.
FL: Forest Land meeting the definition of forests.
CL: Cropland.
GL: Grassland.
SE: Settlements.
OL: Other land, unclassified land.
FM: Forest Management, areas managed under article 3.4.
HWP: Harvested Wood Products
CM: Cropland Management, areas managed under article 3.4.
GM: Grazing land Management, areas managed under article 3.4.

The LULUCF sector differs from the other sectors in that it contains both sources and sinks of carbon dioxide. Removals are given as negative figures and emissions are reported as positive figures according to the guidelines. For 2013 emissions from LULUCF were estimated to be a net source of approximately 2,630 Gg CO_2 equivalents or 4.2 % of the total reported Danish emission.

6.1.2 Methodology overview

Tier

The type of emission factor and the applied tier level for each emission source are shown in Table 6.1 below. The tier level has been determined based on the 2006 Guidebook (IPCC 2006).

Distinguishing between tier level 2 and 3 have been based on the emission factor. The tier levels definitions have been interpreted as follows:

- Tier 1: The emission factor is an IPCC default tier 1 value.
- Tier 2: The emission factors are country specific and based on either a few emission measurements or IPCC tier 2 emission factors.
- Tier 3: Based on models which include carbon stock changes methodologies.

Table 6.1 shows which of the source categories are key in any of the key source analysis[1] (including LULUCF, tier 1/tier 2, level/trend).

Table 6.1 Methodology and type of emission factor.

		Tier	EF	Key category
4.A.1 Forest	CO_2	Tier 3, Tier 1	CS, D	Yes, Level, Trend
4.A.2 Forest, Land converted to	CO_2	Tier 3, Tier 1	CS, D	No
4(II) Drainage and Rewetting	N_2O, CH_4	Tier 2	CS	No
4.B Cropland, Living biomass	CO_2	Tier 2	CS	No
4.B Cropland, Mineral soils	CO_2	Tier 3	CS, D	No
4.B Cropland, Organic soils	CO_2	Tier 2	CS, D	Yes, Level
4(III) Direct nitrous oxide (N_2O) emissions from nitrogen (N) mineralization/immobilization	N_2O	Tier 2	CS, D	No
4.C Grassland, Living biomass	CO_2	Tier 2	CS, D	No
4.C Grassland, Mineral soils	CO_2	Tier 2	CS, D	No
4.C Grassland, Organic soils	CO_2	Tier 2	CS, D	Yes
4.D Wetlands, Living biomass	CO_2	Tier 2	CS, D	No
4.D Wetlands, Soils	CO_2	Tier 2	CS, D	No
4.E.2 Settlements, Living biomass	CO_2	Tier 2	CS, D	No
4(V) Biomass Burning	CH_4	Tier 2, Tier 1	CS, D	No
4(V) Biomass Burning	N_2O	Tier 2, Tier 1	CS, D	No

6.1.3 Key categories

Key Category Analysis (KCA) tier 1 and 2 for year 1990, 2013 and trend for Denmark has been carried out in accordance with the IPCC Good Practice Guidance / IPCC Guidelines (2006). Table 6.2 shows which of the LULUCF categories are identified as key categories. The table is based on the analysis including LULUCF. Detailed key category analysis is shown in NIR Chapter 1.5 and Annex 1.

[1] Key category according to the KCA tier 1 or tier 2 for Denmark (excluding Greenland and Faroe Islands), including LULUCF, level 1990/ level 2013/ trend.

The CO_2 emissions from forests are key for forest remaining forest both on the level and the trend. For Cropland both mineral and organic soils are key sources as well as lime stone.

Table 6.2 Key categories, LULUCF.

			Tier 1			Tier 2		
			1990	2013	1990-2013	1990	2013	1990-2013
LULUCF	4.A.1 Forest land remaining forest land, Living biomass	CO_2		Level	Trend		Level	Trend
LULUCF	4.A.1 Forest land remaining forest land, Dead organic matter	CO_2		Level	Trend			
LULUCF	4.A.1 Forest land remaining forest land, Organic soils	CO_2		Level		Level	Level	Trend
LULUCF	4.B.1 Cropland remaining cropland, Mineral soils	CO_2	Level	Level	Trend	Level	Level	Trend
LULUCF	4.B.1 Cropland remaining cropland, Organic soils	CO_2	Level	Level	Trend	Level	Level	Trend
LULUCF	4.C.1 Grassland remaining grassland, Organic soils	CO_2	Level	Level		Level	Level	
LULUCF	4.E.2 Other land uses converted to settlements	CO_2						Trend
LULUCF	4.G Harvested wood products	CO_2					Level	Trend
LULUCF	4(III) Mineralization/immobilization	N_2O						Trend

6.1.4 Methods

Approximately 2/3 of the total Danish land area is cultivated and 14.8 per cent forested. Together with high number of cattle and pigs there is a high (environmental) pressure on the landscape. To reduce the impact an active policy has been adopted to protect the environment. The adopted policy aims at doubling the forested area within the next 80-100 years, restoration of former wetlands and establishment of protected national parks. In Denmark almost all natural habitats and all forests are protected. Therefore only limited conversions from forest or wetlands into cropland or grassland are occurring.

No permanent snow cover exists in Denmark and only a very small insignificant area with rocks and cliffs. OL is restricted to beaches and sand dunes. The official land area is 43 098 km^2. The land use matrix has estimated the total area to 43 056 km^2. This area includes rivers and lakes. The small discrepancy is due to differences in the definition of the 7000 km long coastline. The land use matrix uses the latest official vector maps from Danish Geodata Agency.

The emission data are reported in the CRF format under IPCC categories 4A (Forestry), 4B (Cropland), 4C (Grassland), 4D (Wetlands) and 4E (Settlements) and 4F (Other Land). Denmark is free from ice and rocks and Other Land therefore represents beaches and sand dunes. Fertilisation of Forests and Other Land is negligible and all fertiliser consumption is therefore reported in the agricultural sector. Field burning of biomass is prohibited in Denmark. Wildfires in forest are reported. This is normally around 0-10 hectares per year. Controlled burning of heathland is taking place of approximately 300-700 hectares to maintain the heath.

Savannas and rice cultivation do not occur in Denmark.

Estimation of carbon stock changes in the Danish forests is based on a combination of surveys and the National Forest Inventory (NFI). Changes in carbon stock in mineral cropland soils are estimated with a nationally developed Tier 3 model, whereas the emission calculation from organic soils is based on nationally developed emission factors.

The Cropland and Grassland area are based on agricultural EU subsidiary systems and very detailed. A drawback is, however, that one field in one year can be classified as CL and the next year as GL and then again converted back to CL. This creates large conversion rates between cropland and grassland but mainly towards grassland as an extensification currently takes place in Denmark (Table 6.3). The switching between CL and GL will, however, have no effect on the emission estimates except for an estimated release of N_2O from mineralisation of organic matter. Table 6.3 shows the overall development from 1990 to 2013. Afforestation is mainly taking place on CL and GL not previous classified as forest. Areas, which are deforestated are mainly converted to WE and clearance of trees as a consequence of clearing of some areas in the State forests towards more open areas and to CL due to conversion of Christmas trees agricultural cropland. Since 1990 more than 33 300 hectares have been changed into SE and other infrastructures. No land is converted into OL.

In the new land use matrix has a linear approach for all land use changes been adopted for the period 1990 to 2005 and from 2005 to 2011. From 2011 and onwards is used annually updated data from the different data suppliers. Some of these data are not updated annually and thus a time lag in the implementation of the land use changes may occur in some areas. Conversion to annual updates may create more fluctuating area changes than in the previous years.

Table 6.3 Land Use Change from 1. January 1990 to 31. December 2013 based on GIS vector layers and Earth Observations. The figures are given in hectares.

1990\2013	Forest	Cropland	Grassland	Wetlands	Lakes	Settlements	Other	Sum
Forest	538 048	1 328	1 721	2 145	346	385	0	543 973
Cropland	52 399	2 583 367	51 122	12 074	2 691	16 708	0	2 718 362
Grassland	47 001	75 859	257 368	3 294	2 691	16 161	0	402 374
Wetlands	20	593	0	69 809	6	81	0	70 509
Lakes	0	0	0	0	58 357	1	0	58 358
Settle-ments	0	0	0	0	0	485 543	0	485 543
Other	0	0	0	0	0	0	26 433	26 433
Sum	637 468	2 661 148	310 211	87 322	64 092	518 879	26 433	4 305 552
Percentage	14.8	61.8	7.2	2.0	1.5	12.1	0.6	100.0

Table 6.4 gives an overview of the emission from the LULUCF sector in Denmark. Forests have been sinks in Denmark for the last decade but due to the age distribution of the forests - containing a majority of mature forests - a slight decrease of the carbon stock is observed, as the old forests are regenerated with young trees and a net source were observed. The changes occur before the 2008-2012 period and the results can also partly be attributed to the recalculations - as described later. Currently the NFI indicates that forests are a sink. Cropland is ranging from being a net source from up to 5,460 Gg in 1990 to be a net source of 4,103 Gg in 2013. Fluctuations in the emission from CL between years are related to the actual crop yield that year and the climatic conditions. Low crop yields combined with high temperatures reduce the total amount of carbon in agricultural soils whereas a year with a high yield and low temperatures increase the carbon stock in soil. From 1990 and onwards a general decrease in the emission from Cropland is estimated

due to a higher incorporation of straw (ban of field burning), demands of growing of catch crops in the autumn, a change from low yielding spring barley to high yielding winter wheat, an increased carbon stock in hedgerows and that a continuous smaller area with organic agricultural soils cultivated. The area with restored wetlands has increased as well as peat excavation has been reduced since 1990 leading to a lower net source.

Table 6.4 Overall emission (Gg CO_2) from the LULUCF sector in Denmark, 1990 - 2013.

CO_2	1990	2000	2005	2010	2011	2012	2013
4. Land use, land-use change and forestry(2)	6,700.1	5,046.3	4,763.8	5,966.1	3,031.8	823.1	2,282.5
A. Forest land	331.9	-734.2	-530.8	859.2	-1,876.4	-3,903.6	-2,424.7
B. Cropland	5,460.5	4,970.4	4,517.8	4,223.7	4,078.5	3,857.3	3,584.5
C. Grassland	793.3	719.4	683.6	716.7	684.8	715.6	984.2
D. Wetlands	102.0	72.9	70.5	127.5	95.5	102.2	47.8
E. Settlements	12.4	17.8	22.7	39.0	49.4	51.5	90.7
F. Other land	NA, NO	NA, NO	NA, NO	NA, NO	NA, NO	NA, NO	NA, NO
G. Harvested wood products	10.2	8.9	30.7	67.4	104.1	111.5	124.6
CH_4	0.7	0.0	0.0	0.0	0.0	0.0	0.0
4. Land use, land-use change and forestry	NO	NO	NO	NO	NO	NO	NO
A. Forest land	0.2	0.2	22.7	60.0	97.4	104.8	117.8
B. Cropland	0.2	0.2	22.7	60.0	97.4	104.8	117.8
C. Grassland	NO	NO	NO	NO	NO	NO	NO
D. Wetlands	NO	NO	NO	NO	NO	NO	NO
E. Settlements	35.8	64.4	41.3	56.0	86.9	63.5	44.0
F. Other land	35.2	34.8	34.7	34.7	34.5	34.5	34.4
G. Harvested wood products	0.2	28.5	4.8	18.5	48.2	24.5	4.2
N_2O	0.1	0.2	0.3	0.5	0.5	0.5	0.7
4. Land use, land-use change and forestry	0.2	0.2	0.2	0.2	0.2	0.2	0.2
A. Forest land	NO	NO	NO	NO	NO	NO	NO
B. Cropland	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO
C. Grassland	6,700.1	5,046.3	4,763.8	5,966.1	3,031.8	823.1	2,282.5
D. Wetlands	331.9	-734.2	-530.8	859.2	-1,876.4	-3,903.6	-2,424.7
E. Settlements	5,460.5	4,970.4	4,517.8	4,223.7	4,078.5	3,857.3	3,584.5
F. Other land	793.3	719.4	683.6	716.7	684.8	715.6	984.2
G. Harvested wood products	102.0	72.9	70.5	127.5	95.5	102.2	47.8
H. Other	12.4	17.8	22.7	39.0	49.4	51.5	90.7

6.2 Forest remaining forest

6.2.1 Forest census

From 1881 to 2000, a National Forest Census has been carried out roughly every 10 years based on questionnaires sent to forest owners (Larsen and Johannsen, 2002). Since the data was based on questionnaires and not field observations, the actual forest definition may have varied. The basic definition was that the tree covered area should be minimum 0.5 ha to be a forest. There were no specific guidelines as to crown cover or the height of the trees. Open woodlands and open areas within the forest were generally not included. All values for growing stock, biomass or carbon pools based on data from the National Forest Census were estimated from the reported data on forest area and its distribution to main species, age class and site productivity classes. The two last censuses were carried out in 1990 and 2000.

The 1990 National Forest Census was based on reported forest statistics from 22,300 respondents, resulting in information on area, main species, age class distribution and productive indicators. The estimated forest area was 445

000 ha or 10.3 % of the land. Of the total forest area 64 % was coniferous forest and 34 % was deciduous forest (the remainder was temporarily unstocked). The total volume was estimated at 55.2 million cubic metres of which 57 % was coniferous.

The number of respondents in the 2000 National Forest Census was 32,300, which is considerably higher than in the 1990 survey. The change in the number of respondents probably contributed to the observed increase in forest area and growing stock between the 1990 and 2000 census. The estimated forest area was 486 000 ha or 11.3 % of the land. Of the total forest area 60 % was coniferous forest and 36 % was deciduous forest (the remainder was temporarily unstocked). The total volume was estimated at 77.9 million cubic metres of which 63 % was coniferous.

6.2.2 National forest inventory

In 2002, a new sample-based National Forest Inventory (NFI) was initiated (Nord-Larsen et al., 2008). This type of forest inventory is very similar to inventories used in other countries, e.g. Sweden or Norway. The NFI has replaced the National Forest Census.

The NFI is a continuous sample-based inventory with partial replacement of sample plots based on a 2 x 2 km grid covering the Danish land surface. At each grid intersection, a cluster of four circular plots (primary sampling unit, PSU) for measuring forest factors (e.g. wood volume) are placed in a 200 x 200 m grid. Each circular plot (secondary sampling unit, SSU) has a radius of 15 meters. When plots are intersected by different land-use classes or different forest stands, the individual plot is divided into tertiary sampling units (TSU).

About one third of the plots is assigned as permanent and is re-measured in subsequent inventories every five years. Two thirds are temporary and are moved randomly within the particular 2x2 km grid cell in subsequent inventories. The sample of permanent and temporary field plots has been systematically divided into five non-overlapping, interpenetrating panels that are each measured in one year and constitute a systematic sample of the entire country. Hence all the plots are measured in a 5-year cycle.

Based on analysis of aerial photos, each sample plot (SSU) is allocated to one of three basic categories, reflecting the likelihood of forest or other wooded land (OWL) cover in the plot: (0) Unlikely to contain forest or other wooded land cover, (1) Likely to contain forest, and (2) Likely to contain other wooded land. All plots in the last two categories are inventoried in the field.

In the most recent five-year rotation of the NFI (2008-2012) the number of clusters (PSU) and sample plots (SSU) were 4.138 and 9.425, respectively. On average 1,885 yr^{-1} plots (SSU) were identified as having forest or other wooded land cover based on the aerial photos and were thus selected for inventory. Only 3 sample plots were missing in the 2008-2012 inventories, due to difficulties of access.

Table 6.5 Number of measured clusters and sample plots in the five year rotation 2008-2012. Forest covered sample plots not inventoried in the field are denoted "Missing".

Year	Clusters			Sample plots		
	Total	Forest	Missing	Total	Forest	Missing
2008	2 212	804	2	8 644	1 896	3
2009	2 195	783	0	8 604	1 800	0
2010	2 196	793	0	8 614	1 855	0
2011	2 173	850	0	8 520	1 896	0
2012	2 200	908	0	8 617	1 978	0
Total	10 976	4 138	2	42 999	9425	3

Each plot is divided into three concentric circles with radius 3.5, 10 and 15 m. A single caliper measurement of diameter is made at breast height for all trees in the 3.5 m circle. Trees with diameter larger than 10 cm are measured in the 10 m circle and only trees larger than 40 cm are measured in the 15 m circle. On a random sample of 2-6 trees further measurements of total height, crown height, age and diameter at stump height are made and the presence of defoliation, discoloration, mast, mosses and lichens are recorded. The presence of regeneration on the plots is registered and the species, age and height of the regeneration are recorded. Stumps from trees harvested within a year from the measurement are measured for diameter.

Deadwood is measured on the sample plots. Standing deadwood with a diameter at breast height diameter larger than 4 cm is measured according to the same principles as live trees. Lying deadwood with a diameter of more than 10 cm is measured within the 15 m radius sample plot. Length of the lying deadwood is measured as the length of the tree that exceeds 10 cm in diameter and is within the sample plot. The diameter is measured at the middle of the lying deadwood measured for length. In addition to the size measurements of deadwood the degree of decay is recorded on an ordinal scale.

On each plot the presence and state of ditches and drainage conditions are recorded. Further, the presence of peatland is recorded and the depth of the peat is measured. Finally, the depth of the humus layer is measured on all plots.

6.2.3 Forest area mapping

Due to differences in methodologies major inconsistencies in forest areas and other forest variables are observed between the different forest inventories (i.e. the 1990 and 2000 Forest Census and the 2006 National Forest Inventory). With the objective to obtain time consistent and precise estimates of forest areas to report to UNFCC and under the Kyoto protocol, two projects have aimed at mapping the forest area in Denmark based on satellite images. Forest area and forest area change have been estimated for the years 1990, 2005 and 2011.

A land use/land cover map was produced for the base year 1990 and for the year 2005 based on EO data (23 August 1990) and other data collected from 1992-2005 and for 2005 using NFI in situ data. Forest maps are developed using Landsat imagery mainly Landsat 5 (TM) and 7 (ETM+) data to classify and estimate the area of forest cover types in Denmark. Portions of seven scenes covering the whole country were classified into forest and non-forest classes. The approach involved the integration of sampling, image processing, and estimation. A detailed QA/QC process was conducted in

2011/2012. Maps for 2011 were produced in 2012 (Huber & Tøttrup, 2012). In order to map the forest cover, multi-spectral and multi-temporal Landsat data of June 2010 and April 2011 with a spatial pixel resolution of 30 m were used. Except of Bornholm, none of the scenes was cloud-free. To still obtain a national forest cover map without gaps, the forest cover map of some minor areas is solely based on one image.

The product is specified by a Minimum Mapping Unit (MMU) of 0.5 ha, a geometric accuracy of < 15 m RMS and a thematic accuracy of 90 % +/- 5 % for the land use class Forest.

6.2.4 Forest definition

The forest definition adopted in the NFI is identical to the FAO definition (TBFRA, 2000). It includes "wooded areas larger than 0.5 ha, that are able to form a forest with a height of at least 5 m and crown cover of at least 10 %. The minimum width is 20 m." Temporarily non-wooded areas, fire breaks and other small open areas, that are an integrated part of the forest, are also included.

6.2.5 Estimation of forest carbon pools

In the following, procedures for estimating forest carbon pools are described. For the specific formulas used in the calculations, readers are referred to Annex 3F.

Estimation of forest area

Based on analysis of aerial photos, each sample plot (SSU) is allocated to one of three forest status categories (Z), reflecting the likelihood of forest or other wooded land (OWL) in the plot: (0) Unlikely to be covered by forest or other wooded land, (1) Likely to be covered by forest, and (2) Likely to be covered by other wooded land.

On individual sample plots (j) the forest cover percentage (X) is calculated as the proportion of the forest area (A) to the total plot area of the 15 m radius circle (A15). The average forest percentage ($\bar{X}$) on plots with forest status Z=1 (and 2) is calculated as the sum of the forest percentages times an indicator variable (R) that is 1 if Z equals 1 (or 2) and 0 otherwise, divided by the number of plots with forest status Z=1 (or 2).

The overall average forest percentage ($\bar{\bar{X}}$) is calculated as the sum of: (1) observed forest cover percentages of the individual sample plots, (2) the number of unobserved sample plots with forest status Z=1 times the average forest cover percentage of sample plots with forest status 1, and (3) the number of unobserved sample plots with forest status 2 times the average forest cover percentage of observed sample plots with forest status Z=2 divided by the number of observed and unobserved sample plots. In this context sample plots with forest status 0 are regarded as observed and assumed to have a forest cover percentage of 0. Finally, the overall forest area (A_{Forest}) is calculated as the overall average forest percentage times the total land area (A_{total}).

When estimating the forest area with a specific characteristic (*k*), such as forest established before or after 1990, the proportion of the plot area with the particular characteristic is found by summing the forested plot areas times an indicator variable (*R*) that is 1 if the plot has the *k*th characteristic and 0 otherwise. Subsequently the plot area with the *k*th characteristic is divided by the total forested plot area.

The total forest area with a particular characteristic (A_k) is found as the forest area percentage with the particular characteristic *k* times the total forest area.

Estimation of volume, biomass and carbon pools

For estimation of volume of individual trees, we use the volume functions developed for the most common Danish forest tree species (Madsen, 1985, Madsen 1987 and Madsen and Heusèrr 1993). The functions use individual tree diameter and height as well as quadratic mean diameter of the forest stand as independent variables.

Based on the trees measured for both height and diameter, diameter-height regressions are developed for each species and growth region. The functions use the observed mean height and mean diameter on each sample plot for creating localized regressions using the regression form suggested by Sloboda et al. (1993). For plots where no height measurements are available, generalized regressions are developed based on the Näslund-equation modified by Johannsen (1992).

The next step is to estimate the quadratic mean diameter of the trees on the sample plot. As the trees are measured in different concentric circles depending on their diameter, the basal area on each sample plot is estimated by scaling the basal area of each tree (standing or felled) according to the circular area in which the tree has been measured. A similar calculation has been made for the number of stems. Finally, mean squared diameter is calculated from the basal area and stem numbers.

Based on the diameter, estimated or measured height of individual trees and the squared mean diameter before thinning, the volume of individual trees is estimated using the species specific volume functions by Madsen (1987) and Madsen & Heusèrr (1993). The volume of trees less than 3 meters tall is estimated using an alternative function. The calculated volumes are total stem volume over bark for conifers and total above ground volume over bark for deciduous species.

Based on the estimated individual tree volumes, above ground biomass of the individual tree (stem biomass for conifers and total above ground biomass for broadleaves) is subsequently calculated as the total volume times the basic density. Species specific basic densities are based on Moltesen (1988), Skovsgaard et al. (2011) and Skovsgaard & Nord-Larsen (2012). Finally, total biomass (below and above ground) is estimated using expansion factors. For coniferous species an expansion factor model developed for Norway spruce (Skovsgaard et al. 2011) is applied whereas for deciduous species an expansion factor model developed for beech (Skovsgaard & Nord-Larsen, 2012) is used.

Total or regional volume, biomass and pools of carbon are estimated based on the estimates of individual tree volumes, biomass and carbon. First, volume, biomass or carbon per hectare is estimated for each of the concentric circles (c=3.5, 10 or 15 m radius) on each plot as the plot area depends on the diameter of the tree. Using the estimates from individual plots, the area weighted mean volume, biomass or carbon per hectare for the three concentric circles is estimated. The overall mean volume, biomass or carbon is estimated as the sum of the average volumes for the three circles. Finally, the total or regional volume, biomass or carbon is estimated as the forest area times the overall mean volume.

The total volume, biomass or carbon pools with a given characteristic are estimated in a similar way as the total figures. First, volume, biomass or carbon per hectare with the given characteristic is estimated for each of the concentric circles (c=3.5, 10 or 15 m radius) on each plot. Using the estimates from individual plots, the area weighted mean volume, biomass or carbon per hectare with the given characteristic for the three concentric circles is estimated. The overall mean volume, biomass or carbon is estimated as the sum of the average volumes for the three circles. Finally, the total or regional volume, biomass or carbon with the given characteristic is estimated as the forest area times the overall mean volume.

Dead wood volume, biomass and carbon content

The volume of standing dead trees is calculated similarly to the calculations for live trees. The volume of lying dead trees within the sample plot is calculated as the length of the dead wood times the cross sectional area at the middle of the dead wood. Biomass of the dead wood is calculated as the volume times the species specific basic density and a reduction factor according to the structural decay of the wood. Finally, carbon content for each standing or lying dead tree is calculated by multiplying the dead wood biomass by 0.5.

Total or regional volume, biomass and carbon pools of deadwood are estimated based on the estimates of volumes, biomass and carbon for individual dead trees or pieces of dead wood. First, deadwood volume, biomass or carbon per hectare is estimated for each of the concentric circles (*c*=3.5, 10 or 15 m radius). Estimates for lying dead wood are made using the 15 m circle. Using the estimates from individual plots, the area weighted mean volume, biomass or carbon per hectare of deadwood for the three concentric circles is estimated. The overall mean deadwood volume, biomass or carbon is estimated as the sum of the average volumes for the three circles. Finally, the total or regional deadwood volume, biomass or carbon is estimated as the forest area times the overall mean volume.

Forest floor

On each NFI plot (SSU) the depth of the forest floor is measured. As peatlands are reported specifically, a maximum depth of 15 cm is used in the calculations. Forest floor carbon for individual species is estimated by multiplication of the forest floor depth with the plot area, a species specific density (Vesterdal & Raulund-Rasmussen, 1998) and the fraction of the individual species. The fractions are based on the proportion of basal area of the individual species and total forest floor carbon is estimated by summation of forest floor carbon of the different species.

Average forest floor carbon is estimated by summation of forest floor carbon on the individual plots and dividing the total by the total plot area. Total forest floor carbon is subsequently estimated by multiplication of the average forest floor carbon by the total forest area.

Forest floor carbon stocks were assessed in the Forest Soil Inventory described below. However, there was no good basis to estimate change over time for this C pool as historic data were very scarce (see below). Hence changes in this C pool were based on depth measurements performed on all NFI plots.

Forest mineral soil

The NFI monitoring was supplemented by an additional forest soil inventory in order to document that forest soils is not an overlooked source for CO_2 emissions. The monitoring of soil C-stocks concerns two of the five carbon pools identified by IPCC (2003), litter (forest floor) and mineral soil to a depth of minimum 30 cm.

There is relatively good information from various soil profile databases on mineral soil carbon stocks to 1 m depth for well-drained Danish forest soils (Vejre et al., 2003; Krogh et al., 2003). However, there has been no spatially systematic study performed on temporal change in forest soil carbon. This has limited the possibility to explore the development in forest soil carbon stocks over time. This need is most pronounced for the quickly changing litter carbon pool and previous C stock estimations (Vejre et al., 2003) did not include moist and wet forest soils.

According to decision 16/CMP "A Party may choose not to account for a given pool in a commitment period if transparent and verifiable information is provided that the pool is not a source." The forest soil inventory aims to document that forest soils are not a major source for emissions of CO2, i.e. that there is no detectable depletion in soil carbon. This may be called the "no source principle"(Somogyi & Horvath, 2007). According to IPCC (2003) the necessary documentation may come from various sources such as:

- Representative and verifiable sampling and analysis to show that the pool has not decreased
- Reasoning based on sound knowledge of likely system responses
- Surveys of peer-reviewed literature for the activity, ecosystem type, region and pool in question
- Combined methods.

Based on literature and reasoning based on sound knowledge there is little evidence to support that the soil C pool in forest remaining forest would currently be changing to an extent that would be detectable by sampling with decadal frequency. For well-drained soils there may be temporal changes in soil carbon stocks at fine spatial resolution (ha-level) due to clear-cutting and replanting, but for the entire forest area with the whole range of age classes, the assumption is that soil carbon stocks are unchanged over time. In fact, the conversion toward close-to-nature forestry with continuous crown cover and abandonment of clearcutting suggests a future increase in soil carbon stocks rather than depletion (Brunner et al., 2005; Yanai et al., 2000). Areas with wet forest soils have probably been sources for increased CO_2 emissions in a period after ditching and drainage activities took place from the late 19th century. These activities led to increased mineralization of peaty soils. However, during the last 20 years, drainage activities have diminished strongly and has almost ceased in state forests as a direct effect of the Strategy for the State forests to convert to more Close to Nature Forest Management, including restoration of more natural hydrology (see more on http://www.naturstyrelsen.dk/). Here, the natural hydrological conditions are actively restored by filling up ditches in some areas. It is expected that this change in management will lead to sequestration of carbon as these forest soils gradually get wetter and the rate of decomposition decreases more than rates of organic matter inputs from litterfall. Exact information on the extent of restored natural hydrology is not available, but is being assessed based on expert judgement and information from forest managers.

Since the reporting in 2009 for 1990-2007, quantitative information has gradually become available; a project (SINKS) initiated in 2007 has delivered data on soil C change based on repeated sampling of soil C pools in forests remaining forests, and more data on soil C pools are being made available. The preliminary data suggest that forest soil C pools are not sources for CO_2 and thus support that more accurate estimate of litter and soil C pool removals/emissions do not need to be included in the reporting.

New data

The only existing systematic sampling of Danish forest soils has been conducted within the so-called Kvadratnet ("Agricultural Network", http://www.landbrugsinfo.dk/Planteavl/Goedskning/Naeringsstoffer/Kvadratnet-for-nitratundersoegelser/Sider/Startside.aspx). It was established in the 1980's in order to optimize the applied amounts of fertilizer in agriculture by monitoring nitrate leaching to groundwater resources in the most common land uses. Soil samples from the years around 1990 exist in soil storages. Given the time constraints of the commitment period and reporting deadlines, changes in soil carbon stocks could only be assessed by repeated sampling of soils within this monitoring grid.

The Agricultural monitoring grid is 7x7 km and by 1990 it included 108 plots with forest cover (Østergaard & Mamsen, 1990). Soil sampling and analysis was conducted in 1986-90 in all 108 forest plots of Agricultural Network, and a subset of 25 plots was resampled in 1994 (Breuning-Madsen & Olsson, 1995) as a part of the Pan-European forest monitoring programme, which uses these 25 plots for assessment of the forest condition. The 25 plots resampled in 1994 have been resampled again in 2007 as a part of the demonstration project BioSoil (http://forest.jrc.ec.europa.eu/contracts/-biosoil), under the Pan-European forest monitoring programme Forest Focus and in 2008/2009 the other 83 plots were resampled, except for one plot for which the land owner did not grant access to re-sampling.

Mineral soil samples from 1990 are thus available from 108 forest plots. The sampling was complete for the period 2007-2010, while soil-archive samples from 1990 were missing for six plots. Soil samples from 1986-1987 were used for one of these plots while it was not possible to retrieve archived soil samples for the last five plots. The sampling of O-horizons was also complete for the 108 plots for the period 2007-2009, while O-horizon samples from 1990 were of a very poor quality and only available from 32 plots. Consequently, forest floor samples from 1994 were used to represent forest floors in 1990, while results based on soil samples 0-100 cm from 1994 were only used to check other data.

The plots were in all cases (with a few exceptions due to practical circumstances) designed as a 50 x 50 m square. In 2007-09 ten forest floor and mineral soil cores were collected along a transect determined as the diagonal from the south-west to north-east corner of the square. In the 1990 16 soil cores were taken randomly across the square plot, while forest floor samples were only collected occasionally in an unspecified manner.

The O-horizon samples from 2007-2009 were area-based samples (Vesterdal & Raulund-Rasmussen, 1998) removed from a 25 x 25 cm area, that were brought to the laboratory in separate bags.

The mineral soil samples from 2007-2009 were taken in the ten sampling points where O-horizons had been removed. A 2-3 cm thick soil corer was used. The mineral soil samples from around 1990 were taken in a similar manner for the 16 sampling points. Samples from 4-5 different horizons were pooled in the field. Only one joint sample pr. plot per depth were analysed for carbon content. Hence, information on within-plot variation in soil carbon contents is not available. The division into horizons differed slightly between the three sampling campaigns: 1986-1990, 2007 and 2008/2009. In 1986-1990 the division was 0-25, 25-50, 50-75 and 75-100 cm; in 2007 (the 25 BioSoil plots) it was 0-10, 10-20, 20-40, 40-80 and 80-100 cm; and in 2008/2009 0-10, 10-25m 25-50, 50-75 and 75-100 cm.

In the lab, all samples were dried at 40°C until constant weight. Before sieving through a 2 mm sieve, more clay-rich mineral soil samples were crushed in a mortar, while sandy soil samples were gently crushed or sieved directly. The stones (>2 mm) left after sieving were weighed (DW_{stone}), while the fine soil (<2 mm) was dried at 40°C for at least 48 h, and then weighed (DW_{soil}). A sub-sample of the fine soil, about 20 g, was removed after thorough mixing for finer grinding in an agate mortar.

The ten O-horizon samples from each plot were weighed separately, and then ground in Retsch grinder through a 2 mm net. From each of the ten samples, 10 % of the material was removed after thorough mixing to get a pooled sample for the plot. About 100 ml of the pooled sample was removed after thorough mixing and then ground more finely in a Tecator mill.

Mineral soil samples were analysed by dry combustion (Elementar Analyzer) for total organic carbon (TOC) and O-horizon samples for total carbon by a laboratory certified according to ISO 10694. Analyses were done by Agrolab/ Institut Koldingen, Sarstedt, Germany.

For each of the plots, the mineral soil carbon stocks in 2007-2009, $C_{m\text{-}2009}$ (tonne C ha^{-1}), was calculated as

$$C_{m-2009} = \sum_{i=1}^{4(or5)} d_{m-2009} \cdot 10000 \cdot (1 - RV_{stone-2009}) \cdot \rho_{soil} \cdot c_{soil-2009}$$

where d_m is the depth of a given horizon (m), and ρ_{soil} is the bulk density of soils (g cm^{-3}) assessed by use of published pedotransfer functions (Vejre et al., 2003). $c_{soil\text{-}2009}$ is the C concentration (mg g^{-1}). RV_{stone} is the relative volume of the stone (versus that of the fine soil):

$$RV_{stone-2009} = \frac{DW_{stone-2009} / \rho_{stone}}{DW_{stone-2009} / \rho_{stone} + DW_{soil-2009} / \rho_{soil}}$$

where ρ_{stone}=2.65 g cm^{-3}, $DW_{soil\text{-}2009}$ (g)is the dry weight of the fine soil (<2 mm) in the soil samples from 2007-2009 and $DW_{stone\text{-}2009}$ (g) is correspondingly the weight of stones in the soil sample (>2 mm).

For each of the plots, the forest floor carbon stocks in 2007-2009, $C_{ff\text{-}2009}$ (t C ha^{-1}), was calculated as

$$C_{ff-2009} = \sum_{i=1}^{10} DW_{ff-2009,i} \cdot 0.0016 \cdot c_{ff-2009}$$

where $DW_{ff\text{-}2009,i}$ (g dry weight) is the dry weight of sample number i, i=1-10 and $c_{ff\text{-}2009}$ is the C concentration of the pooled sample per plot (mg g^{-1})

The mineral soil dry weight in 1990 was calculated in the same manner as for 2007-2009, assuming that the relative stone volume was identical to that of 2007-2009. The forest floor depth was, however, not measured in 1990, nor was an area-based forest floor weight recorded. Forest floor depth (d_{ff}, m) measured for profiles on 25 plots in 1994, was used instead, while forest floor densities for the individual plots were obtained from the new measurements performed in 2007. For these 25 plots, forest floor C-stocks in 1990, $C_{ff\text{-}1990}$ (tonne C ha-1) were calculated as

$$C_{ff-1990} = d_{ff} \cdot 10000 \cdot \rho_{ff-2007} \cdot c_{ff-1990}$$

where $c_{ff\text{-}1990}$ (mg g^{-1}) is the carbon concentration of the forest floor samples from 1994 (measured in 2007), and $\rho_{ff\text{-}2007}$ (g m^{-3}) is the average bulk density of the forest floor for the individual plot as measured in 2007:

$$\rho_{ff-2009} = \frac{\sum_{i=1}^{10} DW_{ff,i}}{0.25 \cdot 0.25}$$

Considering the forest structure in Denmark with many small forests (about 70 % of the forest estates are of less than 5 ha) the "Kvadranet" is a very coarse grid. Even if the grid was fully sampled, it is therefore unlikely that the 108 plots represent the Danish forest area of approximately 500 000 ha. We thus evaluated based on power analyses that further sampling was necessary for future monitoring and chose to include a randomly selected subset of the permanent plots of the National Forest Inventory (NFI) for this purpose. A total of 277 plots were sampled.

It will not be possible, as with the Agricultural Network, to resample soils of the NFI plots for changes in soil C within the short time frame before Kyoto Protocol reporting. From 2012 and onward the NFI plots can be resampled to better support the work to demonstrate that soil carbon stocks are not a source for CO_2 emissions. As the Danish reporting of the three forest carbon pools aboveground biomass, belowground biomass and dead wood is based on the NFI, this will also ensure the consistency of monitoring of all five forest carbon pools defined by IPCC (2003). In the first reporting efforts, however, information on C-stocks and site properties from the NFI will enable better upscaling of results from Agricultural Network to the Danish forest area.

Changes in forest soil carbon stocks in forests planted before 1990

The preliminary results from the Agricultural Network showed that there is a large variation in soil C pools among sites for both forest floors (only 32 plots) and mineral soils. The mean C pool of forest floors was about 22 and 28 tonnes C ha^{-1} in 1990 and 2007-09, respectively. The corresponding C pools for mineral soils were 156 in 1990 and 157 tonnes C ha^{-1} in 2007-09 (Table 6.6). A simple t-test of the mean changes in forest floor and mineral soils pools between 1990 and 2007-2009 (5.6 and 1.5 tonnes C ha^{-1} yr^{-1} respectively) indicate that changes were not significant (Table 6.7, Figure 6.1a-b).

Table 6.6 Basic statistics on soil C pools measured in the Agricultural Network.

	Mean Pool	Standard deviation	Minimum	Maximum
	tonne C ha^{-1}			
Forest floor 1990	22.12	19.12	0.76	80.34
Forest floor 2007-2009	27.68	30.05	3.94	164.48
Mineral soil 1990	155.78	115.91	29.31	848.14
Mineral soil 2007-2009	157.26	100.34	18.66	853.08

Table 6.7 Basic statistics on the differences in C soil pools between 1990 and 2007-2009 and statistics from a simple t-test (H_0: change in soil C-stock = 0).

	Total number of sites	Number of sites in t-test	Mean change	Std	Minimum	Maximum	P-value
			(tonne C ha^{-1})				
Forest floor	108	31	5.56	24.78	-61.44	84.13	0.22
Mineral soil	108	104	1.48	47.56	-182.62	131.51	0.75

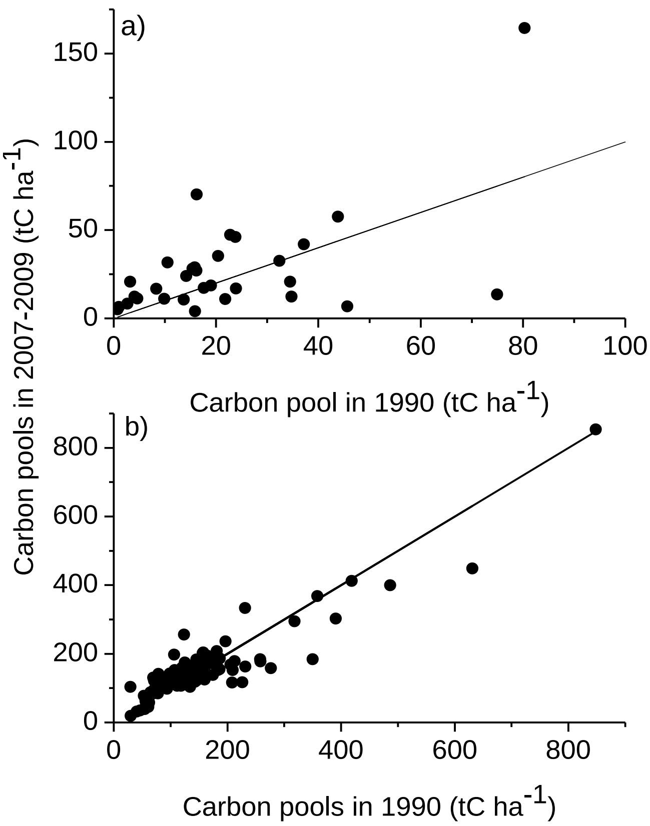

Figure 6.1 C pools in forest soils for forest before 1990. a) Forest floor C in 2007-2009 versus 1990, b) Mineral soil C in 2007-2009 versus 1990. Lines: y=x.

Some mineral soils had one or several horizons of organic origin and these soils had very high soil C-stocks to 1 m depth (>300 tonne C ha^{-1}), and these will probably be handled separately in further work with the data. Determination of true changes in organic soils requires that the total depth of the organic layer is known, while soils were only sampled until 1 m in SINKS.

Carbon pools 2008-2012

Carbon pools in live and dead biomass estimated for the most recent rotation of the NFI (2008-2012) is 41 million tonnes C. The live above ground biomass carbon makes up about 82 % of the total carbon in biomass and dead wood makes up only 1.7 % of the total. Carbon in biomass in forests established after 1990 make up 3.0 % of the total.

Table 6.8 Carbon in forest biomass for NFI rotations with reference years 2008-2012.

			2008	2009	2010	2011	2012	2013
Forests established before 1990	Area, ha		540,124	539,600	539,076	538,553	538,189	538,048
	Live biomass	Above ground	31,109	29,234	29,189	29,965	30,444	31,172
		Below ground	6,086	5,919	5,939	6,095	6,200	6,336
	Dead wood		545	564	635	653	673	693
	Forest soil	Litter	6,042	6,048	6,572	6,839	7,095	6,929
Forests established after 1990	Area, ha		79,787	84,033	88,279	92,525	94,358	99,420
	Live biomass	Above ground	735	976	985	943	854	875
		Below ground	162	230	232	216	189	187
	Dead wood		23	24	23	20	16	11
	Forest soil	Litter	342	358	380	379	380	384

The amount of carbon in biomass in forests established before 1990 has been slowly increasing since 2006. Based on preliminary results of an evaluation of the subsequent measurement cycles 2002-2006 and 2007-2011, the increase is at least partly caused by an increased average biomass per hectare. However, part of the increase is also due to an increase in forest area, which is caused by improved detection of forest caused by improvements of aerial photos used for this.

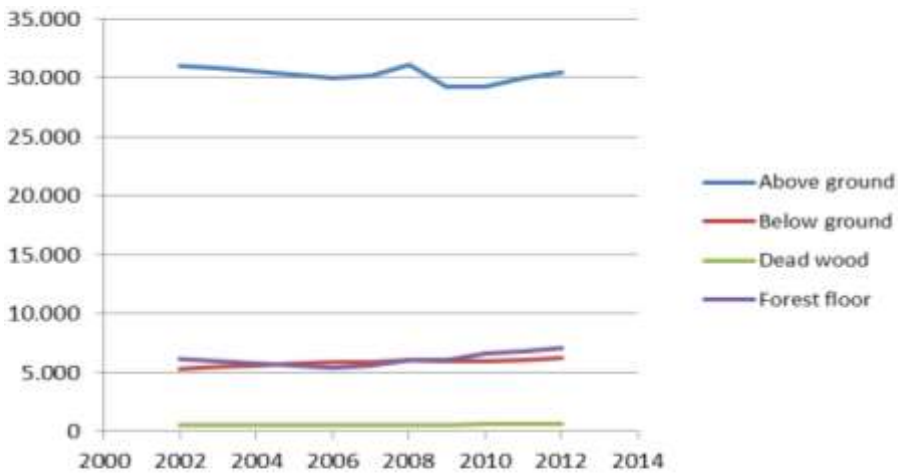

Figure 6.2 Forest carbon in forests established before 1990 estimated from NFI data from 2002-2012. Note that estimates for 2002-2005 are based on only 1-4 years of measurements. Only from 2006 the estimates are based on a full five-year rotation of the NFI.

The amount of carbon in biomass in forests established after 1990 has been increasing rapidly during the time of NFI measurements. The very low estimates of forest carbon at the beginning of the NFI measurements may in part be due to a large number of plots not measured in the field as a result of start-up problems, which may have biased the results. Also, in the early measurements aerial photographs were of a poorer quality and recent afforestations may have been difficult to detect.

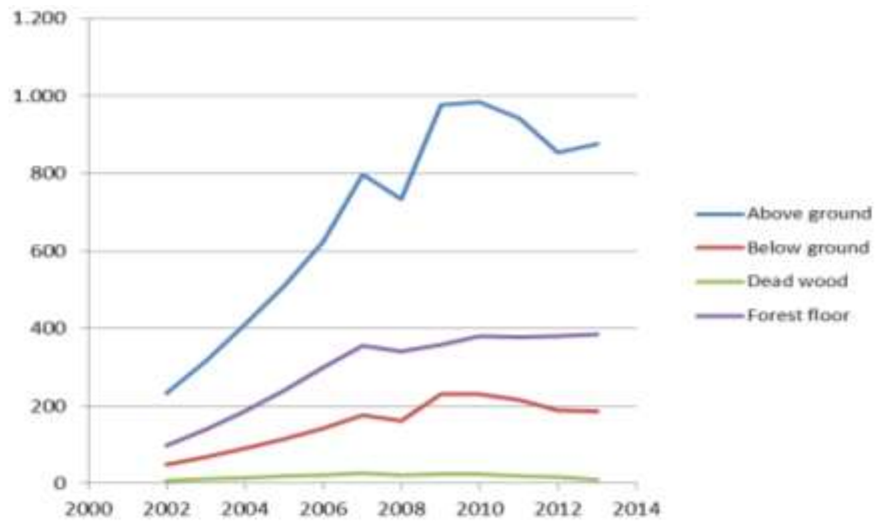

Figure 6.3 Forest carbon in forests established after 1990 estimated from NFI data from 2002-2013. Note that estimates for 2002-2005 are based on only 1-4 years of measurements. Only from 2006 the estimates are based on a full five-year rotation of the NFI.

6.2.6 Uncertainties and time series consistency

Danish national forest inventories have developed over the years from the earliest inventories more than a century ago. More recently the development has been quite rapid, thus influencing the estimation of forest carbon pools in relation to LULUCF.

In the 1990 forest census the number of questionnaires sent to respondents was 22,300. In the subsequent inventory the number of respondents increased to 32,300. Not unexpectedly this led to a substantial increase in estimated forest area, which is not possible to separate from the actual increase in forest area that occurred during that period of time. Also, it is not possible to single out the effect of the increased number of questionnaires on estimates of species distribution, carbon pools etc.

In 2002, the sample based forest inventory released the previous forest census for the first time enabling annual forest statistics. The NFI includes areas and forest owners that have not previously been included in the forest census. Firstly because not every forest owner was included in the previous surveys and secondly because not all forest areas according to the FAO definitions would be perceived as forest by the respondents. Consequently, the change from questionnaire based forest census to sample based forest inventory has led to an increase in forest area estimates that is not possible to separate from the actual increase in forest area that occurred during that period of time.

Specifically, in relation to the reporting of carbon pools in forest, the change from questionnaire based forest census to sample based forest inventory has changed the calculation of forest volume, biomass and carbon. In the forest census, forest carbon is estimated from the reported forest area within different species, age and site classes and a number of forest growth models. In the forest inventory, forest volume (and subsequently carbon) is measured on the plots. The observed forest area and carbon is subsequently expanded to regions or the entire country using statistical models. This has led to a substantial increase in forest volume, biomass and carbon estimates, mainly due to methodological differences.

In the estimation of carbon emissions from existing forests, the information collected in relation to different forest census and inventories is combined with the satellite based land use/land cover map for the base year 1990 and for the year 2005. Hereby, consistent estimates of emissions from existing forests are obtained utilising as much information from the data sources as possible and hereby providing best possible time series. For the period from 2006 and onwards - there is full consistency of the data.

The uncertainty of the estimates of the carbon pools have been analysed by the use of bootstrap analysis. For the total carbon pool of the living biomass standard error is estimated to be 0.6 tonne C pr. ha or equalling 0.9 per cent. Applying the stock change method the emission/sink estimates of the different parts of the carbon pools depend on the certainty of each pool at two consecutive times.

The uncertainty of the estimates for subsets of the full forest area is related to the sampling intensity. With more subdivisions the uncertainty increases as the sampling size is reduced. An initial bootstrap analysis of this has been performed.

Table 6.9 Tier 1 estimate of the uncertainty in the forest.

		1990	2013					
		Emission/ sink, Gg CO_2 eqv.	Emission/ sink, Gg CO_2 eqv.	Activity data, %	Emission factor, %	Combined uncertainty	Total, uncertainty, %	Uncertainty, 95 %, Gg CO_2 eqv.
4.A Forests		368	-2310				5.4	124.4
4.A.1 Forest land remaining forest land, Living biomass	CO_2	0	-3169	5	2	5.4	5.4	170.7
4.A.1 Forest land remaining forest land, Dead organic matter	CO_2	0	534	5	2	5.4	5.4	28.8
4.A.1 Forest land remaining forest land, Mineral soils	CO_2	0	0	5	2	5.4	0.0	0.0
4.A.1 Forest land remaining forest land, Organic soils	CO_2	253	250	10	50	51.0	51.0	127.6
4.A.1 Forest soils, Drained organic soils	N_2O	35	34	10	50	51	51	17.6
4.A.2 Land converted to forest land	CO_2	79	40	10	9	13.3	13.3	5.3
Other forest issues	N_2O, CH_4	-1	0	10	50	51.0	51.0	0.0

6.2.7 QA/QC and verification

A continuous focus on the measurements of carbon pools in forest will contribute to QA/QC and verification in the following submissions. As we gain more data through resampling of permanent plots in the NFI this will further support the verification of the data reported.

On-going development of the NFI in terms of sampling procedures and estimation methods is essential for the continued QA/QC process of the NFI.

New models for biomass calculations have been implemented based on a substantial dataset collected in long term common garden experiments with tree species.

Integration with multi-phase and multi scale inventory - through e.g. other in-situ data like LiDAR scanning or remote sensing like satellite imagery will through research contribute to the continued QA/QC process of the NFI and the carbon stock estimates for forests.

6.2.8 Recalculations and changes made in response to the review process

The estimation methods are similar to the last reporting, with the new expansion functions implemented. There are sampling errors, but basically the continuous sampling, with partial replacement, provide stable estimates of the carbon pools in forests.

6.2.9 Planned improvements

Below is a list of planned improvements.

- A renewed look at the QA/QC of the Land Use matrix will be performed, with focus on Christmas tree plantations and identification of permanent clearing of forest vs temporary unstocked areas.
- A new project has started for documentation for carbon pools in soil and litter. It will take some years before the data is collected and analyzed and ready for application in the reporting.
- Further analysis of uncertainty estimates for all the carbon pools in the forest areas based on the re-measurements and bootstrap analyses, which so far have been confirmed.

6.2.10 Land converted to Forest area

See section 6.2.1 Information on approaches used for representing land areas and on land-use databases used for the inventory preparation.

6.2.11 Forest definition

See section 6.2.1 Land-use definitions and the classification systems used and their correspondence to the LULUCF categories (e.g. land use and land-use change matrix).

6.2.12 Methodological issues for land converted to forest

See also section 6.2.1.

Living biomass

With respect to the option for distinguishing forest with and without harvesting, it is not possible with the available data. Data from the NFI is utilised based on the land use mapping to identify sample plots on afforested/reforested (AR) areas. It is - however not possible to determine the amount of harvesting. Furthermore, Denmark applies an approach utilising total carbon stock change, both growth and harvesting is included in the overall estimation.

When converting land to forest land the standing living above- and below ground biomass are removed from the land. In Table 6.10 the default values for the amount of living biomass is shown.

For land converted from cropland a standard default loss value of 9 577 kg DM (dry matter) per hectare in above-ground biomass and 2 298 kg DM per hectare in below-ground biomass is used. This value is equivalent to the average harvest of living biomass for all cereals grown in Denmark from 2000 to 2010, including straw, stubble and glumes. For conversion from DM to carbon a default fraction of 0.5 kg C per kg DM is used.

Table 6.10 Default values for the amount of DM (dry matter, kg per hectare) used for estimating carbon stock changes where land use conversions take place.

		Dry matter, kg DM pr hectare	
		Above ground biomass	Below ground biomass
Cropland		9 577	2 298
Grassland	Improved Grassland	2 400	6 720
	Unmanaged Grassland	2 200	6 160
Wetlands	Peat extraction	0	0
	Other Wetland	3 600	10 080
Settlements		2 200	2 200
Other land		0	0

Soils

The included soil carbon pool changes concerned only carbon sequestration due to development of forest floors, i.e. the organic layer on top of the mineral soil. Carbon sequestration was included in this layer since national scientific projects had indicated that this was the soil compartment mainly prone to changes following land-use change. The previous NIR reports did not account for possible changes in carbon pools of the mineral soil; based on chronosequence studies of afforested stands, no consistent changes had been detected in mineral soil organic matter during the first 30 years following afforestation (Vesterdal et al., 2002a; Vesterdal et al., 2007). This is also supported by the finding that there was no significant difference in mineral soil carbon stocks in paired forest-cropland sites at 28 different sites in Denmark (Vesterdal et al., 2002b). These conclusions are supported by data from the new national forest soil inventory.

New data

New information on carbon pools in forest soils is available from the national project, SINKS. In this project forest soils are sampled in two grids, Agricultural Network and the National Forest Inventory (NFI), see Section 6.2.1 for a description.

Apart from 108 plots in forests planted before 1990, the Agricultural Network included 15 plots in afforestation since 1990. The sampling took place together with the sampling in forests planted before 1990, and was thus complete for the period 2007-2009. Archived soil samples from 1990, when the plots were arable land, were missing for 1 plot.

The sampling, the sample preparation, chemical analyses and calculations were similar to that performed from forests planted before 1990, see 6.2.1.

A few of the 277 plots sampled in the NFI grid are probably also located in forests planted since 1990. The data calculations are currently being performed, and these data will be reported in the next NIR.

6.2.13 Changes in forest soil carbon stocks in forests planted on arable land since 1990

The average carbon sequestration rates for forest floors for broadleaves and conifers were estimated from the information from scientific projects in afforestation chronosequences; the average annual sequestration of carbon in forests floors was 0.09 and 0.31 tonne C ha^{-1} yr^{-1} under broadleaves and conifers, respectively (Table 6.11.). These rates of change have been used for calculation of forest floor carbon sequestration in afforested land, however, the accumulation of conifer forest floors is assumed to start only after eight years based on observations from chronosequence and other field data.

Table 6.11 Forest floor carbon sequestration rates in afforestation areas for different species in national chronosequential studies.

Tree species category	Tree species	Study type	Age (year)	Forest floor C sequestration (tonne C ha^{-1} yr^{-1})	Source*
Broadleaves	Oak	Chronosequence	29	0.08	1
	Oak	Stand	30	0.02	2
	Oak	Stand	30	0.05	2
	Oak	Stand	30	0.04	2
	Oak	Stand	30	0.02	2
	Oak	Stand	30	0.13	3
	Oak	Stand	40	0.09	3
	Beech	Stand	30	0.09	2
	Beech	Stand	30	0.10	2
	Beech	Stand	30	0.12	2
	Beech	Stand	30	0.13	2
	Beech	Stand	30	0.18	3
	Beech	Stand	40	0.14	3
	Average (SEM)			*0.09 (0.01)*	
Conifers	Norway	Chronosequence	30	0.35	1
	Spruce	Chronosequence	41	0.43	1
		Stand	30	0.21	2
		Stand	30	0.15	2
		Stand	30	0.20	2
		Stand	30	0.30	2
		Stand	30	0.30	3
		Stand	40	0.65	3
	Sitka spruce	Stand	30	0.43	2
		Stand	30	0.24	2
		Stand	30	0.22	2
		Stand	30	0.25	2
	Average (SEM)			*0.31 (0.04)*	

* 1) Vesterdal et al. (2007), 2) Vesterdal & Raulund-Rasmussen (1998), 3) Vesterdal et al. (2008).

The results from scientific projects have lately been checked by analysis of preliminary results from the Agricultural Network. The afforested plots in the monitoring grid also revealed large variation in soil carbon pools among for both forest floors and mineral soils (Table 6.12). The mean carbon pool of the forest floor among the afforested sites was about 2.5 t C ha^{-1} in 2007-2009 (and supposedly 0 t C ha^{-1} at the time of the afforestation) while the mean carbon pools for mineral soils were 114 and 108 t C ha^{-1} in 1990 and 2007-2009 respectively (Table 6.18). A simple t-test on the mean change in mineral soils pools between 1990 and 2007-2009 (-1.87 t C ha^{-1} yr^{-1}) showed that the change was not significant (Table 6.12 and Figure 6.2) while there, as expected, was a significant sequestration of carbon in the forest floor due to litterfall inputs and subsequent buildup of the organic layer (Table 6.13, Figure 6.3). The age of the afforested stands ranged from 8-19 years, so only the establishment phase was covered.

Table 6.12 Basic statistics on soil carbon pools measured in the "Agricultural Network".

	Mean C pool	Std	Min	Max
	(tonne C ha^{-1})			
Forest floor at the time of the afforestation	-	-	-	-
Forest floor 2007-2009	2.53	1.79	0.25	5.56
Mineral soil 1990	113.63	35.37	68.00	186.06
Mineral soil 2007-2009	107.83	41.25	52.82	220.06

Table 6.13 Statistics from a simple t-test on the change in soil carbon between ca. 1990 and 2009 for forests after 1990.

	Total number of sites	Number of sites in t-test	Mean change	Std	Min	Max	P-value
			(tonne C ha^{-1})				
O-horizon	15	15	2.53	1.79	0.25	5.56	<.0001
Mineral soil	15	14	-1.87	17.59	-35.32	34.00	0.70

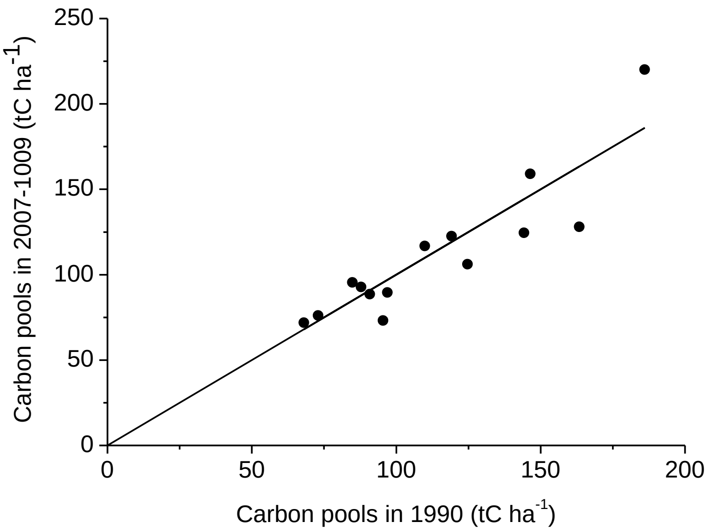

Figure 6.4 Carbon pools in mineral soils in 2009 versus 1990. Forests established on arable land since 1990. Line: y=x.

The amount of carbon in the forest floors increased with the age of the afforested stand (Figure 6.4), while this was not the case for the mineral soil (Figure 6.5).

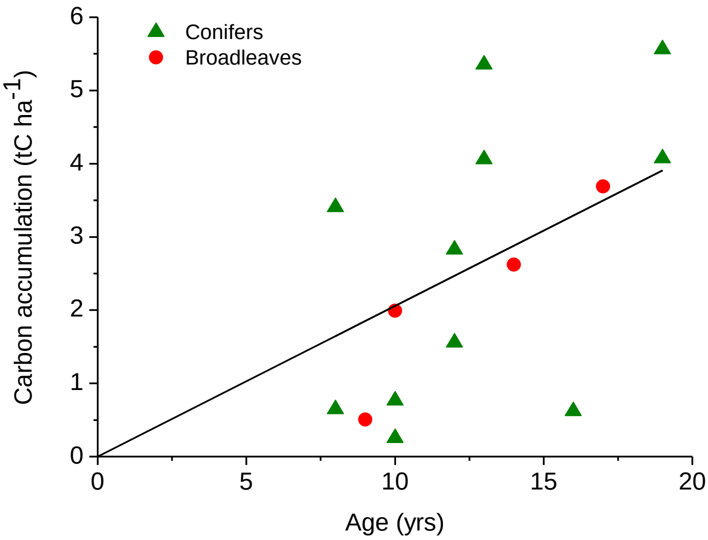

Figure 6.5 Forest floor carbon pools in forests afforested since 1990 in the Agricultural Network. The regression was forced through (0,0) (C acc. = 0.2057 x age, R^2=0.3124, $p<0.0001$).

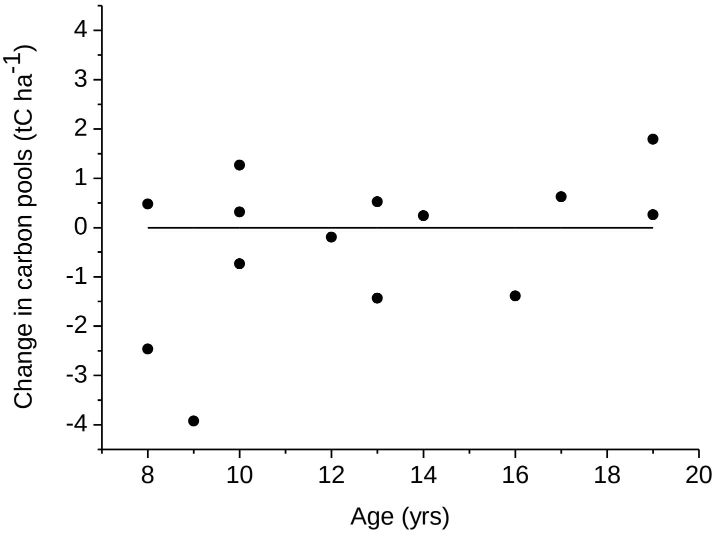

Figure 6.6 Change in mineral soil carbon stocks for forests since 1990. Line: y=0 (Regression line (not shown): R^r=0.0005, p=0.9356).

Average carbon sequestration rates for forest floors for broadleaves and conifers were also estimated from "Agricultural Network" in order to check the forest floor carbon sequestration rates used in reporting; in this case the average annual sequestration of carbon in forests floors was 0.16 and 0.20 t C ha^{-1} yr^{-1} under broadleaves and conifers, respectively (Table 6.14). These values are lower compared to the values obtained from 30-40 year old stands. (Table 6.11).

Table 6.14 Forest floor carbon sequestration rates in afforestation areas for different species. Data from the "Agricultural Network".

Tree species category	Tree species	Study type	Age (year)	Forest floor C sequestration (tonne C ha^{-1} yr^{-1})	Site
Broadleaves	Oak	Monitoring plots	14	0,19	837
	Oak	Monitoring plots	17	0,22	301
	Maple	Monitoring plots	9	0,06	485
	Lime	Monitoring plots	10	0,20	571
	Average (SEM)			*0.16 (0.07)*	
Conifers	Norway spruce	Monitoring plots	19	0,21	479
	Sitka spruce	Monitoring plots	13	0,41	335
	Sitka spruce	Monitoring plots	10	0,03	340
	Normann fir	Monitoring plots	13	0,31	31
	Normann fir	Monitoring plots	16	0,04	171
	Normann fir	Monitoring plots	12	0,13	235
	Normann fir	Monitoring plots	8	0,08	292
	Normann fir	Monitoring plots	12	0,24	689
	Silver fir	Monitoring plots	19	0,29	66
	Larch	Monitoring plots	8	0,43	334
	Mixed conifers	Monitoring plots	10	0,08	509
	Average (SEM)			*0.20 (0.14)*	

Lastly we combined all data to explore the trends in forest floor carbon stocks among broadleaves and conifers (Figure 6.7). The rates used seem reasonable, even if the inclusion of new data indicate that it might be too high for conifers in the stand establishment phase. Thus, accumulation of conifer forest floors is assumed to start after eight years of chronosequences. This is reasonable since observations in chronosequences indicate that there is little litter fall in conifer stands to build up forest floors during the first 10 years.

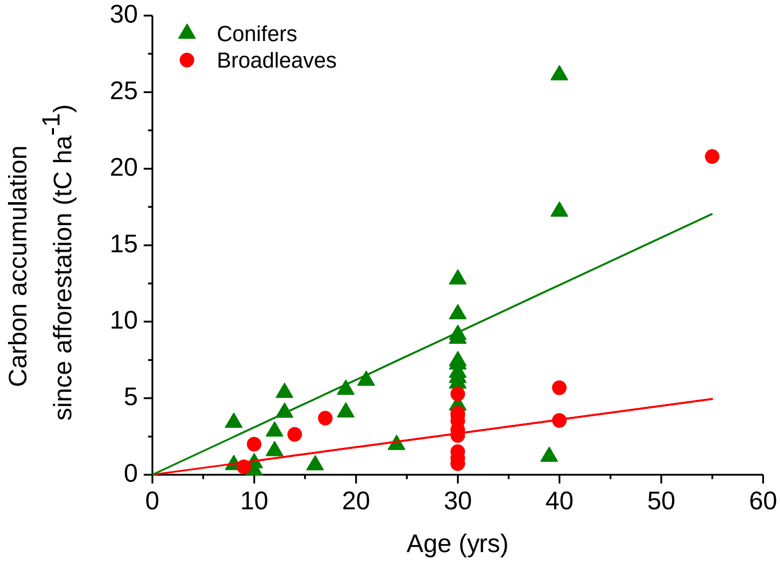

Figure 6.7 Forest floor carbon pools in afforested plots. All available data from chronosequential studies and the "Agricultural Network" are included. Lines show the carbon sequestration rates used in the reporting: 0.31 tonne carbon ha^{-1} yr^{-1} for conifers and 0.09 tonne carbon ha^{-1} yr^{-1} for broadleaves.

Several previous national field studies mentioned above (Vesterdal et al. 2002a, 2002b, 2007) did not suggest measurable decadal changes in mineral soil carbon following afforestation. In the Forest Soil Inventory (SINKS project), soil carbon content to 100 cm in forest land remaining forest land was compared with soil carbon in the same depth found in a parallel project for cropland soils (Table 6.15). These data also support that mineral soils are neither sinks nor sources for CO_2 following afforestation of former cropland. Using a transition time of 50 years, these soil carbon contents were used to calculate the small rates of soil carbon stock change for cropland to forest conversion.

Table 6.15 Mineral soil carbon content (Mg ha^{-1}) in cropland and forest land based on the Agricultural Network. N: number of plots, mean and standard deviation (std).

Land use	Sandy soils			Loamy soils		
	N	mean	std	N	mean	std
Cropland		137			158	
Forest land	261	154	79	116	164	103
Grassland and Other land	19	150	84		150a	84a
Settlements		120 b			120 b	

[a] Same data as for sandy soils.
[b] Agreed with the UFCCC-ERT during the 2011 review.

In conclusion, preliminary results from the Forest Soil Inventory project show no evidence that mineral soil carbon pools for forests on former arable land are neither sinks nor sources for CO_2. The data from the SINKS project support the conclusions drawn from Vesterdal et al. (2002, 2007), Vesterdal and Raulund-Rasmussen (1998), and Vesterdal et al. (2008) for forest floors. The comparison between Danish land-uses (Table 6.15) suggests that particularly sandy soils would sequester carbon following afforestation of cropland, whereas carbon stocks in loamy soils are quite similar between land uses. Thus, a no-source principle would be justified in case of land-use conversions to forest.

Until final results from the Forest Soil Inventory are available we continue to use the previously used average carbon sequestration rates: 0.09 tonne carbon ha^{-1} yr^{-1} for broadleaves and 0.31 for conifers.

The sequestration of CO_2 in forest floors in forests established since 1990 has gradually increased and the annual CO_2 sequestration will increase much more over the next decades when cohorts of afforestation areas enter the stage of maximum current increment.

The reporting of the forest floor in the afforestation in the 2008-2012 period is based on the NFI monitoring of forest floor depth as described above.

6.2.14 Uncertainties and time series consistency

See Section 6.2.1 and 6.2.2 for recalculation since 1990.

6.2.15 QA/QC and verification

A continuous focus on the measurements of carbon pools in land converted to forest will contribute to QA/QC and verification in the following submissions. See also Chapter 6.2.1

6.2.16 Recalculations, including changes made in response to the review process

In the updated land use matrix that now includes mapping of three years: 1990, 2005 and 2011, significant changes have been noted related to land use and land use changes. This includes increased afforestation in areas without support from public funds. This includes establishment of minor forests areas, to improve hunting options and to produce biomass. Some forest areas have been established through natural succession, a method now approved by the Forest Act (from 2005). In the previous reporting, mainly afforestation based on subsidies were expected and included in the reporting.

6.2.17 Planned improvements

A QA/QC of the Land Use matrix is a continuous process.

The basic information utilised to give the data for the emission estimates for units of land subjected to afforestation/reforestation is based on National Forest Inventory (NFI) observations of stock change, specific related to the afforestated areas. This will include all changes in carbon pools - also if affected by harvest - including thinnings of young stands. Based on the NFI it will be possible - for the next reporting to provide some indications of the frequency of harvesting/thinning occurring on the afforestated areas. Given the fact that the afforestated area is still a relatively small part of the full forest area, there will be more uncertainty on the estimate related to afforestated areas compared to the area of forest remaining forest.

Documentation for carbon pools in soil and litter is expected to be further improved in the next submission.

6.3 Cropland

6.3.1 Cropland and cropland management (4B1)

The total Danish cropped agricultural area of approximately 2.7 million hectare can relate to approximately 617 000 individual fields, which again is located at 200 000 land parcels. This gives an average field size of less than four ha. The actual crop grown in each land parcel (LPIS) is known from 1998 and onwards. Since 1990 the agricultural area recorded by Statistics Denmark has decreased from 2.78 million hectare to 2.67 million hectare (Table 6.16). The total crop yield given as kernel, root fruits and grass as measured in dry matter (million kg dry matter per year) is, however, at the same level and increasing due to improved cropping techniques, Figure 6.8

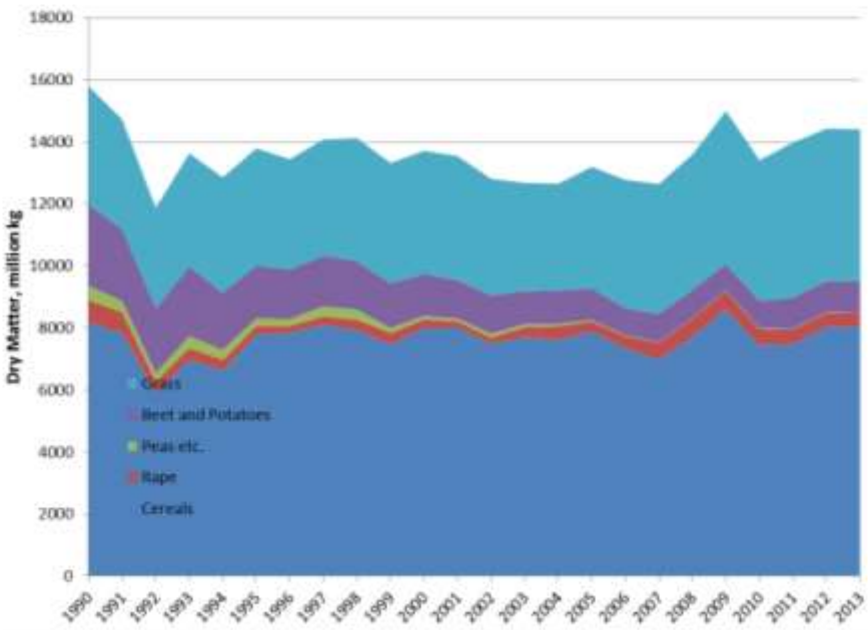

Figure 6.8 Total crop yield given as kernel, root fruits and grass as measured in dry matter (Million kg dry matter per year).

The main reason for the loss of land for agricultural purposes is urbanisation and afforestation. The major part of the agricultural area is grown with annual crops: cereals, grass in rotation, oilseed, sugar beets, potatoes and temporarily set-a-side. Permanent grass outside rotation with none or very little fertiliser application rates (>63 kg N per ha per year) is reported under Grassland. All fertilisation with nitrogen is reported under Agriculture 3D2.

Table 6.16 shows the development in the agricultural area from 1990 to 2013 (Statistics Denmark). A general trend is a continuous decrease of 6 000 - 7 000 ha per year in the agricultural area.

Table 6.16 Cropland area in Denmark 1990- 2013 according to Statistics Denmark and the Land Use Matrix, hectares.

	1990	1995	2000	2005	2010	2012	2013
Annual crops (CL) 1	2 236 535	1 969 275	1 938 633	1 953 306	2 049 304	2 053 093	2 044 704
Grass in rotation (CL)	306 325	310 568	330 834	342 417	327 319	331 512	323 846
Permanent grass (CL and GL)	217 235	207 122	166 261	192 968	199 859	200 413	195 484
Horticulture – vegetables (CL)	16 428	12 915	10 803	9 557	10 812	10 305	9 930
Perennial fruit trees – perennial wooden crops (CL)	10 267	10 669	9 892	9 464	8 181	7 570	7 684
Set-a-side and other land (CL)	3 861	217 801	192 441	200 751	51 309	41 800	46 249
Total agricultural land area reported by Statistics Denmark	2 788 276	2 726 048	2 646 982	2 707 236	2 646 400	2 644 631	2 627 817
Willow and other crops for energy purposes (CL)	588	588	695	1 320	4 049	5 410	6 400
Hedgerows (CL)	61 326	61 019	60 554	60 170	59 791	59 659	59 589
"Other agricultural land"	80 783	107 253	119 847	61 115	105 720	86 433	91 526

[1]CL refers to that the area is treated under Cropland. GL refers to Grassland.

Cropland area

The Cropland area is defined as the agricultural area as given by Statistics Denmark, Perennial wooden crops (fruit trees, orchards and willow), hedgerows (perennial trees/bushes not meeting the forest definition) in the agricultural landscape and “Other agricultural land”. The latter is defined as the difference in the area between the total Cropland area as defined by land use matrix (see Table 6.3) minus agricultural crops in rotation as given by statistics Denmark minus the area with fruit trees and the area with hedgerows. “Other agricultural land” is thus comparable small areas and probably without agricultural and wooden crops, which cannot be allocated to other land use categories. In the inventory carbon in living biomass for “Other agricultural land” is given the same value as for annual crops so than inter-annual changes in the cropland area from Statistics Denmark are eliminated.

The area with Perennial wooden crops are the area given by Statistics Denmark and for some categories it is split further down with data from the EU crop subsidiary system, which gives information on which crops are grown where on species level.

The main data for land use in Cropland (4.B.1) is the agricultural area given by Statistics Denmark. Both annual agricultural and wooden perennial crops are allocated into grids (climatic, soil type and municipality) with the help of the EU Land Parcel Information System (LPIS). LPIS contains information of the exact position of the field. The survey data from Statistics Denmark differs a little from the LPIS system (<±2% for the major crops). Area and yield data from each region is used for the calculations as reported by Statistics Denmark.

The area with hedgerows is based on analysis of aerial photos from 1990 and 2005 combined with planting and removal statistics of hedges from the Ministry of Food, Agriculture and Fisheries. The major part of the hedge erection is subsidies in Denmark and therefore monitored.

Cropland definition

The land area under "CL" consists of: Cropland with annual crops, cropland with wooden perennial crops, area with hedgerows and “Other agricultural area”. The latter consists of small undefined areas lying inside the area, which is allocated as cropland in the cropland area.

For purposes of the calculations for annual crops a division as follows is used: Winter and spring wheat, rye, triticale, winter and spring barley, oat, winter and spring rape, grass for grass seed production, grassland in rotation, potatoes, sugar beets, peas, maize for silage, cereals for silage, vegetables and miscanthus.

For purposes of perennial wooden crops a division as follows is used: Apple, Pears, Cherries, Plumes, Rosehips, Elderberries, Hazel and Walnuts, Grapes, Other fruit trees, Black current, Other fruit bushes, Hedgerows and Willows.

Biomass from Christmas trees in the agricultural area is reported under forests.

Cropland - Methodological issues

The following data sources are used for determination of cropland area, for determination of any land-use changes, for allocation of natural and administrative parameters, for development of emission factors for soils and biomass and for calculation of carbon stocks in soils and biomass at various times.

- Agricultural area data from Statistics Denmark, 1980 to 2013
- Area and harvest surveys from Statistics Denmark, 1980 to 2013.
- Area with willow from the agricultural subsidiary system.
- EUs Land Parcel Information System, 1998 and onwards (grown crops on field and soil level).
- Digital soil map, 1:25.000.
- Arial photos of hedgerows in 1990 and 2005.
- Hedgerow planting data 1977 to 2013.

The model for carbon stock changes in hedges is based on a growth model from the National Forest Inventory (NFI) classified into plant and soil type and height.

Emissions from living biomass

For annual agricultural crops on cropland remaining cropland (4B1) it is assumed that no changes in above-ground, below-ground, dead biomass and litter are occurring cf. IPPC 2006 (5.2.1.1). The variations in the actual agricultural area collected by Statistics Denmark may be up to 100,000 hectares per year. When estimating the carbon stock in living biomass such changes may create large variations between years, which may be artefacts. As the amount of living biomass is defined according to the time where the peak of living biomass is occurring the variation in the area from Statistics Denmark create large fluctuations in the carbon stock in living biomass compared to other sources. To counteract this problem the sub-division "Other agricultural land" has been created with a default carbon stock of living biomass as in the designated agricultural area. The default carbon stock in living biomass is equivalent to an average spring barley crop with aboveground biomass of 9 577 kg DM (dry matter) pr hectare and a below ground DM of 2 298 kg pr hectare. Default dry matter values for the different crop categories used in the inventory was given in Table 6.10.

Fruit trees and other perennial wooden plants

Fruit trees, other perennial commercial wooden plants and durable horticultural plantations are reported separately under Cropland (Table 4.B). These are only of minor importance in Denmark. The total area for different main classes and the used carbon stock in above-ground and below-ground biomass are given in Table 6.17. Due to the limited area and small changes between years the CO_2 removal/emission is calculated without a growth model for the different tree categories. Instead the average stock figures are used in Table 6.17 multiplied with changes in the area to estimate the annual emissions/removals. Perennial horticultural crops account for approximately 0.07 % of the standing carbon stock. Christmas trees are reported under forest (4.A).

The carbon fraction of dry matter (DM) is assumed to be 0.5 for all species. For parameter estimation of living biomass, see Gyldenkærne et al. 2005 for fruit trees, for willow and Miscanthus:
http://www.nordicbiomass.dk/dansk/nye_afgroeder.asp

Table 6.17 Mg living biomass per hectare and area, ha, with perennial wooden trees and – bushes, 1990- 2013.

	Living biomass, Mg DM per ha	1990	1995	2000	2005	2010	2011	2012	2013
Black currant	5,20	1 269	1 828	1 492	2 001	1 935	2 041	1 855	2 167
Other berries	5,20	663	547	611	698	533	608	734	645
Rosehip	13,99	0	0	0	0	197	197	34	159
Cherries	25,45	1 787	2 653	2 804	2 131	1 743	1 466	1 401	1 380
Plumes	25,45	0	0	0	0	68	65	73	72
Hazelnut and Walnuts	25,45	0	0	0	15	14	23	28	28
Aples	33,76	2 726	1 658	1 678	1 751	1 684	1 550	1 703	1 563
Pears	13,99	351	546	441	413	357	336	344	299
Elderberry	25,45	0	0	0	9	9	16	14	10
Grapes	5,20	0	0	0	18	45	50	57	54
Other fruit trees	13,99	0	0	0	110	60	74	67	89
Rowan-berries	33,76	0	0	0	0	16	10	12	18
Willow	17,43	588	588	695	1 320	4 049	4 795	5 410	6 400
Miscanthus	17,43	1	1	6	33	156	774	70	66
Total		7 385	7 821	7 727	8 499	10 865	12 005	11 804	12 951

Hedgerows

Since the beginning of the early 1970s governmental subsidiaries have been given to increase the area with hedgerows to reduce soil erosion. Annually financial support is given to approximately 400-800 km of hedgerow. There are no figures on how many hedgerows have been removed in the same period as these to a large extend are not protected. Therefore 144 aerial photos on a 2x2 km^2 square for 1990 and 2005 have been analysed to monitor and detect changes in the landscape. The squares are distributed throughout Denmark in a stratified way according to primarily soil and wind conditions (Figure 6.9). A very large dynamic in the location of the hedges between 1990 and 2005 was observed (Figure 6.9). Only areas not meeting the definition of forests and areas not classified under Perennial Wooden crops (fruit trees, willows etc.) were included in the analysis. The hedges were further allocated into eight different regions, mainly according to soil type (e.g. growth pattern).

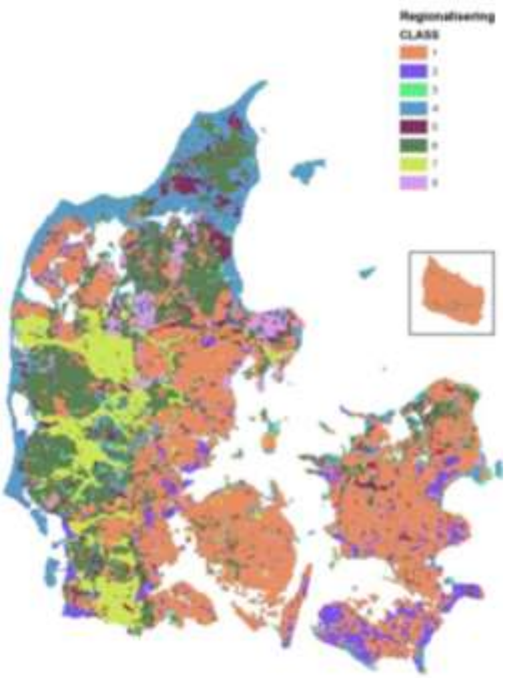

Figure 6.7 Designated areas with different types/classes of hedges.

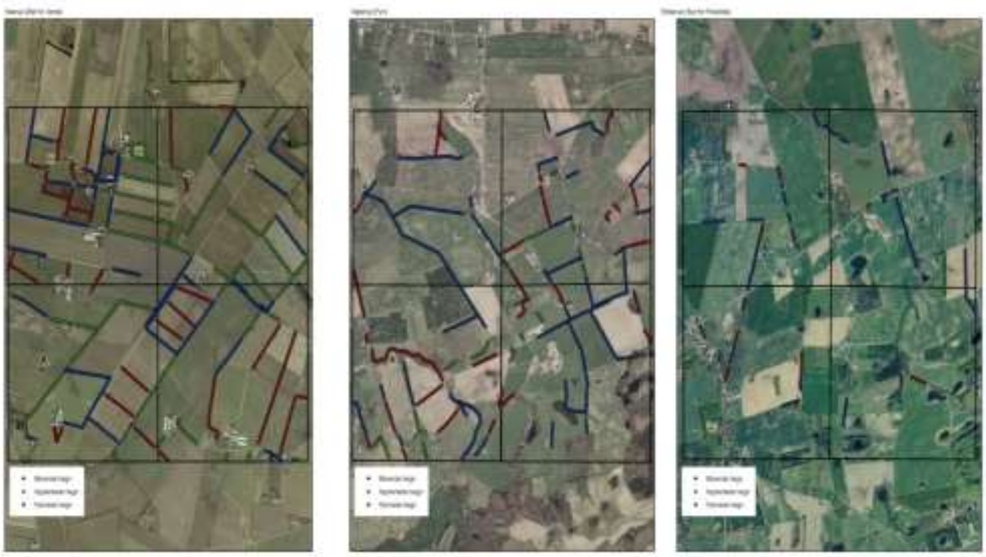

Figure 6.9 The dynamics of hedgerows in the Danish Landscape 1990 to 2005. Blue colour indicates no changes, red colours are removed hedges and green colours are new hedges (Source: M. Fuglsang, DCE).

The overall results from the analysis of hedges are shown in Table 6.18. The total area with hedges has decreased with 2 % but the total volume and the carbon stock has increased due to changed sizes and composition.

Table 6.18 Hedges in the cropland 1990 and 2005.

	1990	2005	Change in percent 1990-2005
Area, ha	61 326	60 093	-2.0
Volume, million. m3	4 139	4 402	6.4
Carbon stock, Gg	939	1 072	14.2

In Table 6.19 the actual planting and removal rates for hedgerows is shown. The 1970s and 1980s have a high concern to protect and maintain the hedgerows and a substantial replacement took place. Currently is the governmental subsidiary targeted to broadleaved hedgerow replacing old single-rowed conifers (mainly white spruce *(Picea glauca)*). In 1990 75 % of the replaced conifers hedgerows were replaced with 3- to 6-rowed broad-leaved hedges. In 2005 only 20 % are replacements and the remaining is new hedges cf. Table 6.19. Over the years a decrease in the number of subsidized hedgerows has taken place. The Ministry of Food, Agriculture and Fisheries is responsible for all administration, registration and mapping of all subsidised hedgerow planting in Denmark.

Table 6.19 Hedges planted and removed under the governmental subsidiary system 1985 to 2013.

	1985	1990	1995	2000	2005	2010	2011	2012	2013
Planted 3-rowed, km	1 082	928	560	852	390	109	96	107	109
Planted 6-rowed, km	0	0	252	250	115	29	37	33	30
Planted small biotopes, ha						64	52	33	36
Percentage removed, %	75	75	36	27	20	20	20	20	20
Percentage new, %	25	25	64	74	80	80	80	80	80
Hedges removed, ha	608	522	218	219	76	21	20	21	21

The biomass estimation of the hedges is based on measurements made in the Danish NFI where plots with similar height and plant species are used as transfer functions (Figure 6.10).

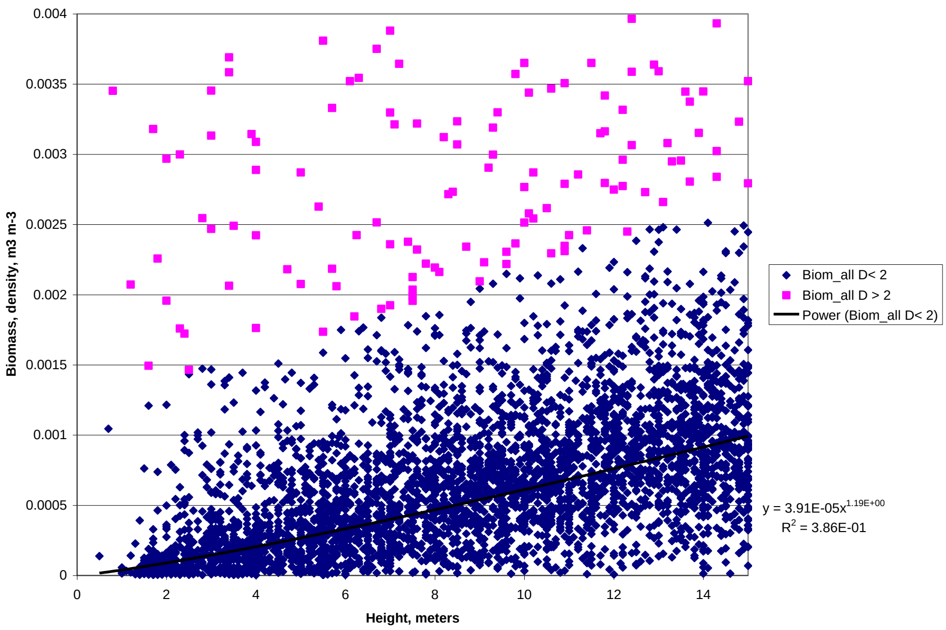

Figure 6.10 Biomass function estimated as m^3 biomass per m^3 versus tree height in NFI plots less than 15 meter (Courtesy Thomas Nord-Larsen, SL, LIFE, KU).

Emission from soils

Based on a GIS analysis of the data in the LPIS and a newly produced soil map of the organic soil the agricultural area is distributed between mineral soils and organic soils and subdivided into cropland and permanent grassland.

Mineral soils – 4B1

For carbon changes in for agricultural crops a 3-pooled dynamic soil model is used (Petersen, 2003; Petersen et al. 2002, 2005, 2010, Gyldenkærne et al. 2005) to calculate the soil carbon dynamics in relation to the Danish commitments to UNFCCC. C-TOOL is only used in CL. No change in the carbon stock in soils under perennial wooden plants, hedgerows and "Other agricultural cropland" is expected and reported as NA. These areas are also only a very minor part of the cropland area. For agricultural crops C-TOOL is run on a regional level.

C-TOOL

C-TOOL is a 3-pooled dynamic model, where the approximate average half-live times for the three different pools, Fresh organic matter (FOM), Humified organic matter (HUM) and ROM (Resilient Organic Matter) are 0.6-0.7 years, 50 years and 600-800 years, respectively. The main part of biomass returned to soil each year is in the first and easiest degradable FOM pool. This pool consists of mainly fresh straw, fresh manure, root residues, fungi and small animals and fluctuates very much between years depending on the harvest yield and climatic conditions. A simple diagram of C-TOOL is shown in Figure 6.11.

C-TOOL is parameterised and validated against long-term field experiments (100-150 years) conducted in Denmark, UK (Rothamsted) and Sweden and is "State-of-the-art". A detailed description of C-TOOL can be found at www.agrsci.dk/c-tool/index.htmls. More recent investigations have shown that C-TOOL is not properly parameterised on soils having more than 6 % organic carbon. Soils having 6-12 % organic carbon is therefore treated as organic soils with an emission factor of 50 % of organic soils > 12 % organic carbon.

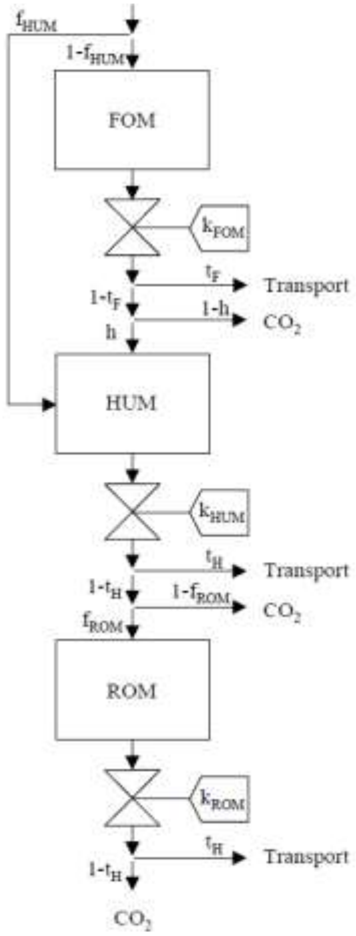

Figure 6.11 A simple diagram of C-TOOL. Please refer to www.agrsci.dk/c-tool for more information.

Input data to C-TOOL and out put

As carbon input to each region for each year is taken the actual crop area and crop yield from Statistics Denmark for that particular region and crop species as given by Statistics Denmark (www.dst.dk Table AFG, AFG07, HST7 and HST77). The dry matter content depends on the actual crop. For cereals it is 15 %.

The amount of agricultural residues returned to soil is the amount estimated by Statistics Denmark (www.dst.dk Table HALM and HALM1). The dry matter content depends on the actual crop. For cereals it is 16 %.

More detailed figures on the distribution as an example of the crop yield and areas are given in Annex 3F, Table 3.F10-12 for a specific region (Eastern Jutland) in year 2010.

The overall input to C-TOOL varies between years (Figure 6.8) due to the actual growing conditions in that year. 2013 was a fairly good year in terms of harvested crops. The cereal yield was not so good, 4 per cent less than in 2012, but on a general decreasing area so the average cereal yield per ha was the same in 2012 and 2013. 2010 and 2011 were medium years, whereas 2009 were the best cereal year ever. The variation in the input to C-TOOL gives a inter-annual variation in the carbon input to the soil for all years of the time series. Combined with inter-annual differences in the temperature this creates inter-annual differences in the net carbon stock change in mineral soils, where low yields combined with high temperatures reduce the total amount of carbon in agricultural soils, whereas in years with a high yield and low temperatures the carbon stock in soils is increased.

The amount of animal manure produced and applied to soil is estimated with the same methodology as in the Agricultural sector for estimating CH_4 and N_2O emission where annually updated feeding and excreting data are provided for the regulation of the animal production in Denmark. Here detailed data on the number of animal, housing and manure type are available on farm level. This also includes data whether the manure has been biogassed or not. The manure data are used as input to C-TOOL.

In Figure 6.12 is shown the overall input of C to the agricultural soils. Due to a ban of field burning in 1990, increased management and demand on catch crops an increase in the C input to soils can be seen.

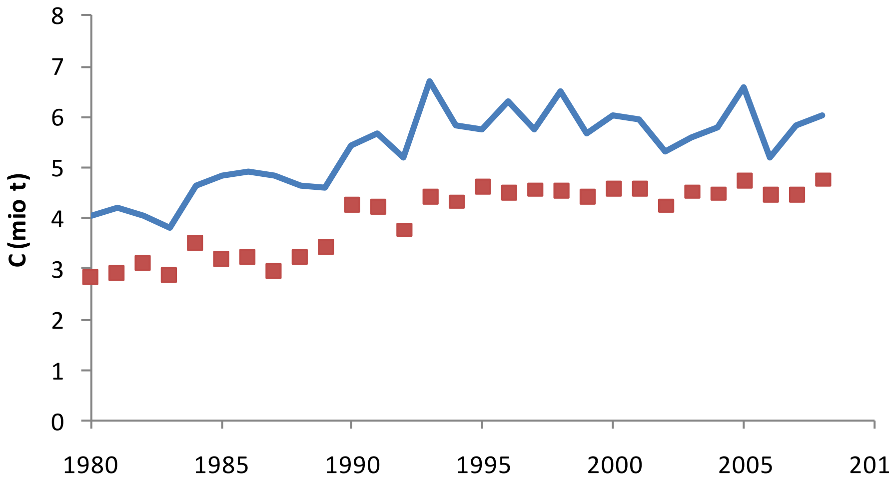

Figure 6.12 Calculated C input to the soil (red squares) and modelled (blue curve) development of the FOM pools, million tonnes C.

Since 1997 there has been a demand for growing N catch crops in Denmark in order to reduce N leaching. Besides reducing the N leaching these crops increase the carbon stock in the soil. Between 120 000 and 200 000 hectares of the agricultural area has this additional crop every year. The demand for catch crops has altered the way of farming in two main ways. For farmers with cattle the farmers are sowing grass seed in their normal cereal fields. This grass sword must not be ploughed into the soil before winter/next spring. For farmers growing grass seed, which is common in Denmark, old grass seed fields are not ploughed before next spring in contradiction to the current situation where it would be ploughed early autumn. It has been estimated that the obligatory catch crops are increasing the amount of C returned to soil with 0.36 to 2.14 tonnes carbon per hectare per year (Olesen et al. 2004). The area with catch crops in each region is estimated from each farms obligatory N accounting, in which the area of catch crops area given on farm level (www.pdir.dk).

C-TOOL is initiated with data from 1980 and run multipliable times until stability, before the emissions from 1980 and onwards was calculated. Actual monthly average temperatures are used as temperature driver. The main drivers in the degradation of soil biomass are temperature and humidity. The Danish climate is quite humid with winter temperatures around zero degrees Celsius and hence the importance of soil humidity on the model outcome is low in contradiction to temperature, which has a high effect on the emission. As mentioned, when biomass is returned to the soil the major part of it is quite easily degradable. Warm winters with unfrozen soils in connection with high inputs of biomass will therefore, as a result, yield high emissions from the soil compared to more cold years, which will yield low emissions.

In recent years (1999 - 2013) Denmark has experienced very warm winters although 2010 was very cold and below the average from 1961 to 1990. In 18 out of the last 20 years the annual average temperature has been above the average temperature from 1961 to 1990. Year 2013 had an average temperature of 8.4 °C or 0.7 °C above the average from 1961 to 1990.

Year 2006 resulted in a high loss due to the warmest year up to now combined with a harvest yield 5 % below the average for 1997 to 2009 (measured as kernel yield from cereals) (Figure 6.13). In this year the organic matter input from crop residues and animal manure were not able to compensate for the loss (Figure 6.13). 2007 was not as warm, which led to an increase in the carbon stock. 2009 was cooler than 2008 but 2009 gave the highest cereal yield ever monitored in Denmark despite the fact that the agricultural area has decreased since 1980. This led to a very high input of organic matter into the soil, which again increased the soil carbon stock.

2010 were very cold with low harvest yields and 2011 were moderate too due to draught. An overall decreasing C stock in mineral soils is therefore estimated.

The combination of a lower yield in 2013 than in 2012 combined with a slightly higher temperature in 2013 than in 2012 has resulted in a higher C loss from soils in 2013 than in 2012.

The FOM-pool (Fresh Organic Matter) which in fact is undecomposed crop residues has a very fast turnover rate (crop residues are reported in section 5, agriculture). It consists of approx. 1.0 % of the total carbon content in the agricultural soil. Because of its large fluctuation between individual years and its small impact on the overall trend in the long-term development of the carbon stock in the soil, it has been agreed with the previous ERT during the in-country review in 2010, that all input sources are included in the modelling but in the reporting on the development an instant turnover of the FOM pool is used. The reported development is thus the two pools, HUM (Humified Organic Matter) and ROM (Resilient Organic Matter) which account for 99 % of the total amount of carbon in the soil. Figure 6.13 shows the development in the two pools. As can be seen there is a small increase in the total modelled carbon stock from 2008 to 2010 but a decrease in HUM and ROM. A new warm year with normal harvest yields will speed up the degradation of the FOM pool and as a consequence the two lines will get closer again.

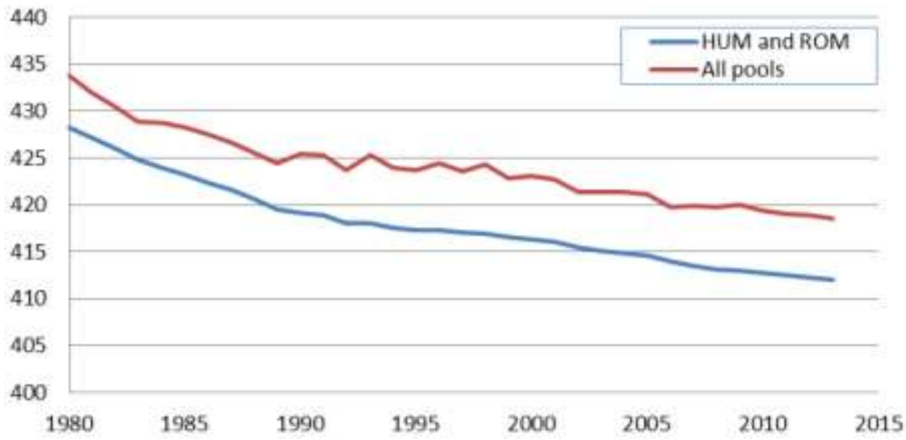

Figure 6.13 The development in the C-stock in agricultural soils, Tg C (million tonne C).

As a whole the modelled emissions are found to be the most realistic emissions estimates for Denmark. As described in the agricultural sector the Danish farmers have faced increased demands for lower environmental impact since the mid-1980s. The general effect on the carbon stock in soil is that the 1980s showed a decrease in the carbon stock. In the 1990s the carbon stock seemed to stabilise due to the higher input of organic matter. Due to the increased global warming a declining carbon stock was modelled between 2000 and 2011. Since 1990 C-TOOL has estimated a loss of 1.5 % of the total carbon stock in the mineral agricultural soils. No precise uncertainty calculation has been made. However, it must be assumed that uncertainty in the estimate in the annual loss/gain is around 25 %. As Denmark has very good data on harvest yields and area data the uncertainty in the trend is very low. The estimated annual amounts of carbon in the agricultural soils are given in Table 6.20.

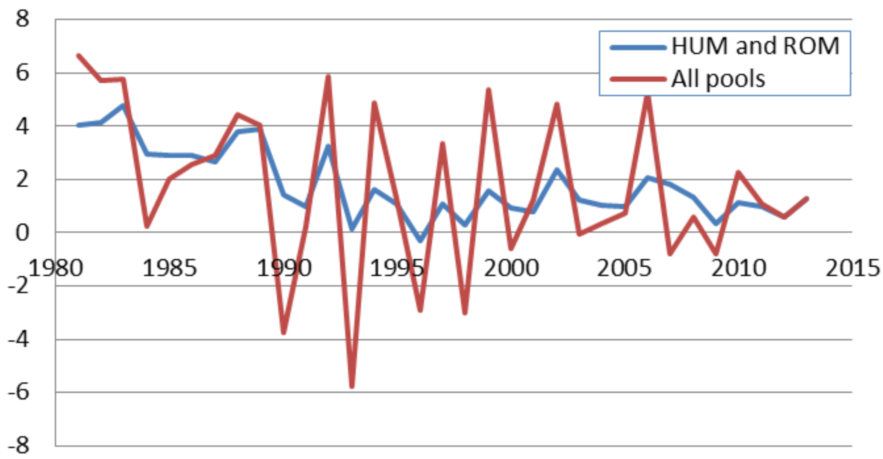

Figure 6.14 Estimated annual emissions from mineral soils 1990 to 2012 (million tonne CO_2 yr^{-1}).

Table 6.20 Modelled carbon stock (0-100 cm) in mineral soils from 1980 to 2013, Tg C.

Year	All pools	Fast FOM model
1980	433,795	428,295
1981	431,976	427,201
1982	430,412	426,068
1983	428,834	424,763
1984	428,764	423,954
1985	428,208	423,168
1986	427,508	422,382
1987	426,710	421,654
1988	425,496	420,625
1989	424,394	419,568
1990	425,419	419,182
1991	425,356	418,920
1992	423,752	418,029
1993	425,330	417,983
1994	423,994	417,545
1995	423,646	417,254
1996	424,436	417,329
1997	423,524	417,032
1998	424,346	416,949
1999	422,883	416,516
2000	423,050	416,266
2001	422,716	416,055
2002	421,398	415,406
2003	421,410	415,075
2004	421,323	414,798
2005	421,127	414,534
2006	419,695	413,975
2007	419,908	413,481
2008	419,755	413,113
2009	419,969	413,014
2010	419,354	412,700
2011	419,058	412,432
2012	418.897	412.274
2013	411.932	418.549

Independent verification of C-TOOL

An independent validation of C-TOOL has been performed by soil sampling in the Danish Agricultural grid. The grid was established in 1987 and in a 7 x 7 km^2 grid square. In 1987 > 600 agricultural plots were sampled and analysed for carbon. Half of them were resampled in 1998 and a full resampling of 464 plots was made in 2008/2009. Figure 6.15 shows the development in the carbon stock in 0-100 cm depth in the paired plots. It can be seen that there has been an increase in the soil C stock in the sandy soils (Coarse Sand, Fine Sand and Loamy Sand). This is mainly due to that the Danish cattle herd is located on these soils combined with large areas with grass in rotation. This favours the soil C stock. Contrary to this is observed a loss in the C stock on the loamy soils (Sandy Loam and Loam). On these soils are annual crops the most common cultivars combined with a limited number of cattle and pigs. On these soils it seems difficult to maintain the soil C stock. Although there is some variability the overall conclusion is that there is a small loss from the Danish agricultural soils.

C-TOOL has estimated an overall loss from 1987 to 2009 of 7-10 million tonnes C and in the soil sampling grind is found an average loss of approx. 5 tonnes C per ha. With approx. 2 million hectares in rotation this gives a total loss of 10 million tonnes C from 1987 to 2009. The conclusion is therefore that the modelled outcome from C-TOOL represents a proper value for the development of the carbon stock in the Danish agricultural soils.

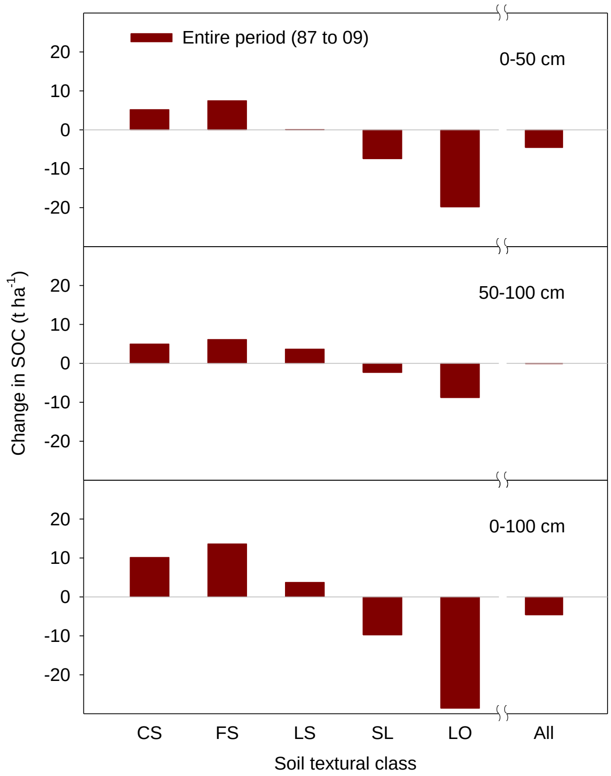

Figure 6.15 The change in carbon stock in soil (0 - 100 cm) in >460 paired agricultural plots from 1987 to 2009 (Taghizadeh-Toosi et al. 2014)

Organic soils - 4B1

A complete new soil map of the organic soils was made in 2010 for the inventory (Figure 6.16). The new soil map is a statistical map based on >10 000 soil samples down to the mineral soil in 30 cm intervals combined with a very detailed digital elevation map (DEM) for each 1.6 x 1.6 m^2 covering the entire Denmark, water table maps and old maps with organic soils. The definition of an organic soil in the new map is 20 % organic matter with a depth of minimum 30 cm (Greve et al., 2014). The total area with organic soils has been estimated to approx. 106 642 ha.

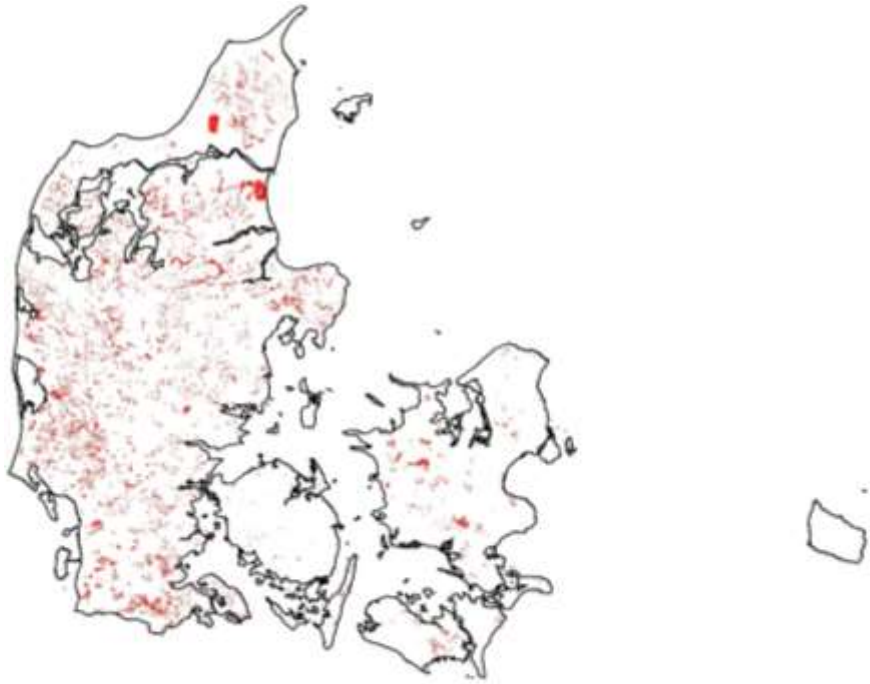

Figure 6.16 The new organic soil map for Denmark for year 2010, > 12 % OC (Greve et al. 2014).

On top of the organic soil map digital maps has been laid a map where 99 % of all Danish farmed fields (>619 000 fields) from the EU subsidiary system are precisely mapped with an uncertainty down to < ± 0.5 meter. The actual grown crop is known for each field. In total more than 270 different crop types or combination of crop and crop management are recorded. In 2013 22 048 hectares with annual crops and 27 712 with grass in rotation were located to be grown on the organic soil area.

The previous Danish soil classification was carried out in 1975. In 1975 it was estimated that there were 178 000 hectares of organic soils (>12 % C). Of this were 118 000 ha in the Cropland and the Grassland area and the remaining 60 000 ha were located in the Forests, Wetlands, Settlements and Other land. Overlay between the field map and the soil map has shown that only around 49 760 hectare in 2013 is farmed in the Cropland area and 16 810 hectare in Grassland and that the depth of the organic layer has become very shallow. The major reason for the drastic reduction is that Denmark is quite flat with shallow organic layers, which combined with intensive agricultural utilisation with high drainage rates has oxidized a major part of the organic matter.

The outcome is that during recent years more and more previously organic soils do not qualify to be organic by definition and that the area will decrease rapidly in future.

Emission factors for organic soils

An intensive research programme has been carried out to monitor the CO_2 emission from three organic soils in Denmark with annual crops in rotation and permanent fertilized grassland (Elsgaard et al. 2012). The overall result is shown in Table 6.21 compared with the IPCC default values. Maljanen et al. (2010) recently reviewed the GHG balance of managed organic peatlands in the Nordic countries. For areas with agricultural grasslands, the available studies suggested a net CO_2 emission of 4.9 ± 3.2 t C m^{-2} yr^{-1} (mean +/-

standard deviation, n = 4). The available studies (n = 4) represented three Finnish and one Norwegian site (Lohila et al., 2004; Maljanen et al., 2001, 2004; Grønlund et al., 2008). The upscaled annual emission from the Danish declining carbon stock is in line with these figures when taking into account the differences in temperatures. Considering that the IPCC temperate cold zone covers the major part of Europe the measured Danish values also seems to be in line with the IPCC guidelines. Emissions from organic soils on permanent grassland are reported under Grassland (CRF Table 4.C.1).

The dominating use of the organic soils is fertilised annual crops and grass in rotation. As C-TOOL has shown not to be able to simulate the emissions from soils having >6 % organic carbon fixed emission factor have been used for this area. No data has been found in the literature as they in the scientific world do not qualify as organic and hence little attention has been paid to these soils. Normally mineral soils in equilibrium will have an organic matter of 1-4 % organic carbon. Soils having higher contents are most likely developed under humid conditions with low degradation rates. Drained and managed soils having > 6 % organic carbon can therefore not be seen as being in their equilibrium state and will evidently lose carbon. We have therefore decided to allocate an emission of 50 % of what we have measured for soils > 12 % organic carbon in an attempt to account for these losses. These emissions are reported under 5B organic soils.

Table 6.21 Emission factors from organic soils, tonne C per ha per year

	Cropland	Grassland
	Annual crops and grass in rotation	Permanent grass
Soils > 12 % OC	11.5 (SE = ±2.0)	8.4 (SE = ±1.0)
Soils 6-12 % OC	5.75	4.2
IPCC, Boreal and temperate	7.9 (CI = 6.5-9.4)	3.8-6.1 (CI = 5.0-7.3)

As emission factor for N_2O from the 2013 Wetland Supplement 2003 default value of 13 kg N_2O-N per ha per year is used for the area with > 12 % organic carbon. This emission is reported in the agricultural sector, 3D2. No CH_4 emission is reported from CL.

In agriculture CRF Table 3D is only reported N_2O emissions from soils having at least 12 % OC. In Table 4B is included the area with 6-12 % OC. The sum of the area in 4B and 4C is therefore not equal to Table 3D.1.6.

To estimate the emission from the organic soils a linear decrease in the area with organic soils between 1975 and 2010 has been assumed. All CO_2 emissions from organic soils converted from other Land Use categories to Cropland are reported under 4.B.1 and not under the respective land use conversion classes 4.B.2.1 to 4.B.2.5. The related N_2O emission is reported in the agricultural sector in CRF Table 3.Ds1.

The total emissions from the organic soils are given in Table 6.22.

Table 6.22 Emissions from cropland organic soils 1990 to 2013.

	1990	1995	2000	2005	2010	2011	2012	2013
Cropland, 6-12 % OC, ha	46 270	43 045	39 820	36 595	33 370	32 734	32 734	30 916
Cropland, > 12 % OC, ha	74 473	69 282	64 092	58 901	53 710	52 687	50 886	49 760
Cropland, total, ha	120 743	112 327	103 912	95 496	87 080	85 420	83 620	80 676
Emission, total, Gg C	-1 122	-1 044	-966	-888	-810	-794	-773	-750
Emission, total, Gg CO2	-4 116	-3 829	-3 542	-3 255	-2 968	-2 912	-2 836	-2 750

Uncertainties and time series consistency

A Tier 1 uncertainty analysis has been made for part of the LULUCF sector cf. Table 6.21. The uncertainty in the activity data for the agricultural sector is very low. The highest uncertainty is associated with the emission factors. Especially the emission/sink from mineral soils and organic soils has a high influence on the overall uncertainty.

The LULUCF sector contributes to a large extend to the total estimated uncertainty. In recognition of the difficulties in analyses of uncertainty, the estimated uptake of CO_2 in the forestry sector must be treated with caution.

Table 6.21 Tier 1 uncertainty analysis for Cropland for 2013.

		1990	2013					
		Emission/ sink, Gg CO_2 eqv.	Emission/ sink, Gg CO_2 eqv.	Activity data, %	Emission factor, %	Combined uncertainty	Total, uncertainty, %	Uncertainty, 95 %, Gg CO_2 eqv.
4.B Cropland		5461	4104				40.4	1659.1
4.B.1 Cropland remaining cropland, Living biomass	CO_2	-81	69	3	15	15.2	15.2	10.5
4.B.1 Cropland remaining cropland, Mineral soils	CO_2	1415	1253	3	75	75.0	75.0	940.3
4.B.1 Cropland remaining cropland, Organic soils	CO_2	4116	2750	3	50	50.1	50.1	1378.0
4.B .2 Forest land converted to cropland	CO_2	16	10	10	50	51.0	51.0	5.1
4.B .2 Other land uses converted to cropland	CO_2	-5	-11	10	50	51.0	51.0	5.9
Other cropland issues	N_2O, CH_4	0	-33	10	50	51.0	51.0	16.7

The time series are complete.

QA/QC and verification

A general QA/QC plan is developed for cropland. The following Points of Measures (PM) are taken into account.

- Collection and error check on in-data.
- Control of sums.
- Comparison with other data.

The area estimates for cropland and grassland in 2012 are very precise due to unrestricted access to detailed data from EUs Integrated Administration and Control System (IACS) on agricultural crops on field level and the use of the vector based Land Parcel Information System (LPIS). This access includes both Statistics Denmark and DCE. The total uncertainty in the major crop data is estimated by Statistics Denmark to be <2 %. Together with detailed soil maps this gives a unique possibility to estimate the agricultural crops on different soil types and hence track changes in land use. However, IACS and LPIS are only available from 1998 and onwards, and estimates for 1990 are therefore more uncertain. The QA of crop data is made by Statistics Denmark.

Data on newly planted and removed hedgerows are based on subsidised hedgerows and QA is carried out by the Ministry of Food, Agriculture and Fisheries, who is responsible for the administration of the subsidy scheme.

The uncertainty in the number of plants used for the hedgerows is not estimated but is assumed to be very low because of the subsidy system.

There is an unknown uncertainty in the number of un-registered removal of hedgerows. A linear approach has therefore been made for "missing" hedges over the years. Establishment of wetlands is based on vector maps received from every county in Denmark. The uncertainty is not estimated but assumed to be very low due to the subsidised system.

As shown in Figure 6.12 and 6.13 the loss estimated by C-TOOL seems very close to the results from 464 paired soil samples.

A range of experts from the Faculty of Agricultural Sciences, Aarhus University, are repeatedly involved in discussions and report writings on topics related to the inventory.

Recalculations, including changes made in response to the review process

Recalculations have been made due to the update to the IPCC 2006 Guidelines. Furthermore was there, by a mistake used a wrong EF for organic soils. Elsgaard et al. (2012) is used for documentation of the EF. In the previous submission was by mistake the Net Ecosystem Exchange (NEE) figures used instead of the net ecosystem carbon balances (NECB) figures. Overall has the recalculations increased the emission from CL.

All changes have been implemented for all years.

Planned improvements

A new version of C-TOOL is under development. It is expected that the new version will be used in the next submission. Verification and investigation of the hedgerows will take place in 2016. A new soil sampling in the agricultural network is planned in 2018/2019.

6.3.2 Land converted to cropland (4B2)

Agriculture covers more than 63 % of the total area giving a large impact on the environment. As a consequence there are many initiatives to transfer agricultural land into natural habitats and forest, and the continuous development of infrastructure demands more land. Land converted to cropland is therefore not an issue. The largest challenge is that the farmers in one year may report that a certain field is cropland and the next year is permanent grassland where it could stay for several years before it again is ploughed and turned into annual cropland for one year. Despite or rather because of the detailed information which is available, is it impossible to have a conservative land use transition between these two land use categories. The land use matrix showed that 51 122 hectares were converted from CL to GL from 1990 to 2013 and that 75 859 hectares were in a transition stage from GL to CL The difference between these two figures indicates these difficulties as this is very likely not real conversion but merely an effect of changes in the farmers registration of the land use or an over classification of the GL area in 1990 in relation to the CL area. No conversion from the other land use categories to CL has been found.

Approaches used for representing land

The area converted from other land use to Cropland is based on remote sensing of the Danish area in 1990, 2005, 2011, 2012 and 2013 combined with data in LPIS on which crops are grown in each field.

Methodological issues

Change in carbon stock in living biomass

For land converted to cropland a standard default gain value of 9 577 kg DM (dry matter) per hectare in above-ground biomass and 2 298 kg DM per hectare in below-ground biomass is used. This value is equivalent to the average harvest of living biomass for all cereals grown in Denmark from 2000 to 2010, including straw, stubble and glumes. For conversion from DM to carbon a default fraction of 0.5 kg C per kg DM is used.

For conversion from cropland to other land use categories the same value is used but recorded as a loss of carbon in the respective category (4A2, 4C2, 4D2 and 4E2).

The loss in living biomass for conversion from another land use category into CL is estimated as the default value for DM in that particular land use category. I.e. for deforestated areas the average carbon stock per hectare for all deforestated areas is used.

Change in carbon stock in dead organic matter

When forest land is converted to cropland it is assumed that all dead organic matter will have an instant oxidation. The actual amount depends on which type of forest is converted. Based on the measured Danish data on the nitrogen content in the litter and by using an emission factor of 7.1 kg N_2O-N per ha.

Conversion from other categories is assumed as NO as no dead organic matter is reported for these categories.

Change in carbon stock in soils

The actual amount depends on which type of land it is converted from, see Table 6.22. To reach the new equilibrium state is used a default transition period of 50 years. The default IPCC-value of 20 years seems according to Danish investigations not to be applicable for Danish conditions.

N_2O emissions for land converted to Cropland is based on the Tier 2 methodology with the default C stock as given in Table 6.15 and using a C:N value of 15 when and an emission factor of 0.01kg N_2O-N kg N^{-1} released.

Uncertainties and time series consistency

The time series are complete.

See uncertainties and time series consistency in Section 6.4.1.

QA/QC and verification

See QA/QC and verification in Section 6.4.

Recalculation

See recalculation in Section 6.4.

Planned improvements

See planned improvements in Section 6.4.

6.4 Grassland

6.4.1 Grassland remaining grassland (4C1)

Denmark is an intensive agricultural country with many small holders and small fields where CL and GL are mixed together making it difficult to distinguish between dedicated CL and dedicated GL. According to the Danish Land Parcel Information System (LPIS) there are approx. 100 000 fields of total 200 000 ha with permanent GL in 2013 giving an average size of two ha. Some of them cannot be regarded as permanent GL and are therefore included in CL.

Grassland area

The total area with grassland has been estimated in the Land Use matrix. In 1990 the grazing grassland were 194 484 hectares and Other grassland were 183 611 hectares. In 2013 the reported area with grazing grassland were 195 484 hectares and 114 727 hectare with other grassland. The main reason for the decrease in grassland is afforestation and conversion to SE but a better classification of the area which has allowed classifying some of the areas as cropland is also important. The fluctuation is mainly due to difficulties to estimate the land use change between CL and GL. Especially from 2011 to 2012 a large reclassification from GL to CL combined with an increase in the area with grazed grassland from Statistics Denmark is observed. From 2012 to 2013 only minor changes are observed. Because of the improved data only minor and more realistic changes are expected in the future.

Grassland definition

Grassland is split into Grazing grassland and Other grassland. Grazing grassland is the area with permanent grassland as recorded by Statistics Denmark. Other Grassland is the difference between the grassland area in the Land Use matrix and the area reported by Statistics Denmark.

Other grassland includes heath land and other areas, e.g. scrub land, which may be grazed by cattle and sheep or land which is kept open for recreational purposes. "Other Grassland" may contain bushes and other wooden plants, which do not meet the thresholds for forest. This is land where the crown cover is below 10 % and where the height at maturity do not reach 5 meter. It includes also nature protection sites, military training sites, electricity network lines etc.

Methodological issues for grassland

The area for grazing grassland is the area reported by statistics Denmark and the rest of the Grassland is the residual part of the grassland area. The area with organic soils in Grassland is estimated from the new organic soil map with an overlay of the fields were the farmers are reporting agricultural crops. Permanent grass fields receiving >63 kg N per ha per year is reported under Grassland. If the farmers are reporting permanent grassland but are using >63 kg N per ha per year it is assumed that this field is grass in rotation because of the fertilization level.

Change in carbon stock in living biomass

No changes in living biomass are assumed for GL remaining GL except for a minor conversion between "Grazing land" and "Other grassland". Because of an increased area reported as grazed grassland in 2012 compared to previous years a quite large emission from GL has been estimated in 2012 compared to previous years. In 2013 the emission is in smaller scale due to the low and more natural land use conversion figures.

Change in carbon stock in dead organic matter

No changes in dead organic matter are estimated as this is not occurring for this category.

Change in carbon stock in soils

No changes in the carbon stock in mineral soils are assumed. For organic soils is a national developed EF of 8 400 kg C per ha per year is used for soils with at least 12 % OC (Elsgaard et al. 2012). In the grassland estimate is only included soils with at least 12 % OC and not soils with 6-12 % OC as in cropland due to uncertain emission factors.

In agriculture CRF Table 3D is only reported N_2O emissions from soils having at least 12 % OC. In Table 4B is included the area with 6-12 % OC. The sum of the area in 4B and 4C is therefore not equal to Table 3D.1.6.

Uncertainties and time series consistency

Table 6.22 Tier 1 uncertainty analysis for Grassland for 2013.

		1990	2013					
		Emission/ sink, Gg CO_2 eqv.	Emission/ sink, Gg CO_2 eqv.	Activity data, %	Emission factor, %	Combined uncertainty	Total, uncertainty, %	Uncertainty, 95 %, Gg CO_2 eqv.
4.C Grassland		803	592				43.8	259.6
4.C.1 Grassland remaining grassland, Living biomass	CO_2	56	51	3	7	7.4	7.4	3.8
4.C.1 Grassland remaining grassland, Organic soils	CO_2	716	518	3	50	50.1	50.1	259.4
4.C.2 Forest land converted to grassland	CO_2	9	2	9	50	50.8	50.8	1.2
4.C.2 Other land uses converted to grassland	CO_2	12	13	9	50	50.8	50.8	6.8
4(II) Grassland on organic soils	CH_4	9	7	10	90	90.6	90.6	6.1
Other grassland issues	N_2O, CH_4	0	-1	10	50	51.0	51.0	0.3

The time series are complete.

QA/QC and verification

See QA/QC and verification in Section 6.3.1.

Recalculations

Recalculated due to the new guidelines.

Planned improvements

None.

6.4.2 Land converted to grassland (4C2)

As agriculture covers more than 63 % of the land area and in order to reduce the environmental impact there is a strategy for turning CL into GL or FL and where deforestation takes place it is often turned into GL or WE.

Approaches used for representing land

The area converted from other land use to GL is based on use of Land Parcel Information data, Natura 2000 vector layers, other vector maps and remote sensing of the Danish area in 1990, 2005, 2011, 2012 and 2013. Areas used for gravel digging are normally converted to GL because the normal procedure is removal of the topsoil, and then gravel digging. After having finished the gravel digging the topsoil is reversed to the land and the area turned into marginal grassland/recreational area. To avoid too many land conversions are gravel digging converted directly from CL to GL instead of CL-SE-GL. As an example with an open gravel pit and a restored area, please see: Hedeland resort.

Methodological issues

Change in carbon stock in living biomass

For land converted to “grazing land” a standard default gain value of 2 400 kg DM (dry matter) per hectare in above-ground biomass (IPCC 2006, Table 6.4) and 6 720 kg DM per hectare in below-ground biomass (IPCC 2006, Table 6.1) is used. For “Other grassland” not purely free of wooden trees/bushes it is assumed that there is a living biomass of 2 200 kg DM per ha in above ground biomass and 6 160 kg DM per ha in below ground biomass (R:S-factor of 2.8, IPCC 2003 default guideline). For conversion from DM to C a default fraction of fraction of 0.5 kg C per kg DM is used (Table 7.10).

For conversion from GL to other land use categories the same value is used, but recorded as a loss of carbon in the respective category (4A2, 4B2, 4D2 and 5E2).

Change in carbon stock in dead organic matter

When forest land is converted to GL it is assumed that all dead organic matter will be cleared and instant oxidation is taking place.

Conversion from other categories is assumed as NA as no dead organic matter is reported for this category.

Change in carbon stock in soils

The actual amount depends on which type of land it is converted from, see Table 6.15. To reach the new equilibrium state a default transition period of 50 years is used. The default IPCC-value of 20 years seems according to Danish investigations not to be applicable for Danish conditions.

Uncertainties and time series consistency

See Section 6.5.1.

6.5 Wetlands

Wetland includes:

- unmanaged fully water covered wetlands (lakes and rivers)
- unmanaged partly water covered wetlands (fens and bogs)
- managed water reservoirs (currently not occurring in Denmark)
- managed drained land for peat extraction
- managed partly water covered wetlands (re-established wetlands on primarily former cropland and grassland).

In the beginning of 1990 the total area with wetland has been estimated to 128 867 hectares. By end of 2013 this area has increased to 151 414 hectares. Of this was 58 538 ha lakes and rivers in 1990 increasing to 64 092 ha by end of 2013 inside the > 7000 km long coastline.

6.5.1 Wetlands remaining wetlands – peat extraction (4D1)

The new land use matrix has provided updated figures on the area with partly water covered and fully water covered wetland areas. Partly water covered areas are moors and other areas with raised water table. Fully water covered areas are lakes and rivers.

Wetland area

In the beginning of 1990 the total area with partly covered WE remaining WE has been estimated to 70 509 hectares and the area with lakes to 58 358 hectares. By end of 2013 the area with partly water covered WE remaining WE has decreased slightly to 69 808 hectares. The estimated area with lakes has been reduced with one hectare. The total area with peat extraction is about 300 hectares open surface (Lykke Larsen, Pindstrup Mosebrug, personal comm.). Based on aerial photos it was previous estimated to 1 596 hectares are land connected to the peat extraction areas. This has now been reduced to 800 hectares affected by drainage and extraction due to a smaller area.

Approaches used for representing land areas

The area for wetlands remaining wetlands is primarily based on data from Danish Geodata Agency and Natura 2000 maps (moors and other natural habitats). The area with peat excavation is a vector map layer made by DCE based on aerial photos of the four excavation sites (Figure 6.17). The actual three locations are Fuglsø mose on Djursland, Lille Vildmose and Store Vildmose – both in Northern Jutland. All locations are nutrient poor raised bogs.

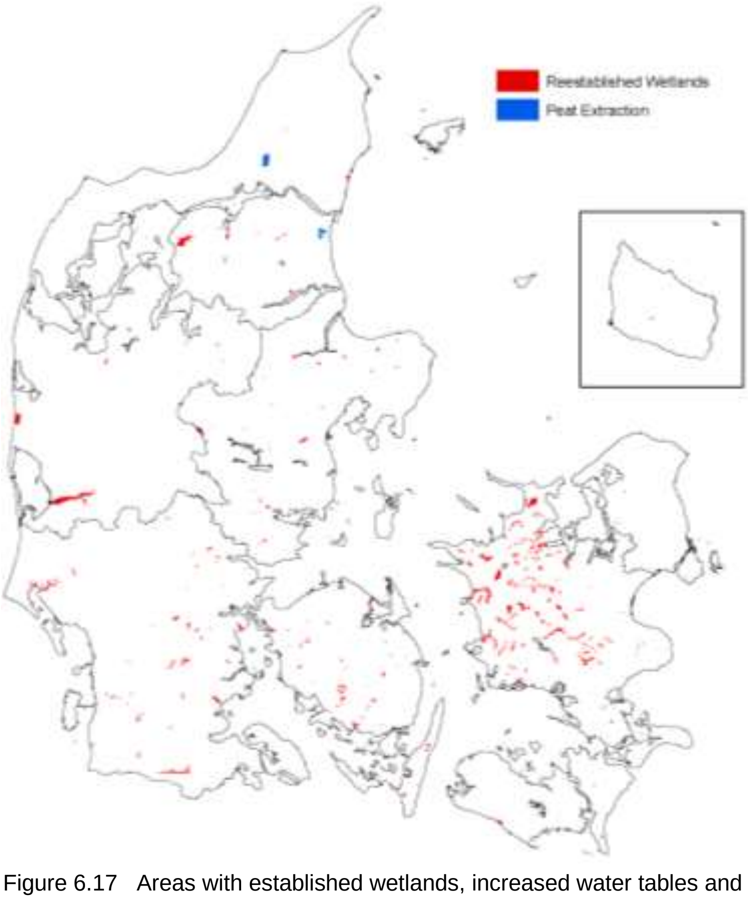

Figure 6.17 Areas with established wetlands, increased water tables and peat extraction in 2008.

Methodological issues for partly water covered wetlands
No changes in the carbon stocks and emissions are reported.

Methodological issues for peat extraction areas
Change in carbon stock in living biomass
No changes in living biomass occurring on the area are reported.

Change in carbon stock in dead organic matter
Dead organic matter is not occurring.

Change in carbon stock in soils
The surface emission from the open peat extraction area is calculated according to Tier 1 from the 2013 Wetlands Supplement (IPCC, 2014).

The amount of excavated peat (m^3 per year) is for each individual extraction site reported to and published by Statistics Denmark (www.dst.dk, Table RST). The total amount of peat excavated has since 1990 been reduced from 399 000 m^3 to 154 000 m^3 in 2013. This is a >50 % reduction compared to the 10 years ago. For conversion to carbon a density factor of 200 kg per m^3 is used (personal comm. with Pindstrup Mosebrug, www.pindstrup.dk who is responsible for the majority of the extraction sites). Furthermore, a DM content of 0.5, an ash content of 0.02 (www.pdir.dk) and a carbon content of 0.58 kg C per kg OM are applied.

For other areas in WE remaining WE is no changes reported.

Nitrous oxide emission
The nitrous oxide emission from peat land extraction areas is based on the 2013 Wetland Supplement (IPCC 2014). N_2O from N in the excavated peat is not estimated.

Uncertainties and time series consistency

Table 6.23 Tier 1 uncertainty analysis for WE remaining WEs and re-established WE for 2013.

		1990	2013					
		Emission/ sink, Gg CO_2 eqv.	Emission/ sink, Gg CO_2 eqv.	Activity data, %	Emission factor, %	Combined uncertainty	Total, uncertainty, %	Uncertainty, 95 %, Gg CO_2 eqv.
4.D Wetlands		102	41				75.0	30.5
4.D.1.1 Peat extraction remaining peat extraction	CO_2	**99.5**	**40.3**	**10.0**	**75.0**	75.7	75.7	30.5
4.D.1.2 Flooded land remaining flooded land	CO_2	0	0	10	75	75.7	0.0	0.0
4.D.2 Land converted to wetlands	CO_2	2	0	25	50	55.9	55.9	0.0
4(II) Peat extraction remaining peat extraction	CH_4	0.2	0.1	10	90	90.6	90.6	0.1
4(II) Peat extraction remaining peat extraction	N_2O	0.2	0.1	10	50	51.0	51.0	0.1
4(II) Land converted to wetlands	CH_4	0.0	0.0	10	90	90.6	90.6	0.0
Other wetland issues	N_2O, CH_4	0.0	-0.1	10	50	51.0	51.0	0.0

The time series are complete.

QA/QC and verification
The peat excavation area has been verified with aerial photos and the amount of excavated peat is made by Statistics Denmark.

Recalculation

Recalculated due to the new guidelines.

Category-specific planned improvements

No improvements are planned.

6.5.2 Land converted to wetland (4D2)

In order to restore nature and reduce the environmental impact Denmark has actively re-established WE (Figure 6.17). The size of each restoration project range from less than 1 ha up to 2 500 ha. The benefit of the restoration programme is more nature but also a reduction in leaching of nitrogen into lakes, rivers and coastal water. The establishment of WE takes place either as large areas turned into lakes or low laying fens.

Since 1990 23 248 ha have been established. These are primarily on CL and GL. Of this is 5 734 hectares converted into new lakes. A major part is restored as a part of the Danish Action Plan for the Aquatic Environment part two (VMP II, running from 1997 to 2006) where land was bought for this purpose but also 2 145 hectares of forest has been converted to partly water covered wetlands. This has primarily taken place in the state owned forest. It is accounted for that the establishment often takes place in connection to existing wetlands.

Water reservoirs for human purposes have not been established for the past 100 years and therefore currently reported as NO.

Approaches used for representing land areas

Geographical vector layers are available for almost all established WE.

Methodological issues

Change in carbon stock in living biomass

For land converted to partly covered wetland a standard default gain value of 4 000 kg DM (dry matter) per hectare in above-ground biomass and 1 200 kg DM per hectare in below-ground biomass is used. For conversion from DM to carbon a default fraction of 0.5 kg C per kg DM is used.

For conversion from wetland to other land use categories the same value but recorded as a loss of carbon in the respective category (4A2, 4B2, 4C2 and 4E2) are used.

Change in carbon stock in dead organic matter

When forest land is converted to wetland it is assumed that all dead organic matter will be cleared with instant oxidation.

Conversion from other categories is assumed as NA as no dead organic matter is reported for these categories.

Change in carbon stock in soils

No carbon sequestration or carbon loss is assumed for land converted to partly covered wetlands of fully water covered wetlands (lakes).

Nitrous oxide emission

According to the 2013 Wetlands Supplement is the N_2O emission legible from restored wetlands (Chapter 3). Therefore no has no N_2O emission been estimated for land converted to WE.

Methane emission

According to the 2013 Wetlands Supplement is the CH_4 emission 216 kg CH_4-C per ha for temperate areas, equivalent to 288 kg CH_4 per ha from restored wetlands (Chapter 3). This has been included in the inventory.

Uncertainties and time series consistency

The time series are complete.

QA/QC and verification

No verification has been made yet.

Recalculation

No recalculation has been made.

Planned improvements

None.

6.6 Settlements

The annual changes in carbon stock in settlements are assumed to be negligible, and because no estimates have been made, most changes are reported as NA in the CRF Table 4.E. For reporting purposes for land use conversions a default biomass in low buildings, grave yards is established.

The total area with SE has been estimated to 485 543 hectares in 1990 increasing to 518 879 hectares by end of 2013 or to approx. 12 % of the total Danish area.

6.6.1 Settlements remaining settlement (4E1)

Settlement area

No changes in the area with Settlements remaining Settlements are taking place. The area is estimated from the cadastral maps and the date where the land parcel was included in the cadastral map, e.g. a change from agriculture to a permanent residence or a road.

Settlement definition

Settlements are defined as all areas with infrastructures, roads, grave yards, sport facilities etc.

Methodological issues

Change in carbon stock in living biomass

No changes in carbon stocks are reported for SE remaining SE.

Change in carbon stock in dead organic matter

No changes in carbon stocks are reported for SE remaining SE.

Change in carbon stock in soils

No changes in carbon stock in soils are assumed.

Uncertainties and time series consistency

Table 6.24 Tier 1 uncertainty analysis for Settlements for 2013.

		1990	2013					
		Emission/ sink, Gg CO_2 eqv.	Emission/ sink, Gg CO_2 eqv.	Activity data, %	Emission factor, %	Combined uncertainty	Total, uncertainty, %	Uncertainty, 95 %, Gg CO_2 eqv.
4.E Settlements		13	79				59.6	46.9
4.E.2 Forest land converted to settlements	CO_2	3	13	10	75	75.7	75.7	10.2
4.E.2 Other land uses converted to settlements	CO_2	10	60	10	75	75.7	75.7	45.7
Other Settlement issues	N_2O, CH_4	0.4	-4.8	10	50	51.0	51.0	2.4

The time series are complete.

QA/QC and verification

No QA/QC has been performed.

Recalculations

Recalculations have been made due to the new guidelines.

Planned improvements

No improvements are planned.

6.6.2 Land converted to settlement (4E2)

Land converted to SE is mostly taking place around the big cities and primarily on cropland and grassland.

Settlement area

The area converted to SE is based on cadastral maps and other digital maps. For simplicity for the years 1990 to 2011 is only used three occasions 1990, 2005 and 2011 with a linear increase in the area in the years between. From 2011 and onwards are annual recorded changes in cadastral maps used to estimate the annual changes, so the increase from 2012 to 2013 is all new houses and roads included in the cadastral map from 31.12.2012 to 31.12.2013

Methodological issues

Change in carbon stock in living biomass

For land converted to single-family houses a standard default gain value of 2 200 kg DM (dry matter) per hectare in above-ground biomass and 2 200 kg DM per hectare in below-ground biomass is used. For conversion from DM to carbon a default fraction of 0.5 kg carbon per kg DM is used.

For conversion from settlements to other land use categories the same value is used, but recorded as a loss of carbon in the respective category (4A2, 4B2, 4C2 and 4D2).

Change in carbon stock in dead organic matter

When forest land is converted to settlements it is assumed that all dead organic matter will be cleared. Conversion from other categories is assumed as NA as no dead organic matter is reported for these categories.

The N_2O emission is estimated from an instant oxidation of the litter layer.

Change in carbon stock in soils

A default value of 120 tonnes carbon per ha is assumed to be areas Settlements (Table 6.15) or approximately 80 % of the carbon stock in mineral agricultural soils. For all areas converted from other land use to Settlement is assumed that equilibrium state will be reached after 100 years from the carbon stock in the previous land use category. This is agreed with the UNFCCCs review team during the review in 2012. The 100 years period is chosen because of the relatively cold climate in Denmark with an average annual temperature of 8°C, that the degradation rates of soil organic carbon according to C-TOOL shows a 99 % of the SOM has half-lives with > 40 years and that the IPCC 2006 GL assumes that 20 % of the SOC can be lose (IPCC 2006, Chapter 8.3.3.2)

Uncertainties and time series consistency

See uncertainties and time series consistency in Section 6.7.1

The time series are complete.

QA/QC and verification

No QA/QC has been performed.

Category-specific recalculations

None

Planned improvements

No improvements are planned.

6.7 Other Land

No permanent snow cover exists in Denmark and only a very small insignificant area with rocks and cliffs. OL is restricted to beaches and sand dunes and estimated to 26 433 hectares.

No land use changes from 4A, 4B, 4C, 4D and 4E is reported.

6.8 Direct N_2O emissions from N fertilization of Forest Land and Other land use

Only a very small amount of nitrogen fertilisers are used in the Danish forests and primarily to Christmas trees. All emissions are reported under Agriculture CRF Table 4.Ds1 since there is only one common national statistics for N fertilization in agriculture and forestry.

6.9 Emissions and removals from drainage and rewetting and other management of organic and mineral soils

CO_2 emissions are reported in Table 4A-F. N_2O emissions from CL and GL are reported under agriculture, CRF Table 3D. The N_2O emissions reported here is primarily from forest soils. CH_4 emissions from organic soils converted to other land uses are reported here. Until further no CH4 emission from organic forest soils has been estimated.

A large proportion of the Danish forest area may be considered as drained in the sense that the natural hydrology has been modified by establishment of ditches. Large forest areas have been drained in order to enable establishment of Norway spruce in depressions, fens and pond areas. As an example, a major state forest Gribskov in Northern Zealand by 1850 had an estimated wetland area 400 % larger than that of 1988 (http://www.skovognatur.dk/Ud/Beskrivelser/Hovedstaden/Gribskov/VandetTilbage.htm). During the recent years, there has been an effort to restore wetland habitat in the state forests and several drained areas have been restored by filling up ditches, and in many areas of the state forests ditches are no longer maintained and will be gradually more and more ineffective over time. This is a direct consequence of the strategic plan for the state forests to convert to more Close to Nature Forest Management with a specific aim to restore natural hydrology in as many places as possible.

6.9.1 Methodological issues

Very few data exist for N_2O emissions in Danish forests. A Tier 1 emission factor of 2.8 kg N_2O-N per ha drained forest soil from the 2013 Wetland Supplement is included.

Rewetted forest soils were assumed to have an N_2O emission corresponding to the natural level and emissions were therefore by default set to zero.

No CH_4 emission from forest soils is reported.

6.9.2 Areas of drained forest soils

Based on expert judgment, the area of drained forest soils were 65 % of mineral forest soils and 75 % of organic forest soils in 1990. It is further judged that the amount of drained forest soils have decreased in the period until 2008 resulting in an area of drained forest soils with 55 % of mineral forest soils and 50 % of organic forest soils. Organic soils constituted 5 % of the forest area based on information on presence of peat from the NFI. A more detailed analysis of forest soils including a mapping is under preparation. A detailed analysis of the re-measurements of the NFI since 2002 will give some indications of the changes in that period, but no data exists prior to 2002. The combined analysis will be included in the next reporting.

6.9.3 Emissions of N_2O from drained forest soils

The total N_2O emission from forest soils has been estimated to 0.074 Gg N_2O in 1990 and 0.058 Gg N_2O in 2013.

6.9.4 Emissions of CH_4 from drained grassland soils

The default CH_4 emission factor of 16 kg CH_4/ha/yr for drained organic grassland soils from the 2013 Wetland Supplement has been applied. The area is the drained grassland area with at least 12 % OC.

6.10 Direct nitrous oxide (N_2O) emissions from nitrogen (N) mineralization/immobilization associated with loss/gain of soil organic matter

The main land-use conversion involving deforestation is the conversion from forest to cropland and grassland and a minor deforestation to SE. 80

per cent of the deforestation in 2013 is conversion of christmas trees plantations to cropland and grassland.

This land-use change is expected to be a source for N_2O emissions due to the decomposition of forest floors and corresponding increased mineralization of N. It is assumed that forest floors are completely decomposed during the conversion. Emissions of N_2O are based on default emission factors (IPCC, 2006, 2014). A default N_2O emission from the litter layer in forest of 7.1 kg N_2O-N/ha is used for forest conversions.

N_2O emissions due to long term changes in the carbon stock in mineral cropland soils are reported under Agriculture, CRF Table 3D.1.5.

6.10.1 Methodological issues

For all deforestated areas it is assumed that the forest floor disappears regardless if the land use conversion is into CL, GL, WE or SE.

The average nitrogen content of forest floors based on the repeated soil inventory with a default C:N value of 10 was used to estimate the N mineralized for conifers and broadleaves, respectively. A proportion of 1 % of the N stock mineralized is assumed to be emitted as N_2O-N.

6.10.2 Emissions of N_2O from deforestation and land-use conversion

According to IPCC (2006), a default fraction of 1 % is assumed emitted as N_2O-N during mineralization of the total N content following conversion.

In 1990, emissions of N_2O from deforestation were estimated at 0.0005 Gg N_2O for mineral soils and 0.00004 Gg N_2O for organic soils. In 2013 the figures were 0.0016 and 0.0001 Gg N_2O for mineral and organic soils, respectively.

For land use conversion from GL and WE to CL is used the default methodology from the 2006 GL (IPCC 2006). The used average carbon stocks are given in Table 6.15. The default methodology assume that an N_2O emission only occur if there is a decrease in the carbon stock the methodology will only estimate a N_2O emission if the land converted from has a higher carbon stock than the land converted to. As the carbon stock in Danish GL soil has been estimated to a lower value than in cropland soils the default methodology will not estimate a N_2O emission for these occasions but estimate a N_2O emission when converted from CL to GL.

6.11 Biomass burning

Burning of forest is prohibited as well as burning of wooden debris from hedgerows are very seldom. In 2013 there forest fires on two hectares and 724 hectares with controlled burning of heathland and five hectares with Mountain Pine (*Pinus Mungo*). Due to the humid climate wildfires in the forest are very seldom and normally 0-10 hectares per year.

Data on wild and controlled fires has been collected by the Danish Nature Agency from the forest departments for the period 1990 to 2013. The emission factors are taken from the IPCC 2006 guidelines. As the burned forest is located on poor sandy soils are the default standing carbon stock assumed to be 150 Cubic meter per hectare, which is slightly lower than the average standing carbon stock in the Danish forests. The fraction burned for forest is taken from the guidelines whereas for heat land a factor of 0.33 is used. It is based on expert judgment made by the Danish Nature Agency who is responsible from for the controlled burning.

Table 6.27 Burned areas 1990 –2013, ha per year.

	1990	2000	2005	2010	2011	2012	2013
Forestland area burned	150.0	0.0	0.0	0.0	0.0	0.0	2.0
Heathland area burned	47.0	121.6	638.4	359.0	377.0	709.0	729.0
Total burned area	197.0	121.6	638.4	359.0	377.0	709.0	731.0

Table 6.28 Tier 1 uncertainty analysis for Biomass burning for 2013.

		1990	2013					
		Emission/ sink, Gg CO_2 eqv.	Emission/ sink, Gg CO_2 eqv.	Activity data, %	Emission factor, %	Combined uncertainty	Total, uncertainty, %	Uncertainty, 95 %, Gg CO_2 eqv.
4.(V) Biomass Burning		1	0				22.4	0.019
4(V) Biomass Burning	CH_4	1	0	10	30	31.6	31.6	0.013
4(V) Biomass burning	N_2O	0	0	10	30	31.6	31.6	0.013

6.12 Harvested Wood Products (HWP)

Carbon emissions from harvested wood products (HWP) must now be reported. Denmark has chosen to report under Approach B, the production approach, which refers to equations 12.1, 12.3 and 12.A.6 of volume 4 of the 2006 IPCC Guidelines and the 2013 Supplementary GPG.

Carbon in the HWP pool is accounted for based on the semi-finished wood product categories: sawnwood, wood-based panels and paper and paper products with default half-lives of 35, 25 and 2 years, respectively, stipulated by the 2013 Supplementary GPG. HWP originating from imported wood is excluded. HWP originating from deforestation activities is assumed instantaneous oxidized.

For calculating carbon stocks in HWP, Denmark has applied the default first order decay (FOD) model stipulated by the IPCC, with the default half-lives (IPCC Tier 2 methodology). Activity data has been collected from international databases as well as from surveying the Danish wood industry. Carbon conversion factors have been derived from national forest inventory data (IPCC Tier 3 methodology). An extensive validation of activity data was carried out leading to corrections of historic data, especially regarding the production and export of sawnwood. In this process a questionnaire was sent out to the Danish wood industry in June 2014. The objective was to obtain production figures for sawnwood and wood-based panels for the years 2011, 2012 and 2013 in order to provide accurate estimates for the most recent inflow to the HWP pool and to assist the validation of historic data.

According to a questionnaire on the production of the Danish wood industry the production of sawnwood in 2013 was about 356.000 m3, while the production of wood-based panels was about 346.000 m3. The questionnaire covered an estimated 95 % of the revenue generated in the sawnwood sector and 100 % of the sector revenue for wood-based panels (there was only 1 relevant company). A cross validation of the roundwood consumption showed an average deviation of 8 % for 2011-2013 between the Questionnaire and the figures reported by Statistics Denmark based on harvest and trade statistics. As of 2013 the HWP pool originating from domestic harvest and domestic consumption consisted of about 5 million tonnes carbon (67 % from sawnwood and 33 % from wood-based panels – the paper pool was insignificant). This is equivalent to 13 % of the carbon stock in live forest biomass. If imported wood were also included, the pool increases to about 29 million tonnes carbon equivalent to 75 % of the carbon stock in live forest biomass. The total inflow of carbon to the HWP pool in 2013 is reported to about 144.000 tonnes carbon - 63.000 tonnes from sawnwood and 81.000 tonnes from wood-based panels. The outflow from the pool is reported to about 110.000 tonnes carbon in 2013 - 65.000 tonnes from sawnwood and 45.000 tonnes carbon from wood-based panels. Thus there has been a net carbon sequestration in HWP of about 34.000 tonnes carbon in 2013. This corresponds to 0,13 % of Denmark's total CO_2 emissions for 2012. The projected net sequestration is about 22.000 tonnes carbon.

The uncertainty on the HWP estimates should be noted. The estimate of the size of the total HWP stock is quite uncertain, as the empirical basis for the FOD model and the attached half-lives is weak. Conducting direct inventories of the carbon stock may be a method to reduce uncertainty. In the case of Denmark estimates based on the FOD model for the total HWP pool including imported wood and converted to finished wood products actually came quite close, when measured per capita, to estimates from Finland originating from a direct inventory. Regarding estimates for pool changes, uncertainty on half-life may be of less importance, as longer retention time in the pool may be traded off against higher emissions levels from the historic pool. This depends on the characteristics of the pool, i.e. the size of the pool vs. the recent inflow. Uncertainty on activity data relates both to uncertainty on measurements, e.g. caused by reporting errors, and statistical uncertainty, caused by variation in the sampled population.

Judging from the coverage and the validation results, surveying the production of semi-finished wood products in Denmark by questionnaire has been successful. It will be repeated in the following years as part of the future reporting of HWP.

Table 6.28 HWP in use from domestic harvest (CRF table 4.Gs1).

GREENHOUSE GAS SOURCE AND SINK CATEGORIES(3)	HWP in use from domestic harvest				Net emissions/ removals from HWP in use (6)
	Gains(4)	Losses(4)	Half-life(5)	Annual Change in stock (ΔC HWP IU DH)	
	(t C)		(yr)	(kt C)	(kt CO_2)
HWP produced and consumed domestically (ΔC HWPdom IU DH)(13)					
Total	144,317.11	-111,719.82		32.60	-119.45
1. Solid wood(7)	144,317.11	-111,654.89		32.66	-119.68
Sawnwood	62,722.34	-65,163.09	35.00	-2.44	8.94
Wood panels	81,594.77	-46,491.80	25.00	35.10	-128.63
2. Paper and paperboard	**NO**	**-64.93**	2.00	**-0.06**	**0.24**
HWP produced and exported (ΔC HWPexp IU DH)(13)					
Total	22,807.92	-31,156.13		-8.35	30.59
1. Solid wood(7)	22,807.92	-31,099.90		-8.29	30.38
Sawnwood	11,681.36	-11,786.65	35.00	-0.11	0.39
Wood panels	11,126.56	-19,313.26	25.00	-8.19	30.00
2. Paper and paperboard	**NO**	**-56.23**	**2.00**	**-0.06**	**0.21**

Table 6.29 Tier 1 uncertainty analysis for Harvested Wood Products for 2013.

		1990	2013					
		Emission/ sink, Gg CO_2 eqv.	Emission/ sink, Gg CO_2 eqv.	Activity data, %	Emission factor, %	Combined uncertainty	Total, uncertainty, %	Uncertainty, 95 %, Gg CO_2 eqv.
4.G Harvested wood products		-2	-89				79.1	70.3
4.G Harvested wood products	CO_2	-2	-89	25	75	79.1	79.1	70.3

6.13 Uncertainty, Tier 2 analysis

An approach has been done to run a Tier 2 Monte Carlo uncertainty simulation for the LULUCF sector. The results are given in Table 6.29 and Table 6.30.

Table 6.29 shows the estimated median emission for the major sources in the LULUCF sector. The organic agricultural soil shows the highest uncertainty in 2013 and Forest remaining Forest the 2nd highest.

In the overall uncertainty estimates for Denmark only Tier 1 uncertainty estimates are included.

In the next submission an update will take place of the uncertainty factors and the Tier 2 uncertainty estimates in the LULUCF sector will be included in the overall Danish inventory.

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7 Waste

7.1 Overview of the sector

The waste sector consists of the *CRF source categories: 5.A. Solid Waste Disposal*, *5.B. Biological treatment of solid waste*, *5.C. Incineration and open burning of waste*, *5.D. Waste water treatment and discharge* and *5.E. Other*. The data presented in Chapter 7 relate to Denmark only, whereas information for Greenland is included in Chapter 16 and for the Faroe Islands in Annex 8.

For the CRF category 5.A Solid Waste Disposal, the CH_4 emissions reported in this chapter are a result of calculations in continuation of previously used and reported methodology. Changes in the time trend for this year´s submission are due to re-allocation and verification of reported waste types according to the harmonised European waste codes (Statutory Order no. 1309, 18/12/2012). The new harmonised European waste code data collection system and the old ISAG system result in 18 new waste types and associated model input parameters as described in Chapter 8.2 and Thomsen & Hjelgaard (2015).

The *CRF category 5.B. Biological treatment of solid waste*, includes CH_4 and N_2O emissions from composting of garden and park waste (GPW), organic waste from households (and other sources), sludge and home composting of garden and vegetable food waste. Composting were formerly included in the CRF category 6.D. Waste Other.

For the CRF source category *5.C. Incineration and open burning of waste*, the main emissions are included in the energy sector since all incineration of municipal, industrial, medical and hazardous waste in Denmark is done with energy recovery. The Waste Incineration category includes CH_4 and N_2O emissions from the minor sources of cremation of corpses and carcasses.

For the CRF source category *5.D. Waste water treatment and discharge*, the emissions reported in this chapter are a result of calculations in continuation of previously used and reported methodology. Changes in the time trend for this year's submission are below 1% and due to updated activity data on the biological oxygen demand and a change in the methane correction factor, MCF, from 1 to 0.8 according to the 2006 IPCC guidelines (IPCC, 2006) and in agreement with available plant level data on methane production, flaring and venting as presented in Chapter 8.5.5. It is not possible to obtain completeness in plant specific data regarding the methane production, flaring and venting. However, updated data are presented in Chapter 8.3 and in Thomsen, 201 (see Chapter 8.9).

The CRF source category *5.E. Other* covers CO_2, CH_4 and N_2O emissions from the sources: accidental building fires and accidental vehicle fires.

Emissions from sludge spreading on fields are included in agriculture, see Chapter 4.

Chapter 7.8 and 7.9 presents improved QA/QC procedures and recalculations reflecting the recommended improvements of the 2014 centralised review.

In Table 7.1.1, an overview of all emissions from the waste sector is presented. The emissions are taken from the CRF tables and are presented as rounded figures. The full time series is presented in Annex 3G, Table 3G-1.1.

Table 7.1.1 Emissions for the waste sector, Gg CO_2 equivalents.

		1990	1995	2000	2005	2010	2011	2012	2013
5.A. Solid waste disposal	CH_4	1,774	1,556	1,276	1,099	931	925	879	844
5.B. Biological treatment of solid waste	CH_4	35	47	81	85	77	97	89	126
5.B. Biological treatment of solid waste	N_2O	12	22	154	60	75	95	87	123
5.C. Incineration and open burning of waste	CH_4	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02
5.C. Incineration and open burning of waste	N_2O	0.19	0.21	0.21	0.23	0.28	0.26	0.26	0.26
5.D. Waste water treatment and discharge	CH_4	99	102	107	109	111	111	112	113
5.D. Waste water treatment and discharge	N_2O	101	104	87	81	73	77	70	74
5.E. Other	CO_2	18	20	18	18	18	18	16	16
5.E. Other	CH_4	1.9	2.2	2.0	2.0	2.0	2.0	1.8	1.8
5. Waste	total	2,041	1,853	1,725	1,454	1,288	1,324	1,255	1,298

5.A. Solid Waste Disposal is the dominant source in the waste sector with contributions in the time series varying from 87 % (1990) to 65 % (2013) of the total emission, given in CO_2 equivalents. Throughout the time series, the emissions are decreasing due to a reduction in the amount of waste deposited. Comparing 2013 with 1990, the emissions from Solid Waste Disposal Sites have decreased with 52%.

5.B. Biological treatment of solid waste. This source contributes with CH_4 and N_2O emissions from composting. The contribution to CO_2 equivalent emissions from the sum of CH_4 and N_2O is for the time series 1990-2013 between 2.3 % (1990) and 15.4 % (2002). CH_4 contributes the most to the sectorial total, varying between contributions of 1.7 % (1990) and 9.7 % (2013). N_2O contributes with between 1 % (1990) and 9.5 % (2013) of the sectorial total. The emissions increase steadily over the time series for both components. Comparing 2013 with 1990, the sum of CH_4 and N_2O emissions (in units CO_2 equivalent) from composting have increased with 430 %. The great increase in the emission comes from the category *5.B.1. Composting* is almost entirely caused by an increasing use of composting of garden and park waste at municipal treatment sites.

5.C. Incineration and open burning of waste. This source contributes with CH_4 and N_2O emissions from human and animal cremations. The contribution to CO_2 equivalent emissions from the sum of CH_4 and N_2O is for the time series 1990-2013 between 0.01 % (1991) and 0.02 % (2010). The trend for the total emissions 1990 - 2013 from this source is increasing; compared to 1990 the 2013 and 2010 emissions have increased with 39 % and 49 % respectively. This increase is almost entirely caused by the increase in animal cremation as this activity has risen with 665 % from 1990 to 2013.

5.D. Waste water treatment and discharge. For this source, N_2O contributes the most to the sectorial total, varying between contributions of 4.2 % (2003) and 6.5 % (2008). In 2013 the contribution of N_2O to the sectorial total is 5.7 % showing a decreasing trend of 27 % from 1990 to 2013. CH_4 from this source contributes with between 4.9 % (1990) and 8.9 % (2012) of the sectorial total.

In 2013 the contribution of CH_4 to the sectorial total is 8.7 % showing a continuous increasing trend from 1990 to 2013 of 13 %. Comparing 2013 with 1990, the CO_2 equivalent emissions from the sum of CH_4 and N_2O emissions from Wastewater Handling have decreased with 7 %.

5.D. Other. This source contributes with CO_2, CH_4 and N_2O emissions from accidental fires. The contribution to the total emissions from the waste sector varies from 1 % (1990) to 1.6 % (2008). Throughout the time series, emissions from accidental fires are decreasing; from 1990 to 2013 this category increases with 36 %.

As a result for the entire waste sector, the sectorial total emission in units of CO_2 equivalents (provided in Table 7.1.1) is decreasing throughout the time series; the emission in 2013 has decreased with 36 % compared to 1990.

Table 7.1.2 Reported emissions, calculated methods and type of emissions factors for the subcategory waste handling in the Danish inventory. (CS=country specific, D=default, OTH=other).

CRF Source	Emissions reported	Method	Emission factor
5.A. Solid Waste Disposal	CH_4	Tier 2,CS	CS,D
5.B. Biological treatment of solid waste			
5.B.1. Composting	CH_4	Tier 1, CS	CS, OTH
5.B.1. Composting	N_2O	Tier 1, CS	CS, OTH
5.C. Incineration and open burning of waste			
5.C.1. Incineration of corpses	CH_4	Tier 1	D/CS
5.C.1. Incineration of corpses	N_2O	Tier 1	D/CS
5.C.2. Incineration of carcasses	CH_4	Tier 1	D/CS
5.C.2. Incineration of carcasses	N_2O	Tier 1	D/CS
5.D Wastewater treatment and discharge			
5.D.1. Wastewater aerobic treatment	N_2O	CS	CS
5.D.2. Wastewater anaerobic treatment	CH_4	CS	CS
5.D.3. Discharge	N_2O	CS	CS
5.E. Other			
5.E.1. Accidental fires	CO_2	Tier 1, CS	CS, OTH
5.E.1. Accidental fires	CH_4	Tier 1, CS	CS, OTH

7.1.1 Key category identification

In the key category analysis (KCA) the waste emissions are divided into eleven categories. In the Tier 1 and Tier 2 KCA, three of the eleven source categories are identified as key categories in 2013 (Table 7.1.3). The Tier 1 key source identification is based on ranking of absolute quantitative emission, while the Tier 2 KCA takes into account the uncertainties in the calculated emissions, cf. Chapter 1.5).

Off the eleven categories, *5.A. Solid Waste Disposal* and *5.B.1. Composting* are the only categories identified as key sources for level. According to the level assessment for both Tier 1 and Tier 2 KCAs, *5.A. Solid Waste Disposal* is a key source for level for both year 1990 and 2013, while only the Tier 2 KCA assessment identified category *5.B.1. Composting* as key source for level in 2013 only. Both category *5.A. Solid Waste Disposal* and *5.B.1. Composting* are key category contributions to the trend of the national total of greenhouse gases, calculated in CO_2 equivalents, from 1990 to 2013; in case of *5.A. Solid Waste Disposal* for both Tier 1 and Tier 2 KCA and in case of *5.B.1. Composting* only for the Tier 2 KCA.

Identified key categories within the waste sector are presented in Table 7.1.3. For further information on the KCA level and trend assessments please refer to Chapter 1.5 and Annex 1.

Table 7.1.3 Key category identification Tier1 and Tier 2 from the waste sector 1990 and 2012.

		Tier 1			Tier 2		
		1990	2012	1990-2012	1990	2012	1990-2012
5.A Solid waste disposal	CH_4	Level	Level	Trend	Level	Level	Trend
5.B.Biological treatment of solid waste							
5.B.1. Composting	CH_4	-	-	-	-	Level	Trend
5.B.1. Composting	N_2O	-	-		-	Level	Trend
5.C. Incineration and open burning of waste							
5.C.1 Incineration of corpses	CH_4	-	-	-	-	-	-
5.C.1 Incineration of corpses	N_2O	-	-	-	-	-	-
5.C.2 Incineration of carcasses	CH_4	-	-	-	-	-	-
5.C.2 Incineration of carcasses	N_2O	-	-	-	-	-	-
5.D Wastewater treatment and discharge							
5.D Anaerobic wastewater treatment	CH_4	-	-	-	-	-	-
5.D Aerobic wastewater treatment and discharge*	N_2O	-	-	-	-	-	-
5.E. Other							
5.E Accidental fires**	CO_2	-	-	-	-	-	-
5.E Accidental fires**	CH_4	-	-	-	-	-	-

*Indirect and indirect emissions

** Vehicles and Buildings

7.2 Solid waste disposal

For many years, only managed waste disposal sites have existed in Denmark. Unmanaged and illegal disposal of waste is considered to play a negligible role in the context of this category. The amount of deposited waste has decreased markedly throughout the time series and is reported under the CRF source category *5.A.1 Managed waste disposal sites*.

In 2010, the Danish EPA implemented to the new Waste Data System to collect waste statistics. The design of the Waste Data System is considerably different from the ISAG Waste Information System it succeeds. Unlike the previous ISAG system, all waste operators, and not only the plants receiving waste, must now report to the Waste Data System. The fact that waste operators must report to the system makes it possible to collect more accurate data about what industry from which the waste originates. However, the waste operators still have to get used to the new reporting system, which is why the data are considered of increased uncertainty (The Danish Government, 2013). The Danish EPA are still conducting quality assurance of the reported data in the new data reporting system, and corrections have been received for the time period 2010-2013 in the reporting year 2015.

The general development for solid waste at disposal sites is a result of action plans by the Danish government called the "Action plan for Waste and Recycling 1993-1997" and "Waste 21 1998-2004" (The Danish Government, 1999). The latter plan had, inter alia, the goal to recycle 64 %, incinerate 24 % and deposit 12 % of all waste. The goal for deposited waste was met in 2000. Further, in 1996 a municipal obligation to assign combustible waste to incineration was introduced. In 2003, the Danish Government set up targets for the year 2008 for waste handling in a “Waste Strategy 2005-2008” report (The Danish Government, 2003). According to this strategy, the target for 2008 is a maximum of 9 % of the total waste to be deposited. In the waste statistics report for the year 2004, data shows that this target was met, since 7.7 % of total waste was deposited in 2004 (DEPA, 2006a). Waste Strategy 2009-12, part I (The Danish Government, 2009) was the sixth waste management plan or strategy adopted by the successive governments dating back to 1986. Waste Strategy 2009-12 set up targets for 2012 according to which a maximum of 6 % of the total waste produced is to be deposited (The Danish Government, 2009). In 2009, it appears that this target has already been met as only 5.6 % of all produced waste was deposited. Data on this level of information from the ISAG database/waste statistics (1994-2013) is presented in Annex 3G, Table 3G-2.1.

Waste Strategy 2009-2012, Part II included goals of continued decrease in the amount of waste being deposited in Denmark and an increase in reuse, recycling and recovery (Danish Ministry of Environment, 2010). This report includes an evaluation of the capacity of Danish solid waste disposal sites divided into waste classes: inert, mineral, mixed and hazardous waste (DEPA, 2010c). The same waste classes are defined in the new Statutory Order for Landfill (Statutory Order no. 719, 24/06/2011), which refers to the Statutory Order for Waste (Statutory Order no. 1309, 18/12/2012) regarding characterisation of the waste according to the European waste code system; the EWC-code list included in Annex 2 of the statutory Order no. 1319. The New Danish Waste Reporting System (www.mst.dk) is based on the EWC-code system, which forms the basis for the estimation of yearly deposited 18 waste types as presented for the second time in this year´s NIR. Details are further described in this chapter, in Annex 3G and in Thomsen and Hjelgaard (2015).

7.2.1 Source category description

From 1994 to 2005, the number of registered solid waste disposal sites (SWDSs) landfill sites in Denmark has decreased from 176 to 134 (DEPA, 2006b, 2013). Of the closed and still active solid waste disposal sites (SWDS) existing today, 81 of the 134 was closed in 2003, leaving 53 still active SWDS reported to the new waste data system in 2012. Methane collections from 26 of these SWDS are reported to be used at energy-producing installations and 29 are included in the Energy statistics (DEPA, 2003a; Inter-ministerial report, 2007; DEA, 2013a and b).

A quantitative overview of the source category are provided in Table 7.2.1 presenting the amounts of landfilled waste, the annual gross emissions of CH_4, the recovered CH_4 in terms of collected biogas at the landfill sites used for energy production, the amount of CH_4 oxidised in the top layers and the resulting net CH_4 emissions. The CH_4 emission estimate has decreased with 52 % from 1990 to 2013.

A full time series (1990-2013) of these data are shown in Annex 3G, Table 3G-2.2. The amount of waste and the resulting CH_4 emission can also be found in the CRF tables submitted (http://unfccc.int/national_reports/annex_i_ghg_inventories/national_inventories_submissions/items/8812.php).

Table 7.2.1 Annual amounts of deposited waste, generated methane, recovered methane collected for biogas production, oxidised methane in the top layer and resulting net emission for the Danish SWDS.

Year	Landfilled waste	Gross methane emission	Recovered methane	Methane oxidised in the top layers	Net methane emission	
	Gg	Gg CH_4	Gg CH_4	Gg CH_4	Gg CH_4	Gg CO_2 eq
1990	3,190	79.4	0.5	7.9	71.0	1,774
1995	1,969	76.8	7.6	6.9	62.2	1,556
2000	1,489	68.0	11.3	5.7	51.0	1,276
2005	983	58.8	9.9	4.9	44.0	1,099
2010	2,203	47.1	5.7	4.1	37.2	931
2011	2,428	45.0	3.9	4.1	37.0	925
2012	2,276	43.3	4.2	3.9	35.1	879
2013	2,310	41.4	3.9	3.8	33.8	844

The decrease in the emission throughout the time series seems steeper than the general decrease in the amount of total waste deposited. However, compared to the amount of degradable organic waste deposited, the picture is opposite; partly due to the lag time involved in the exponential degradation processes generating the CH_4 (cf. eq. 7.2.4) and partly due to a significant decrease in the amount of degradable organic waste deposited at landfills in Denmark (cf. Table 7.2.3 and 7.2.6 and Annex 3G, Table 3G-2.2 and Table 3G-2.3).

Methodological issues

The estimation of CH_4 emission from Danish SWDSs is based on a First Order Decay (FOD) model equivalent to the IPCC Tier 2 methodology (IPCC 1997, 2000 and 2006). The model calculations are performed using national statistics on landfill waste categories reported in the national waste statistics. This year's submission is based on allocation of the old ISAG and the new waste data for which amount are reported according to the European waste codes into 18 defined waste types with individual content of degradable organic matter and half-life´s as provided in Table 7.2.2.

The degradation of a deposited waste type of quantity N is modelled according to first order kinetics. The mathematical formulation of this type of exponential decay is

$$\frac{dN}{dt} = -k \cdot N \qquad \text{Eq. 7.2.1}$$

where k is the decay constant. Equation 8.2.1 can be solved for the simple case of a momentarily single deposition at time t (W_t) yielding:

$$N(t) = W_t \cdot e^{-k\,t} \qquad \text{Eq. 7.2.2}$$

where k relates to the half-life time for the content of degradable organic carbon (DOC) in the bulk waste, as:

$$t_{1/2} = \frac{ln2}{k} \Rightarrow k = \frac{ln2}{t_{1/2}} \qquad \text{Eq. 7.2.3}$$

The content of degradable organic carbon (DOC_i), half-life times ($t_{½}$) and the corresponding methane generation constants (k) are presented in Table 7.2.2.

Table 7.2.2 Half-life times ($t_{½}$), degradation rates constants (k) and content of degradable organic matter (DOC_i) according to 18 waste type, of which 11 are characterised as inert*.

Waste type[1]	DOC_i, [%, ww][2]	$t_{½}$, [yr, ww][3]	k, [yr^{-1}, ww]
Food	15	4	0.173
Paper and cardboard	40	12	0.058
Wood	43	23	0.0
Plastic*	0		
Textile, fur and leather	24	12	0.058
Biodegradable garden waste	20	7	0.099
Chemicals, inert*	0		
Electric & Hazardous*	0		
Glass*	0		
Metal*	0		
Scrap vehicles*	0		
Demolition	4	23	0.030
Soil & Stone*	0		
Particulate matter and dust*	0		
Sludge, inert*	0		
Sludge, degradable	57	12	0.058
Ash & Slag*	0		
Other not combustible waste*	0		

[1]Waste types marked "*"are characterised as being inert, meaning that these fraction do not decompose, i.e. $DOC_f = 0$.

[2]Default IPCC, 2006, Vol. 5, Chapter 2, Table 2.4.

[3]Default IPCC, 2006, Vol. 5, Chapter 3, Table 3.4.

[4]For demolition waste, the degradable fraction is assumed to be wood and the half-life for wood is therefore used.

The amount of generated methane decreases exponentially over time according to first order degradation kinetics of the content of degradable organic carbon in the deposited waste.

At a given year (t) the amount of degradable organic carbon (D$DOCm$(t)) which decomposes is a result of accumulated contributions from all former years deposit of waste ($W(x)$), where x is year since depositing. The residue of organic matter, i.e. decomposable DOC, left from waste deposited at landfill sites x years ago, is calculated using the exponential decomposition rule (Eq. 7.2.4).

$$DDOCm(t) = W_i \cdot DOC_i \cdot DOC_f \cdot MCF + DDOCm(t-1) \cdot e^{-k} \qquad \text{Eq. 7.2.4}$$

where the methane conversion factor, MCF, is set to the default value of 1 for managed SWDS corresponding to the situation in Denmark (page 3.14, IPCC 2006). DOC_i is the mass fraction of degradable organic carbon in the deposited waste types (Table 7.2.2), and DOC_f represents the fraction of the degradable organic carbon that decompose as function of e.g. pH, temperature and waste composition at the SDWS. For Denmark the default DOC_f value is set to 0.5 (IPCC 2006, page 3.13).

Eq. 7.2.4 assumes that the deposition of degradable organic carbon takes place momentarily once a year and just after the time *t*, where *t* is defined as whole years (integer: *t*=1,2,..), so Eq. 7.2.4 consists of two overall contributions that may be expressed as

DDOCm(t) = New deposit + Remaining part of former years deposit

The total amount of degraded organic matter during year *t* ($DDOCm\ decomp_T$) is assumed to be equal to the degradation during year t of the organic matter that was deposited at the beginning of the year (*DDOCm*(*t*-1)):

$$DDOCm\,decomp_T = DDOCm(t-1)\cdot(1-e^{-k}) \qquad \text{Eq. 7.2.5}$$

Based on Equation 7.2.4 and 7.2.5 it is possible to calculate the degraded amount of organic matter in a step wise manner based on last year result. The degraded amount of organic matter is assumed to generate the CH_4 as described by

$$CH_4\ generated_T = DDOCm\,decomp_T \cdot F \cdot 16/12 \qquad \text{Eq. 7.2.6}$$

where *F*, which is the fraction of methane in the gas from landfills, is set equal to 0.41 (DGC, 2009) and 16/12 is the conversion factor from units of C to CH_4

For deriving the net emissions, the amount of recovered or collected methane as well as the amount of oxidised methane in the SWDS top layers needs to be subtracted from the generated methane:

$$CH_4\ Emissions = \left(\sum_x CH_4\ generated_{x,T} - R_T\right)\cdot(1-OX_T) \qquad \text{Eq. 7.2.7}$$

where CH_4 *Emissions* is the methane emitted in year *T*, in units of Gg. *T* is the inventory year, *x* is the waste category or type.
R_T is the amount of recovered CH_4 at the Danish disposal sites which are used for energy production. Energy producing installations at 16 sites are registered. The Danish Energy Agency registers the biogas amounts recovered at disposal sites in energy units (TJ) (DEA, 2012). The amount of gas in energy unit is converted to volume of gas using the net calorific value of 15.19 MJ per Nm^3 (DGC, 2009; Vattenfall, 2010; Verdo, 2011). As for the FOD model, the content of CH_4 in the gas recovered is estimated to 41 % and the density of CH_4 is 0.678 kg per m^3.

OX_T is the assumed oxidation of CH_4 in the top layer. The amount oxidised is uncertain and varies according to SWDS characteristics and management practices. For the Danish model an oxidation factor (OX) of 0.1 used; i.e. the default value for industrialised countries with well-managed disposal sites (IPCC, 2000 and 2006).

The amount of CH_4 recovered, *R(t)*, is calculated as:

$$R_T = \frac{B\cdot 0.41\cdot 0.678\text{kg/m}^3}{15.19\text{MJ/m}^3} \qquad \text{Eq. 7.2.8}$$

where B is the collected amount of biogas as reported by the DEA in units of MJ. The CH_4 recovered is reported in Table 7.2.1 and 7.2.9 in units of Gg.

Model results and activity data

The amounts of waste deposited are registered and published in the national ISAG and new waste system (www.mst.dk) databases and have been allocated into 18 waste types as presented in Table 7.2.3 and in Annex 3G-2.3.

Table 7.2.3 Waste amounts divided between eighteen waste types of which eleven* have been identified as inert waste fractions (cf. Table 7.2.2), Gg.

Waste types	1990	1995	2000	2005	2010	2011	2012	2013
Food	111.7	52.0	26.5	4.6	1.3	1.0	1.2	1.0
Paper and cardboard	180.2	84.1	43.0	7.5	3.3	3.5	2.5	4.1
Wood	201.5	260.9	254.8	2.6	10.6	18.7	11.6	9.3
Plastic	27.0	14.2	8.8	4.6	7.1	7.8	10.4	5.0
Textile, fur and leather	5.0	3.1	2.3	0.8	3.8	4.2	3.1	4.1
Biodegradable garden waste	136.0	65.2	35.2	7.0	0.1	31.0	6.9	7.7
Chemicals, inert	7.7	4.7	3.6	1.4	1.0	0.6	0.1	0.2
Electric & Hazardous*	0.5	0.3	0.7	83.7	0.0	0.1	1.6	0.2
Glass*	37.3	18.5	10.6	4.8	5.6	5.3	2.9	4.4
Metal*	184.3	127.8	107.4	77.9	179.6	156.0	132.6	124.1
Scrap vehicles	104.5	64.5	48.8	48.7	21.4	17.2	1.5	0.0
Demolition, inert*	282.8	174.5	132.0	87.1	163.8	239.4	213.1	193.7
Soil & Stone*	466.1	308.6	271.3	174.0	1,676.4	1,774.0	1,761.7	1,851.3
Particulate matter and dust*	32.1	0.0	0.3	0.1	3.3	5.4	25.1	8.5
Sludge, inert	90.7	44.5	25.0	10.7	2.7	9.6	10.7	8.7
Sludge, degradable	210.7	135.7	107.1	37.7	23.9	25.3	17.2	9.4
Ash & Slag	465.8	145.0	8.5	33.8	52.5	44.4	18.2	35.9
Other not combustible waste	645.9	464.8	402.9	395.9	47.1	84.5	55.6	41.9
Total degradable	1,128	776	601	147	207	323	256	229
Total inert	2,062	1,193	888	836	1,997	2,105	2,020	2,080
Total	3,190	1,969	1,489	983	2,203	2,428	2,276	2,310

Data on the amounts of municipal solid waste deposited at managed solid waste disposal sites are reported by the Danish Environmental Protection Agency (DEPA) in old database ISAG database for the years 1994-2009 and the new waste data system (2010-2012). The ISAG data system provides landfill data for the years 1994-2009 (DEPA, 1996a, 1998a, 1999a, 2001a, 2001b, 2002a, 2004a, 2004b, 2005a, 2006a, 2006b, 2008, 2010a, 2011a) and the new waste data system provides data for 2011 (DEPA, 2013). Data for 2010 to 2013 have been received from the Danish EPA.

For the years 2010-2013 allocations has been performed according to the reported European waste codes (Statutory Order no. 1309, 18/12/2012) in the new waste data system (cf. Annex 3G, Table 3G-2.4 and 3G-2.5).

For the old ISAG database, 1994-2009, have been analysed in depth and specific waste fractions have been allocated according to the 18 defined waste types as provided in Table 7.2.3 (and Annex 3G, Table 3G-2.3).

Waste characterization data for the year 1985 and information on the total amount of waste deposited at SWDSs in 1970 reported by the Danish EPA in 1993 (DEPA, 1993) was used in the back calculation of the time series from 1994-1985.

Data for 1971-1984 have been determined by assuming a linear development between 1970 and 1985. 1960-1969 data are assumed constant at the 1970 level.

Waste amounts for the whole time series, i.e. 1960- 2013, categorised, allocated and divided into 18 waste types as described above, are provided in Annex 3G, Table 3G-2.4 and Table 3G-2.5. Corresponding annual fractional distributions of the total amount of deposited waste according to type, respecting mass conservation, is presented in units of mass fractions in Table 7.2.4 (for the whole time series the reader is referred to Annex 3G, Table 3G-2.6).

Table 7.2.4 Fractional distribution of reported waste, according to the old ISAG and the new waste data system (EWC), allocated according to the 18 waste types.

Waste types	1990	1995	2000	2005	2010	2011	2012	2013
Food	3.5	2.6	1.8	0.5	0.06	0.04	0.05	0.04
Paper and cardboard	5.7	4.3	2.9	0.8	0.1	0.1	0.1	0.2
Wood	6.3	13.3	17.1	0.3	0.5	0.8	0.5	0.4
Plastic*	0.8	0.7	0.6	0.5	0.3	0.3	0.5	0.2
Textile, fur and leather	0.2	0.2	0.2	0.1	0.2	0.2	0.1	0.2
Biodegradable garden waste	4.3	3.3	2.4	0.7	0.002	1.3	0.3	0.3
Chemicals, inert*	0.2	0.2	0.2	0.1	0.04	0.02	0.003	0.007
Electric & Hazardous*	0.02	0.02	0.05	8.5	0.0003	0.004	0.07	0.008
Glass*	1.2	0.9	0.7	0.5	0.3	0.2	0.1	0.2
Metal*	5.8	6.5	7.2	7.9	8.2	6.4	5.8	5.4
Scrap vehicles*	3.3	3.3	3.3	5.0	1.0	0.7	0.07	0.0008
Demolition	8.9	8.9	8.9	8.9	7.4	9.9	9.4	8.4
Soil & Stone*	14.6	15.7	18.2	17.7	76.1	73.1	77.4	80.2
Particulate matter and dust*	1.01	0.0004	0.02	0.01	0.2	0.2	1.1	0.4
Sludge, inert*	2.8	2.3	1.7	1.1	0.1	0.4	0.5	0.4
Sludge, degradable	6.6	6.9	7.2	3.8	1.1	1.0	0.8	0.4
Ash & Slag*	14.6	7.4	0.6	3.4	2.4	1.8	0.8	1.6
Other waste, inert*/**	20.3	23.6	27.1	40.3	2.1	3.5	2.4	1.8

*inert waste fractions,**50 percent is assumed inert and the 50 % mixed degradable waste which have been allocated according to the relative amounts of degradable waste types of each reporting year 2010-2013

While Table 7.2.4 presents the fractional distribution of 18 identified waste types of known DOC_i values, corresponding methane generation potentials are presented in Table 7.2.5.

Table 7.2.5 Methane generation potential for each of the 18 waste types, Gg CH_4 per Gg waste.

Waste types	$L_{o,i}/W_i$
Food	0.041
Paper and cardboard	0.109
Wood	0.118
Plastic*	0
Textile, fur and leather	0.066
Biodegradable garden waste	0.055
Chemicals, inert*	0
Electric & Hazardous*	0
Glass*	0
Metal*	0
Scrap vehicles*	0
Demolition	0.011
Soil & Stone*	0
Particulate matter and dust*	0
Sludge, inert*	0
Sludge, degradable	0.156
Ash & Slag*	0
Other waste, inert*	0

The content of degradable organic matter, DOC_i values, in each waste type is shown separately in Table 7.2.2 and has been kept constant for the whole time series. The methane generation potential per unit waste type *i* is obtained from equation 7.2.9:

$$\frac{L_{o,i}}{W_i} = DOC_f \cdot MCF \cdot F \cdot 16/12 \cdot DOC_i$$

$$\Rightarrow \frac{L_{o,i}}{W_i} = 0.27 \cdot DOC_i$$

Eq. 7.2.9

where the yearly decomposable fraction of the organic carbon content, DOC_f, are set equal to 0.5, the methane conversion factor, *MCF* are set equal to 1 and the volume fraction of CH_4 in generated landfill gas, F, are 0.41 (DGC, 2009). The methane generation potentials according to waste types are reported in Table 7.2.5. A detailed description of the reallocation of waste statistics according to the 18 waste types is presented in Thomsen and Hjelgaard, 2015.

The annual amounts of the waste types (Table 7.2.3) and their emission generation potentials per mass unit (Eq. 7.2.9 and Table 7.2.6) are used to calculate the deposited CH_4 generation potential and the actual generated CH_4 emission from the annually amount of deposited waste (Eq. 7.2.6).

Figure 7.2.1 shows the time trend in annual amounts of deposited methane generation potential for each of the deposited waste type per year.

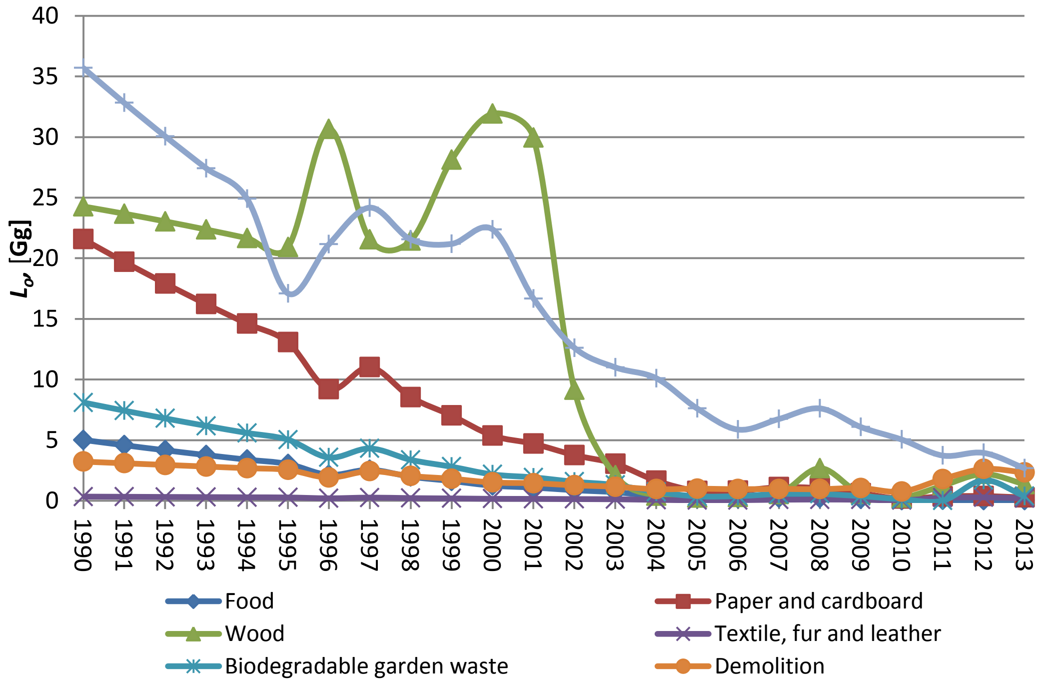

Figure 7.2.1 Annual amounts of deposited methane generation potential per waste type.

As shown from Figure 7.2.1, there is a general tendency for decreasing solid waste deposition in Denmark. Also, significant fluctuations are observed; fluctuations that is greatest for the inert waste types with a methane generation potential of zero (Table 7.2.5) and therefore not included in Figure 7.2.1. The same fluctuations may be observed from the amount of deposited degradable waste types; i.e. deposited waste types influences the yearly deposited methane generation potential more than the variation in degradable organic carbon for the individual waste types, DOC_i values.

However, only a fraction of the methane generation potential is release per year; i.e. a function of the degradation rate constants of the individual waste types, the content of degradable organic carbon and according to first order degradation kinetics for each waste type (Eq. 7.2.1 to 7.2.6 and Table 7.2.2). These seemingly significant fluctuations in the yearly amounts of deposited waste and methane generation potentials becomes insignificant when looking at the annual implied emission factors, calculated from the net methane emission per waste type divided by the accumulated amount of decomposable organic matter per waste type, as illustrated in Figure 7.2.2.

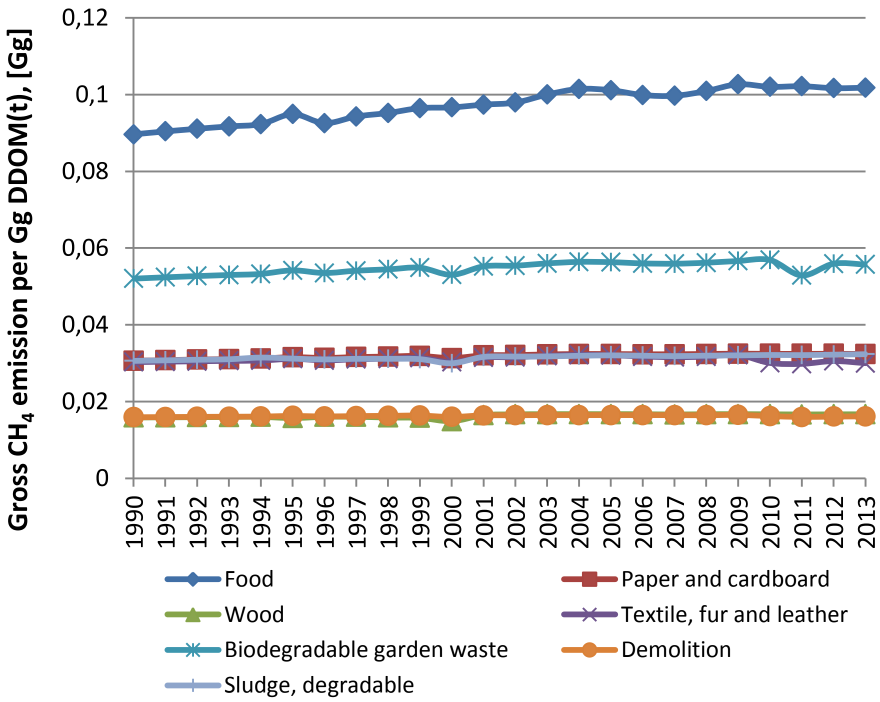

Figure 7.2.2 Annual gross emission factors for each waste type.

Figure 7.2.2 shows the time trend in the gross methane emission factor calculated as the gross methane emission divided by the remaining amount of degradable organic carbon within each waste type. As may be observed from comparing Figure 7.2.2 with 7.2.1, food waste has the highest gross methane emission factor and one of the lowest yearly methane generation potentials. The highest methane emission factor (Figure 7.2.2) for food waste throughout the time series may be explained by the lowest half-life (high CH_4 release rate) and content of degradable organic carbon for food waste compared to other waste types. Still, the yearly amounts of deposited food waste is low and so is the yearly methane generation potential (Eq. 7.2.9).

The net CH_4 emission (Eq. 7.2.7) is obtained upon subtraction of the recovered CH_4, utilized for energy production by biogas combustion installations at some of the sites, and the amount of oxidized methane in the SWDS top layers from the gross methane emission. The annual total amounts of deposited waste, accumulated degradable organic waste, degraded organic matter and the calculated CH_4 emissions are presented in Table 7.2.6.

Table 7.2.6 Waste deposited, total organic degradable matter, amounts of annual degraded organic matter and resulting CH_4 emissions for 1990-2013.

Year	Total Deposited Waste	Accumulated amount of decomposable DDOCm Eq. 7.2.4	Annual amount of degraded DDOCm, Eq. 7.2.5	Annual deposited CH_4 potential	Annual Gross CH_4 emission, Eq. 7.2.6	Recovered methane	Annual net emission before oxidation	Annual net emission after oxidation. Eq. 7.2.7	Implied emissions factor	
		[Gg]				[Gg CH_4]			Gg CH_4/Gg waste	Gg CH_4/Gg *DDOCm*
1990	3,190	2,813	135	98	79.4	0.5	78.8	71.0	0.022	0.025
1995	1,969	2,768	132	62	76.8	7.6	69.2	62.2	0.032	0.022
2000	1,489	2,664	124	65	68.0	11.3	56.7	51.0	0.034	0.019
2005	983	2,227	105	10	58.8	9.9	48.9	44.0	0.045	0.020
2010	2,203	1,840	85	6	47.1	5.7	41.4	37.2	0.017	0.020
2011	2,428	1,778	81	7	45.0	3.9	41.1	37.0	0.015	0.021
2012	2,276	1,712	78	11	43.3	4.2	39.1	35.1	0.015	0.021
2013	2,310	1,647	75	7	41.4	3.9	37.5	33.8	0.015	0.020

The total waste amount in the second column of Table 7.2.6 is the sum of the amounts of the 18 different waste types (Table 7.2.3). The total waste amount is reported as the activity data for the Annual Municipal Solid Waste (MSW) at SWDSs in the CRF Table 5.A.

The implied emission factor (IEF) in the CRF Table 5.A reflects an aggregated emission factor for the model calculated as the net methane emission divided by the total amount of waste deposited in the current year (second last column in Table 7.2.6). However, the IEF value in the last column in Table 7.2.6 represents a more appropriate IEF value, i.e. calculated as the net methane emission divided by the total amount of decomposable degradable organic matter, *DDOCm*, provided in the third column in Table 7.2.6.

The time trend for the total decomposable DOC and annual degraded organic matter are provided in the third and fourth column in Table 7.2.6 and visualised in Figure 7.2.3.

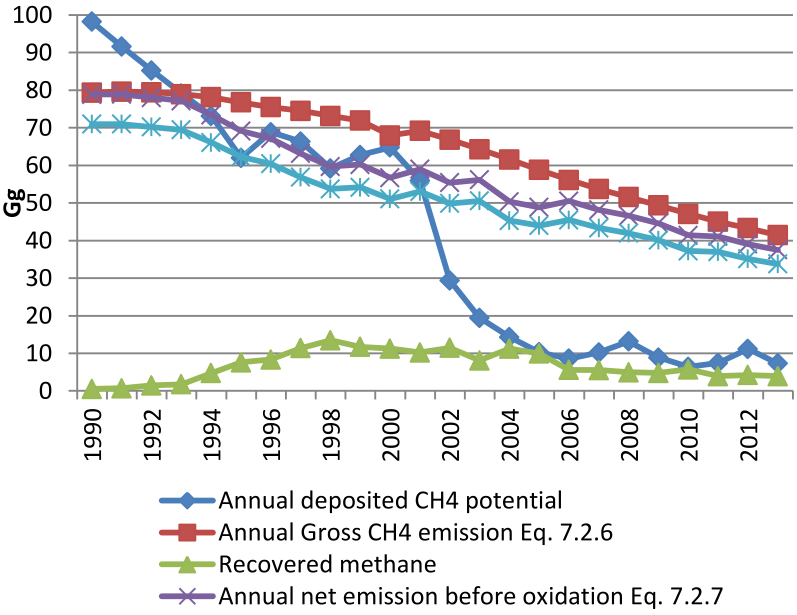

Figure 7.2.3 Time trend in the annual deposited methane potential, gross methane emission, collected methane, annual net methane emission before and after oxidation.

In total a reduction in the net methane emission from 1990 to 2013 of 52 % is observed. This reduction in the methane emission is accompanied by a decrease in the accumulated amount of decomposable degradable organic matter, D*DOCm* of 41 % and a 93 % decrease in the amount of deposited methane potential from 1990 to 2013. The fluctuation in the net methane emission is explained by the fluctuations in the amount of recovered methane.

7.3 Biological treatment of solid waste

This sector provides an overview of the Danish greenhouse gas emission from the CRF source category *5.B Biological treatment of solid waste*, which consists of the presently of the *sub-category 5.B.1 Composting,* while documentation for the methane emissions from anaerobic sludge digestion is presented in Chapter 7.3.2 and 7.5 respectively.

7.3.1 Composting

This section covers the sub-category of biological treatment of solid wastes called composting. Greenhouse gasses that are emitted from this process are CH_4, N_2O and CO_2 as presented in Table 7.3.1. CO_2 emissions from compost production are biogenic. The full time series for emissions related to composting are shown in Annex 3G, Table 3G-3.1.

Table 7.3.1 National emissions from composting – 1990 to 2013, Mg.

Year	1990	1995	2000	2005	2010	2011	2012	2013
CH_4	1,386.1	1,860.2	3,240.0	3,419.9	3,066.5	3,863.2	3,558.5	5,025.0
N_2O	41.5	72.8	515.7	200.2	252.5	318.1	293.0	413.8

Methodological issues

Emissions from composting have been calculated according to a country specific Tier 1 method. However, a Tier 1 default methodological guidance is available in the 2006 IPCC Guidelines (IPCC, 2006).

In Denmark, composting of solid biological waste includes composting of:

- garden and park waste (GPW)
- organic waste from households and other sources
- sludge
- home composting of garden and vegetable food waste

In 2001, 123 composting facilities treated only garden and park waste (type 2 facilities), nine facilities treated organic waste mixed with GPW or other organic waste (type 1 facilities) and 10 facilities treated GPW mixed with sludge and/or "other organic waste" (type 3 facilities). 92 % of these facilities consisted entirely of windrow composting, which is a simple technology composting method with access to only natural air. It is assumed that all facilities can be considered as using windrow composting (Petersen & Hansen, 2003).

Composting is performed with simple technology in Denmark; this implies that temperature, moisture and aeration are not consistently controlled or regulated. Temperature is measured but not controlled, moisture is regulated by watering the windrows in respect to weather conditions and aeration is assisted by turning the windrows (Petersen & Hansen, 2003).

During composting a large fraction of the degradable organic carbon (DOC) in the waste material is converted into CO_2. Even though the windrows are occasionally turned to support aeration, anaerobic sections are inevitable and will cause emissions of CH_4. In the same manner, aerobic biological digestion of N leads to emission of N_2O (IPCC, 2006).

Activity data

All Danish waste treatment plants are obligated to statutory registration and reporting of all waste entering and leaving the plants. All waste streams are weighed, categorised with a waste type and a type of treatment and registered to the ISAG waste information system, which contain data for 1995-2009 (ISAG, 2010). For 201-2014 data from the new waste reporting system have been used and allocation according to the four compost types have been performed using the fractional distribution in 2009 to allocate the total amount of compost.

Figure 7.3.1 illustrates the composted amount of waste divided in the four categories mentioned earlier.

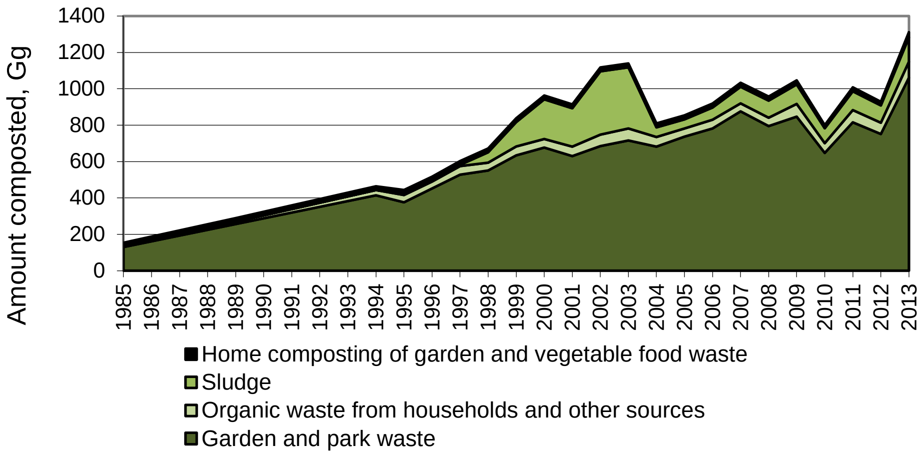

Figure 7.3.1 Trends in the national amount of composted waste.

Activity data for the years 1995-2009 are collected from the ISAG database for the categories: "sludge", "organic waste from households and other sources" and "garden and park waste". Activities for 2010-2013 have been received from the Danish EPA and have been grouped according to the distributional amounts four types reported in ISAG in 2009.

The Danish legislation on sludge (DEPA, 2006c) was implemented in the summer of 2003. This stated that composted sludge may only be used as a fertilizer on areas not intended for growing foods of any kind for at least 2-3 years. This restriction caused the amount of composted sludge to drop drastically from 2003 to 2004.

The trend in composting of sludge does not demonstrate a convincing trend that can be used for estimation of activity data for previous years. Since this activity is insignificant for 1995-1997 (1-2 %) it is assumed to be "not occurring" for 1990-1994.

The amount of organic waste from households composted in the years 1990-1994 is estimated by multiplying the number of facilities treating this type of waste with the average amount composted per facility in the years 1995-2001 (2.6-3.8 Gg per facility per year). The following Table 7.3.2 shows the number of composting sites divided in the three types described in "Methodological issues" (Petersen, 2001 and Petersen & Hansen, 2003).

Table 7.3.2 Number of composting facilities in the years 1990-2001.

Facility type	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Type 1	5	6	7	8	9	13	14	13	14	13	11	9
Type 2	38	54	70	86	102	113	108	99	102	111	115	123
Type 3	1	2	2	3	4	9	9	11	10	10	7	10
Total	44	62	79	97	115	136	133	126	130	139	138	149

Type 1 waste treatment sites normally includes biogas producing facilities, but these have been excluded in Table 7.3.1.

The ISAG activity data for composting of garden and park waste (GPW) include wood chipping. Compost data for GPW provided by Petersen (2001) and Petersen & Hansen (2003) show that for 1997-2001, wood chipping accounts for about 3 % of the total chosen ISAG activity data for GPW. Activity data for GPW for the years 1985-1994 and 2010-2013 are estimated by extrapolating the trend.

The last waste category involved in composting is home composting of garden waste and vegetable waste. The activity data for this category are known from Petersen & Kielland (2003) to be 21.4 Gg in 2001. It is assumed that the following estimates made by Petersen & Kielland (2003) are valid for all years 1990-2013.

- 28 % of all residential buildings with private gardens (including summer cottages) are actively contributing to home composting.
- 14 % of all multi-dwelling houses are actively contributing to home composting.
- 50 kg waste per year will in average be composted at every contributing residential building.
- 10 kg waste per year will in average be composted at every contributing multi-dwelling house.

Multi-dwelling houses include apartment buildings, it is very un-common for people in these types of buildings to compost their bio waste and the average amount of composted waste is therefore lower in spite of the higher number of residents. The total number of occupied residential buildings, summer cottages and multi-dwelling houses are found at the Statistics Denmark's website. The calculated activity data for composting are shown in Table 7.3.3 and in Annex 3G, Table 3G-3.2.

Table 7.3.3 Activity data composting, Gg.

	1990	1995	2000	2005	2010	2011	2012	2013
Composting of garden and park waste	288	376	677	737	648	816	751	1061
Composting of organic waste from house_holds and other sources	16	40	47	45	54	67	62	88
Composting of sludge	NO*	7	218	50	82	103	95	134
Home composting of garden and vegetable food waste	20	21	21	22	18	22	20	29
Total	324	444	963	854	800	1008	929	1312

*NO = Not occurring.

Emission factors

The emissions from composting strongly depend on both the composition of the treated waste and on process conditions such as aeration, mechanical agitation, moisture control and temperature pattern (Amlinger et al., 2008).

The emission factors stated in Table 7.3.4 are considered the best available for the calculation of Danish emissions from composting.

Table 7.3.4 Emission factors for composting.

	Garden and park waste (GPW)	Organic waste from households and other sources	Sludge	Home composting of garden and vegetable food waste
Unit	kg per Mg	kg per Mg	kg per Mg	kg per Mg
CH_4	4.20	4.00	0.41	5.63
N_2O	0.12	0.30	1.92	0.11
Source	Boldrin et al., 2009	EEA, 2009	MST, 2013	Boldrin et al., 2009

Emission factors for composting of GPW and for home composting of garden and vegetable food waste are derived from Boldrin et al. (2009). No other sources were found that describe the emission from home composting.

Boldrin et al. (2009) and MST (2013) do not directly provide any emission factors, the following assumptions were made to derive the factors shown in Table 7.3.3:

- 0.5 % N per dry matter waste water sludge
- 25 % moisture in waste water sludge.
- 2 % N per dry matter garden waste (incl. home composting)
- 25-50 % DOC per dry matter garden waste (incl. home composting)
- 50 % moisture in garden waste (incl. home composting)

The CO_2 produced and emitted during composting is short-cycled C and is therefore regarded as CO_2 neutral (Boldrin et al., 2009).

7.3.2 Anerobic digestion at biogas plants

Biogas production in this sector covers emissions from the handling of biological waste including garden and park waste, household waste, sludge and manure.

Methane emission from biogas plants using landfill gas as feedstock is implicitly included in the CRF source category *5.A.1. Managed Waste Disposal Sites*, as the collected biogas is monitored in terms of energy production subtracted from the yearly methane release from SWDS in Denmark.

Emissions from storage of manure are included in the agricultural sector (cf. Chapter 5), while emissions from anaerobic digestion at biogas plants will be included in the present sector in future inventories.

At present, emissions from anaerobic digestion at biogas producing plants are only included in the inventory for the CRF source category *5.B. Wastewater treatment and discharge*. Fugitive emissions of CH_4 from anaerobic digestion of sludge have been set equal to 1.3% of the biogas production as reported in the Danish Energy Statistics, and are included in Chapter 7.5. In the below section a presentation of status for available plant level data on the loss of methane via flaring and venting from WWTP using anaerobic sludge digestion as sludge management strategy is provided.

Flaring and venting from biogas production at WWTPs

Flaring and venting may occur in different degrees at WWTPs which have implemented anaerobic treatment of sludge for biogas generation. Venting may occur intentionally or unintentionally if there are technical problems at the plant. Flaring is intentional combustion of biogas and occurs for regulation of the gas pressure.

Table 7.3.5 presents available information on the amount of flared and vented biogas in absolute numbers as well as in per cent of the recovered biogas at three of the biggest wastewater treatment plants in Denmark as further detailed in Thomsen (2015).

Table 7.3.5 Biogas production data for the WWTPs Lynetten, Avedøre and Damhusåen.

WWTP		2007	2008	2009	2010	2011	2012
Lynetten[1]							
Biogas produced	Nm^3/year		6,330,381	5,942,571	5,792,838	6,695,142	7,154,932
Flaring	Nm^3/year		284,615	659,576	494,972	946,468	903,613
	%		4.50%	11.10%	8.54%	14.14%	12.63%
Venting	Nm^3/year		NR	NR	NR	NR	NR
	%		NR	NR	NR	NR	NR
Biogas consumed at plant	Nm^3/year		6,045,766	5,282,995	5,297,866	5,748,674	6,251,319
Biogas reported to DEA[3]	Nm^3/year	4,417,670	4,953,913	4,650,708	4,533,525	3,969,338	6,251,318
	%		82%	88%	86%	69%	100%
Avedøre[3]							
Biogas produced	Nm^3/year	3,300,000	3,400,000	3,100,000	3,300,000	3,100,000	3,300,000
Flaring	Nm^3/year	140,000	140,000	54,000	170,000	36,000	10,000
	%	4.24%	4.12%	1.74%	5.15%	1.16%	0.30%
Venting	Nm^3/year	0	2661	9179	54400	130063	50246
	%	0%	0.08%	0.30%	1.65%	4.20%	1.52%
Biogas consumed at plant	Nm^3/year	3,200,000	3,300,000	3,000,000	3,200,000	2,900,000	3,300,000
Biogas reported to DEA[3]	Nm^3/year	2,874,932	3,161,242	2,813,589	2,769,597	2,581,438	2,966,742
	%	90%	96%	94%	87%	89%	90%
Damhusåen[2]							
Biogas produced	Nm3/year		2,690,037	1,665,416	2,123,357	1,997,333	1,918,325
Flaring	Nm3/year		57,750	57,750	307,335	94,150	236,950
	%		2.15%	3.47%	14.47%	4.71%	12.35%
Venting	Nm3/year		NR	NR	NR	NR	NR
	%		NR	NR	NR	NR	NR
Biogas consumed at plant	Nm3/year		2,632,287	1,607,666	1,816,022	1,903,183	1,681,375
Biogas reported to DEA[3]	Nm3/year		NR	NR	NR	NR	NR
	%		NR	NR	NR	NR	NR

[1]Lynettefællesskabet (2009. 2010. 2011. 2012. 2013);[2]Spildevandscenter Avedøre (2012. 2013);[3]DEA (2013);[4]NR:Not Reported.

As may be observed from Table 7.3.5, the amount of flaring is varying from year to year for the same plant as well as between WWTPs. The average flaring is 10 % at Lynetten (data for five years), 2.8 % at Avedøre (data for six years) and 7.4 % at Damhusåen (data for five years). Venting is only reported for Avedøre and constitute in average 1.3 % of the produced amount of biogas. Work is ongoing to extent the documentation for flaring and venting at biogas producing WWTPs (cf. Chapter 7.5).

The methodology used for estimating the CH_4 and N_2O emissions from wastewater handling are described in Chapter 7.5.

7.4 Incineration and open burning

The CRF source category *5.C. Incineration and open burning* includes cremation of human bodies and animal carcasses.

Incineration of municipal, industrial, clinical and hazardous waste takes place with energy recovery and therefore the emissions are included in the relevant subsectors under CRF sector 1A. For documentation please refer to Chapter 3.2. Flaring off-shore and in refineries are included under CRF sector 1B2c. for documentation please refer to Chapter 3.5. No flaring in chemical industry occurs in Denmark.

Table 7.4.1 gives an overview of the Danish greenhouse gas emission from the CRF source category *5.C Incineration and open burning* comprised by emission from human and animal cremations. CO_2 emissions from animal and human cremations are considered biogenic.

Table 7.4.1 Methane and Nitrous oxide emissions from human and animal cremations.

Year	1990	1995	2000	2005	2010	2011	2012	2013
CH_4 emission from								
Human cremation	0.48	0.52	0.49	0.48	0.49	0.49	0.48	0.50
Animal cremation	0.03	0.04	0.08	0.14	0.26	0.22	0.22	0.21
Total	0.51	0.55	0.57	0.62	0.76	0.71	0.70	0.71
N_2O emission from								
Human cremation	0.60	0.64	0.61	0.60	0.62	0.61	0.60	0.62
Animal cremation	0.03	0.05	0.10	0.17	0.33	0.28	0.28	0.26
Total	0.64	0.69	0.71	0.77	0.95	0.88	0.88	0.88
Total human cremation CO_2 eqv.	191.62	204.97	194.70	190.53	196.57	192.82	191.23	197.96
Total animal cremation CO_2 eqv.	10.79	14.38	31.89	54.83	104.19	87.64	89.00	82.56

While emissions from human cremations have been steady over the last two decades, emissions from animal cremations have increased. In 1990, animal cremations represented 5 % of the total emission of CO_2 eqv. from cremations. In 2013 this number has increased to 29 %. GHG emissions from cremations are very small; 0.20 CO_2 eqv. in 1990 and 0.28 CO_2 eqv in 2013. Emissions for the whole time series are provided in Annex 3G, Table 3G-4.1.

7.4.1 Human cremation

The incineration of human corpses is a common practice that is performed on an increasing part of the deceased. All Danish crematoria use optimised and controlled cremation facilities with temperatures reaching 800-850 °C, secondary combustion chambers, controlled combustion air flow and regulations for coffin materials.

Methodological issues

During the 1990es all Danish crematoria were rebuilt to meet new standards. This included installation of secondary combustion chambers and in most cases replacement of old primary combustion chambers (Schleicher et al., 2001). All Danish crematoria are therefore performing controlled incinerations with a good burn-out of the gases and a low emission of pollutants.

Following the development of new technology, the emission limit values for crematoria were lowered again in January 2011. These new standards were originally expected from January 2009 but were postponed two years for existing crematoria. Table 7.4.2 shows a comparison of the emission limit values from February 1993 and the new standard limits.

Table 7.4.2 Emission limit values, mg per Nm^3 at 11 % O_2 (Schleicher et al., 2008).

Component	Report 2/1993	Standard terms (1/2011)
	Emission limit value mg per normal m^3 at 11 % O_2	
CO_2	500	500
Other demands:		
Stack height	3 m above rooftop	3 m above rooftop
Temperature in stack	Minimum 150 °C	Minimum 110 °C
Flue gas flow in stack	8 – 20 m/s	No demands
Temperature in after burner	850 °C	800 °C
Residence time in after burner	2 seconds	2 seconds

To meet the new standards, some crematoria have been rebuilt to larger capacity while others are closed (MILIKI, 2006). In 2012, there were 26 operating crematoria in Denmark, some with multiple furnaces. In 2010 there were 31 operating crematoria (DKL, 2013).

Crematoria that are not closed are equipped with flue gas cleaning (bag filters with activated carbon). The use of air pollution control devices. The use of air pollution control devices, will however not affect the greenhouse gas emissions.

Around half of the Danish crematoria are currently connected to the district heating system and in addition, a few crematoria produce heat for use in their own buildings. The bag filter cleaning system requires that the flue gas is cooled down to 125-150 °C, and the cheapest way to do so is to use the surplus heat in the district heating system (DKL, 2009). The heat contribution from crematoria is negligible compared to the total district heat production and is not part of the Danish energy statistics. Therefore, it is not included in the Energy sector.

Activity data

Table 7.4.3 shows the time series of total number of nationally deceased persons (Statistics Denmark, 2013), number of cremations and the fraction of cremated corpses in relation to the total number of deceased (DKL, 2013). Annex 3G, Table 3G-4.2 presents data for the entire time series 1990-2013.

Table 7.4.3 Data human cremations. DKL (2013). Statistics Denmark (2013)

Year	1990	1995	2000	2005	2010	2011	2012	2013
Nationally deceased	60,926	63,127	57,998	54,962	54,368	52,516	52,325	52,471
Cremations	40,991	43,847	41,651	40,758	42,050	41,248	40,909	42,349
Cremation fraction. %	67.3	69.5	71.8	74.2	77.3	78.6	79.6	80.7

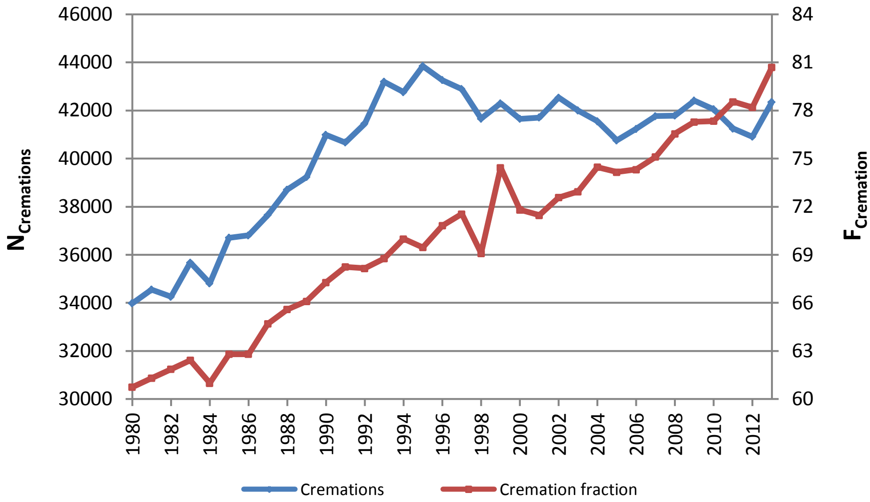

Figure 7.4.1 Visualisation of the development in cremations (DKL 2013), where the number of cremation, $N_{cremations}$, is shown at the left Y-axis. The cremation percentage, $F_{cremations}$, shows the percentage of cremated deceased of the total number of deceased for the years 1990-2013.

Even though the total number of annual cremations is fluctuating, the cremation percentage has been steadily increasing since 1990, and is likely to continue to increase. The average body weight is assumed to be 65 kg (EEA. 2009).

Figure 7.4.2 presents the trend of the number of deceased persons together with the activity data for human cremation. The figure shows a direct connection between the number of deceased and the activity of human cremation as the two trends are quite similar. Figure 7.4.2 also shows the effect of the increasing fraction of cremations per deceased. as the number of cremations is not decreasing along with the number of deceased. The cremation fraction has increased from 67 % in 1990 to 92 % in 2013; the trend of this fraction is shown in Figure 7.4.1.

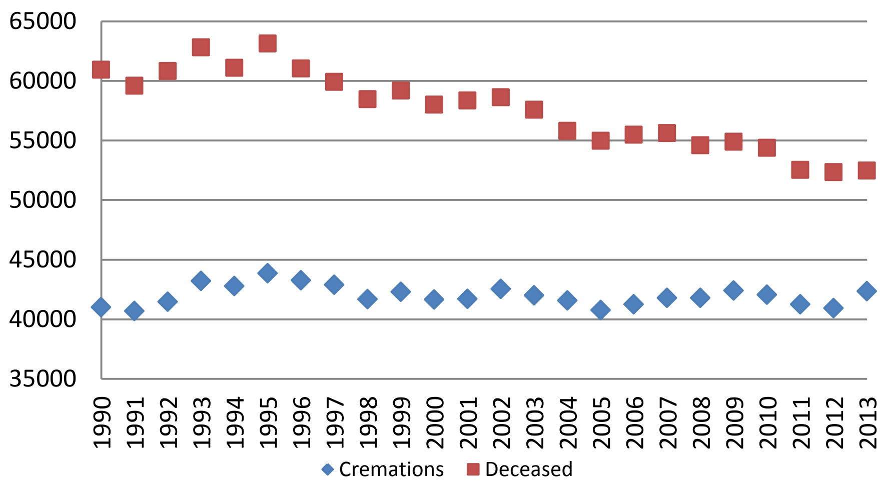

Figure 7.4.2 Trends of the activity data for cremation of human corpses and the national number of deceased persons.

Emission factors

For human cremation, emissions are calculated by multiplying the total number of human cremations by the emission factors. Since there are no continuous measurements available of the annual emission from Danish crematoria, the estimation of emissions is based on emission factors from literature.

A literature search has provided the emission factors shown in Table 7.4.4. It has not been possible to find any additional data to validate the emission factors.

Table 7.4.4 Emission factors for human cremation with references.

Pollutant name	Unit	Emission factor	Reference
CH_4	g/body	11.8	Aasestad. 2008
N_2O	g/body	14.7	Aasestad. 2008

7.4.2 Animal cremation

The incineration of animal carcasses in animal crematoria follows much the same procedure as human cremation. Animal crematoria use similar two chambered furnaces and controlled incineration. However, animal carcasses are incinerated in special designed plastic (PE) bags rather than coffins. Emissions from animal cremation are similar to those from human cremation.

Animal cremations are performed in two ways, individually where the owner often pays for receiving the ashes in an urn or collectively which is most often the case with animal carcasses that are left at the veterinarian.

Methodological issues

Open burning of animal carcasses is illegal in Denmark and is not occurring, and small-scale incinerators are not known to be used at Danish farms. Livestock that is diseased or in other ways unfit for consumption is disposed of through rendering plants. Incineration of livestock carcasses is illegal and these carcasses are therefore commonly used in the production of fat and soap at Daka Bio-industries.

The only animal carcasses that are approved for cremation in Denmark are deceased pets and animals used for experimental purposes, where the incineration must take place at a specialised animal crematorium. There are four animal crematoria in Denmark but one of these is situated at a waste incineration company in northern Jutland called AVV. The specially designed cremation furnaces are at this location connected to the flue gas cleaning equipment of the municipal waste incineration plant with energy recovery and the emission from the cremations are therefore included in the annual inventory from AVV and consequently included under the energy sector in this report. Therefore only three animal crematoria are included in this section.

Animal by-products are regulated under the EU commission regulation no. 142/2011. This states that animal crematoria must be approved by the authority and comply either with the EU directive (2000/76/EC) on waste incineration or with Regulation (EC) No. 1069/2009 (EC. 2011).

The incineration of animal carcasses is, as the incineration of human corpses, performed in special incineration chambers. All Danish animal crematoria have primary combustion chambers with temperatures around 850 ºC and secondary combustion chambers with temperatures around 1100 ºC. The support fuel used at the Danish facilities is natural gas.

Activity data

Activity data for animal cremation are gathered directly from the animal crematoria. There is no national statistics available on the activity from these facilities. The precision of activity data therefore depends on the information provided by the crematoria.

Table 7.4.5 lists the four Danish animal crematoria, their foundation year and provides each crematorium with an id letter.

Table 7.4.5 Animal crematoria in Denmark.

Id	Name of crematorium	Founded in
A	Dansk Dyrekremering ApS	May 2006
B	Ada's Kæledyrskrematorium ApS	Unknown. Has existed for more than 30 years
C	Kæledyrskrematoriet	2006
D	Kæledyrskrematoriet v. Modtage-station Vendsyssel I/S	-

Crematoria D is situated at the AVV municipal waste incineration site and the emissions from this site are, as previously mentioned, included in the annual emission reporting from AVV and consequently included in the energy sector in this report as waste incineration with energy recovery. Therefore, only crematoria A-C are considered in this chapter.

Table 7.4.6 lists the activity data for animal crematoria A-C. The entire dataset for 1990-2013 is available in Annex 3G, Table 3G-4.3.

Table 7.4.6 Activity data. Source: direct contact with all Danish crematoria.

	1990	1995	2000	2005	2010	2011	2012	2013
Total. Mg	150	200	443	762	1,449	1,219	1,238	1,146

Crematorium B delivered exact annual activity data for the years 1998-2011. They were not certain about the founding year but believe to have existed since the early 1980es. Activity data for 1990-1997, 2012 and 2013 has therefore been estimated by the author's expert judgement. It is not possible to extrapolate data back to 1990 because the activity, due to the steep trend line, in this case would become negative.

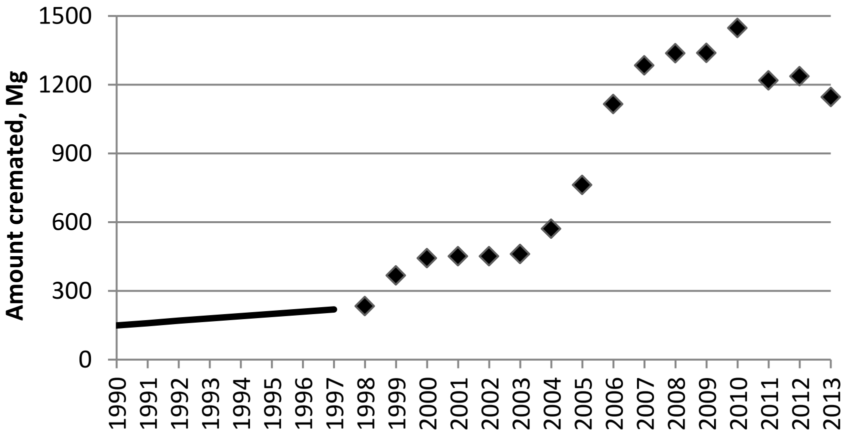

Figure 7.4.3 The amount of animal carcasses cremated (Mg). Data from 1998-2013 are delivered by the crematoria and is considered to be exact; these data are marked as points. Data from 1990-1997 are estimated and are shown as the thick line in the figure.

It is not possible to extrapolate data linearly back to 1980 because the activity, due to the steep increase, in this case would become negative from 1993 and back in time.

Emission factors

Concerning the incineration of animal carcasses in animal crematoria there is not much literature to be found.

Emission factors for CH_4 and N_2O are collected from the literature search on human cremation and it is assumed that humans and animals are similar in composition for this purpose. Emission factors from human cremation are recalculated to match the activity data for animal cremation. Table 7.4.7 lists the emission factors and their respective references.

Table 7.4.7 Emission factors for animal cremation.

Pollutant name	Unit	Emission factor	Reference
CH_4	g/Mg	182	Aasestad. 2008
N_2O	g/Mg	226	Aasestad. 2008

7.5 Wastewater treatment and discharge

The Danish wastewater treatment system is characterised by few big and advanced wastewater treatment plants (WWTPs) and many smaller WWTPs. From 1993 to 2013 the amount of wastewater treated at the most advanced technological WWTPs in Denmark has increased from 53 % to above 90 %. Improvements of the decentralised wastewater treatment system as well as the sewer system are on-going in Denmark (DEPA, 2010b). For the part of the population which is not connected to the collective sewer system, i.e. scattered houses, septic sludge are collected once per year or as appropriate by judgement of the local authorities (DEPA. 1999b). Municipal collection and transportation of sludge from septic tanks for treatment at the centralised WWTPs occurs at a frequency set by the local authorities and in general septic tanks are emptied one time each year.

A presentation of methodological approach, emission factors, activity data and recalculations are presented in the following sub-chapters.

7.5.1 Source category description

This source category includes an estimation of the emission of CH_4 and N_2O from wastewater handling; i.e. wastewater collection and treatment. CH_4 is produced during anaerobic conditions and treatment processes, while N_2O may be emitted as a by-product from nitrification and denitrification processes under anaerobic as well as aerobic conditions (e.g. Adouani et al., 2010; Kampschreur et al., 2009).

No distinction between emissions from industrial and municipal WWTPs is made, as Danish industries to a great extent are connected to the municipal sewer system. Wastewater streams from households and industries are therefore mixed in the sewer system prior to further treatment at centralised WWTPs. The contribution from the industry to the influent wastewater at the centralised WWTPs has increased from zero in 1987 to around 40% from 2006 (Annex 3G, Table 3G-3.3) with the highest influent contribution occurring at the biggest and most advanced technological WWTPs in Denmark (Thomsen & Lyck, 2005; ASEP, 2010). Monitoring data on the influent and effluent resources, i.e. N, P, biological oxygen demand (BOD) and chemical oxygen demand (COD) for the wastewater are available for all WWTPs (Thomsen, 2015).

Documentation for a decreased fraction of the population not connected sewer system is still missing. and therefore the fraction of the population not connected to the collective sewer system is kept at 10% (Thomsen. 2015).

Regarding diffuse emissions from the sewer system, very little data are available (e.g. Lyngby-Taarbæk Kommune, 2013). It is known that centralized wastewater treatment plants are associated with increased residence times, which increases the risk of the occurrence of bottom sediments and thus biological decomposition of organic matter in the sewage system. The sewer system is, however, hydraulically designed to prevent the accumulation of bottom sediments and under such conditions, temporary anaerobic processes will be dominated by fermentation and sulphate reduction, which means that the possibility of methane formation may be ignored (Danva, 2008; Hvitved-Jacobsen, 2001).

It should be mentioned that no activity data have been available for separate industrial WWTPs. The direct emissions from industries having separate wastewater treatment are therefore not included in the Danish inventory for category *5.D.Wastewater treatment and discharge* (see chapter 7.5.2). A methodology for estimating the direct emission from separate industries is however presented in Thomsen (2015) and will be included in the reporting year 2016. The indirect N_2O emissions from separate industries are however included, as effluent N data are available from DEPA reports (DEPA, 1994, 1996b, 1997, 1998b, 1999b, 2000, 2001c, 2002b, 2003b, 2004c, 2005b, 2005c and ASEP, 2007, 2010, 2011, 2012, 2013).

Methane emission

Fugitive methane emissions from the municipal and private WWTPs have been divided into contributions from 1) the sewer system, primary settling tank and biological N and P removal processes, 2) from anaerobic treatment processes in closed systems with biogas recovery for energy production and 3) septic tanks. The individual contribution to the net methane emission is given in Table 7.5.1, data for the whole time series is provided in Annex 3G, Table 3G-5.1.

Table 7.5.1 Produced, recovered and emitted CH_4 from wastewater treatment, Gg.

Year	1990	1995	2000	2005	2010	2011	2012	2013
$CH_{4.AD.\ gross}$	10.57	15.37	23.20	23.12	23.82	26.44	30.86	29.80
$CH_{4.recovery}$	10.45	15.21	22.97	22.88	23.59	26.22	30.63	29.55
$CH_{4.AD.net}$	0.12	0.16	0.23	0.24	0.22	0.22	0.24	0.26
$CH_{4.sewer+MB}$	0.23	0.25	0.28	0.28	0.28	0.29	0.28	0.29
$CH_{4.st}$	3.63	3.69	3.77	3.83	3.91	3.93	3.95	3.96
$CH_{4.total}$	3.98	4.10	4.28	4.35	4.42	4.44	4.46	4.51

The net CH_4 emission from the *5.D Wastewater treatment and discharge* has increased by 112% from 1990 to 2013. Regarding the fraction of the population not connected to the collective sewer system ($CH_{4.st}$) an increase of 9.1 % is observed from 1990 to 2013. Lastly, the amount of recovered methane for energy production has increased 183 % from 1990 to 2013 (cf. chapter 7.5.2 for further documentation).

Nitrous oxide emission

N_2O formation and releases both during the treatment processes at the WWTPs and also from discharged effluent wastewater are included.

The emission of N_2O from wastewater handling is calculated as the sum of contributions from wastewater treatment processes at the WWTPs (direct emissions) and from sewage effluents (indirect emissions). The emission from effluent wastewater, i.e. indirect emissions, includes separate industrial discharges, rainwater-conditioned effluents as well as effluents from scattered houses and from aquaculture.

Table 7.5.2 shows the total N_2O emission originating from treatment processes at the Danish WWTPs (direct emissions) and effluents to the Danish surface waters (indirect emissions). The full time series 1990-2013 is shown in Annex 3G, Table G-5.2.

Table 7.5.2 N_2O emissions from wastewater, Mg.

	1990	1995	2000	2005	2006	2007	2008	2009	2010	2011	2012	2013
$N_2O_{.\ indirect}$	265	238	157	111	109	116	103	108	109	107	104	101
$N_2O_{.\ direct}$	73	111	134	161	127	154	214	127	136	150	131	147
$N_2O_{.\ total}$	339	350	292	272	236	270	317	235	246	257	235	248

Regarding the time trend, the indirect N_2O emission has decreased 62 % N_2O from 1990 to 2013, while the direct N_2O emission has increased 101 %. In absolute figures the indirect emission is a major contributor and the resulting total N_2O emission has decreased 27 % from 1990 to 2013.

7.5.2 Methodology and data

The methodology developed for this submission for estimating emission of methane and nitrous oxide from wastewater handling follows the IPCC Guidelines (IPCC. 1997) and the IPCC Good Practice Guidance (IPCC. 2000).

A review of plant specific data was initiated with the purpose of identifying process emissions from the biogas production at wastewater treatment plants. Data on biogas lost via venting is scarce but based on a review of plant level environmental account data reported voluntary by the WWTPs an EF value of 1.3 % of the gross energy production were applied in this year´s inventory (Thomsen, 2015). This has led to a small decrease in the methane lost by venting ranging between 2.9%-6.4%.

The main reason for the increase in the methane emission from sector *5.D. Wastewater treatment and discharge* are to be found in the change in the default COD value for the 10% of the population not connected to the collective sewer system from 45.625 to 56.575 kg COD/person/yr. (IPCC, 1996, IPCC, 2006), which results in an increase in the methane emission from septic tanks of 29.2%. Likewise, the use of COD data in place of BOD data for the influent organic matter (TOW) have resulted in an increase in the methane emission from the sewer system and biological treatment of 0-30% (cf. Equation 7.5.5, Text below Table 7.5.3 and Chapter 7.9).

Only a minor update in the influent N for the year 2011 resulting in a small increase in the N_2O emission of 0.24% (cf. Chapter 7.9, Table 7.9.1), while no methodological changes have occurred.

For the methane emission, the methodology is being modified according to recommendations of the UNFCCC review team, asking for documentation of the methane balance according to equation 6.1 (IPCC, 2006). Such mas balance has not been included in the present NIR, but status methodological improvements are presented in Thomsen (2015) and will be included in the NIR when the review at plant-level are complete.

The UNFCCC review has furthermore recommended increased transparency and completeness in the national activity data and derived emissions factor.

In terms of a mass balance documenting the methane loss, the activity data in this year's inventory is provided in units of COD (Chemical Oxygen Demand) in place of BOD (Biological Oxygen Demand) as such data make it possible to set up a COD mass balance verifying the size of the EF_{AD} value (Thomsen, 2015). As COD data are available for final sludge in the plant level environmental reports as well as in the influent wastewater and as more theoretical knowledge on the relationship between the energy content and COD, an increased degree of completeness are obtained from the use of COD as activity data. A plant level integration of COD data and energy production data have made it possible to quantify the fraction of influent COD treated at WWTPs using anaerobic digestion as sludge management strategy (cf. Table 7.5.3). The relative standard deviation of the results originating from the two methodological approaches range between 0.9 and 17.4%, which is within the range of the uncertainty reported for the influent amount of TOW (Chapter 7.7, Table 7.7.4).

This section is divided into methodological issues related to the CH_4 and N_2O emission calculations, respectively.

Methane emissions from private and municipal WWTPs

The methane emissions from WWTP are divided into a contribution from the sewer system, primary settling tank and biological N and P removal processes, $CH_{4.\ sewer+MB}$, and from anaerobic treatment processes in closed systems with biogas extraction for energy production, $CH_{4.AD}$.

$$CH_{4,WWTP} = CH_{4,sewer+MB} + CH_{4,AD} \qquad \text{Eq. 7.5.1}$$

<u>The fugitive emissions from the sewer system, primary settling tank and biological N and P removal processes, $CH_{sewer+MB}$, are estimated as:</u>

$$CH_{4,sewer+MB} = EF_{sewer+MB} \cdot TOW_{inlet}$$
$$\Downarrow$$
$$CH_{4,sewer+MB} = B_o \cdot MCF_{sewer+MB} \cdot TOW_{inlet}$$ Eq. 7.5.2

where

$\boldsymbol{TOW_{inlet}}$ equals the influent organic degradable matter measured as the chemical oxygen demand (COD) in the influent wastewater flow.

Bo is the default maximum CH_4 producing capacity, i.e. 0.25 kg CH_4 per kg COD (IPCC, 2006).

$\boldsymbol{MCF_{sewer+MB}}$ is the fraction of DOC that is anaerobically converted in sewers and WWTPs. $\boldsymbol{MCF_{sewer+MB}}$ equals 0.003 based on an expert judgement (personal communication: Professor Jes Vollertsen) of a conservative estimate of the fugitive methane emission from the primary settling tanks and biological treatment processes is well below 0.1 % of influent COD, while the fugitive emission from the sewer system is judged to be negligible or zero (DANVA, 2008).

The emission factor, $\boldsymbol{EF_{sewer+MB}}$, for these three processes and systems equals **0.0008 kg CH_4 per kg COD.**

<u>The methane emission from anaerobic digestion is calculated as:</u>

The gross methane emissions, $CH_{4,AD,gross}$, are calculated as:

$$CH_{4,AD,gross} = f_{AD} \cdot MCF_{AD} \cdot B_o \cdot TOW_{inlet}$$ Eq. 7.5.3

where

$\boldsymbol{f_{AD}}$ is the fraction of the COD in the influent wastewater that are conserved in the ingestate set equal to 0.6 (Jensen et al., 2015, Thomsen et al., 2015),

$\boldsymbol{MCF_{AD}}$, the methane correction factor, adjust the default maximum CH_4 producing capacity or theoretical methane yield to the expected conversion under real operating conditions and is set equal to 0.8 (IPCC, 2006),

$\boldsymbol{TOW_{inlet}}$ equals the influent organic degradable matter measured as the sum of chemical oxygen demand (COD) in the influent wastewater at WWTPs using anaerobic sludge digestion in a digester tank for the production of biogas,

$\boldsymbol{B_o}$ is the default maximum CH_4 producing capacity, i.e. 0.25 kg CH_4 per kg COD (IPCC, 2006). By dividing B_o with the density of methane, i.e. 0.72 kg CH_4/m^3, the theoretical methane yield of 0.35 Nm^3 CH_4 per kg COD is obtained, a value which, as expected, is strongly under matched in real operating conditions.

The net methane emission from anaerobic digestion in biogas tanks are at present estimated according to equation 5 for the whole time series:

$$CH_{4,AD,net} = EF_{AD} \cdot CH_{4,AD,recovered}$$ Eq. 7.5.4

where the emission factor, EF_{AD}, has been set equal to 1.3 % of the methane content in the gross energy production at national level reported by the Danish Energy Agency, i.e. 0.013 (see Table 7.3.5 and 7.5.3 and Thomsen, 2015).

At the present stage of verification of activity data, equation 7.5.4 has been applied for estimating the net methane emission from anaerobic digestion of sludge, i.e. the net methane emission from anaerobic digestion equals the methane emissions due to venting (Thomsen, 2015).

Methane emissions from septic tanks

For the part of the population not connected to the collective sewer system, simple decentralised wastewater handling is assumed and modelled as septic tanks. Only little knowledge is available about the frequency of collection and no measurements of the methane emissions from septic tanks and the pumping and management of septage, including its transportation to a wastewater treatment facility exist. Methane emission from septic tanks is calculated as:

$$CH_{4,st} = EF_{st} \cdot f_{nc} \cdot P \cdot DOC_{st}$$
$$\Downarrow$$
$$CH_{4,st} = B_o \cdot MCF_{st} \cdot f_{nc} \cdot P \cdot DOC_{st} \qquad \text{Eq. 7.5.5}$$

where

Bo is the default maximum CH_4 producing capacity, i.e. **0.25 kg CH_4 per kg COD** (IPCC, 2006).

MCF_{st} is the methane conversion factor. It depends on the extent to which COD settles in the septic tanks. MCF_{st} has been set **equal to 0.5** (IPCC, 2006) assuming that degradation for the settled DOC occurs under 100 % anaerobic conditions.

F_{nc} is the fraction of the population that is not connected to the sewer system, i.e. scattered houses, which is set equal to **10 %.**

DOC_{st} is the per capita produced degradable organic matter (DOC) which equals **56.575 kg COD per 1000 persons per year** derived from the default value of 62 g BOD/person/year multiplied by the COD/BOD factor of 2.5 (IPCC, 2006).

P is the population number.

Using the default maximum methane producing capacity and a methane conversion factor of 0.5 (IPCC guidelines, 2006, Table 6.3) results in an emission factor, ***EF_{st}*, equal to 0.125**.

Annual activity data and emission factors used for calculation the net methane emission

Monitoring data on the influent BOD and COD are available for mixed industrial and household wastewater, which are used for calculating the total organic waste (TOW) in the influent wastewater. From 1990 to 1998, the IPCC default methodology for household wastewater has been applied by accounting and correcting for the industrial influent load (Thomsen & Lyck, 2005). For the years 1999 to 2013 monitoring data from the national monitoring program exists. The time series for activity data on TOW are presented in Table 7.5.3. The full time series is presented in Annex 3G, Table 3G-5.3.

Table 7.5.3.Total degradable organic waste in the influent wastewater (TOW), Gg.

Year	1990	1995	2000	2005	2010	2011	2012	2013
Contribution from industrial inlet [%]	2.5	22.2	42.0	40.5	40.5	40.5	40.5	40.5
Population-Estimates (1000)	5135	5216	5330	5411	5535	5561	5581	5603
TOW (Gg COD/year)	300.73	334.50	375.02	369.31	379.01	380.82	374.46	387.59
TOW (Gg BOD/year)	96.53	116.32	148.53	140.87	144.55	150.92	134.64	136.40
COD/BOD ratio	3.1	2.9	2.5	2.6	2.6	2.5	2.8	2.8
$COD_{influent,anaerobic}$ [Gg]*	88.1	128.1	193.3	192.7	198.5	220.3	257.2	248.4

* The amount of the influent TOW at Danish WWTP using anaerobic digestion as sludge management strategy (Thomsen, 2015).

The COD data were used to estimate the fugitive methane emissions from the sewer system, primary settling tank and biological N and P removal processes according to equation 7.5.2.

For the anaerobic digestion of sludge, the Danish energy statistics were used to quantify the amount of recovered methane together with the EF_{AD} value of 0.013 (Equation 7.5.4). This has resulted in higher degree of completeness and transparency in the methodological approach. A detailed verification of the methodology is presented in Thomsen (2015), the change in results according to methodological changes are presented in terms of relative uncertainty in results from last year and this year´s inventory in Chapter 7.9 and further improvements are described in Chapter 7.10.

Regarding the methane emission from scattered houses, i.e. the fraction of the population which is not connected to the collective sewer system, the default IPCC value of 22.63 kg BOD per person per year (62 g BOD/person/year*365/1000) was selected in place of the national value of 21.9 kg BOD per person per year (www.mst.dk). The default IPCC value corresponds to an COD value of 56.575 kg COD per persons per year compared to a country-specific value 59.130 kg COD per person per year, using the average Danish BOD/COD conversion factor reported in Table 7.5.3 and a value of 54.750 kg COD per person per year using the default IPCC conversion factor of 2.5. As the average Danish BOD/COD conversion factor reflects the presence of industrial wastewater in the influent wastewater at Danish WWTPs (Thomsen, 2015), the default and most conservative IPCC value of 56.575 kg COD per persons per year were used to estimate the methane emission from scattered houses modelled as septic tanks (Equation 7.5.5).

Overall methane emission time trends

The trends in the CH_4 emission from the Danish WWTPs, as summarised in Table 7.5.1, are presented graphically in Figure 7.5.1.

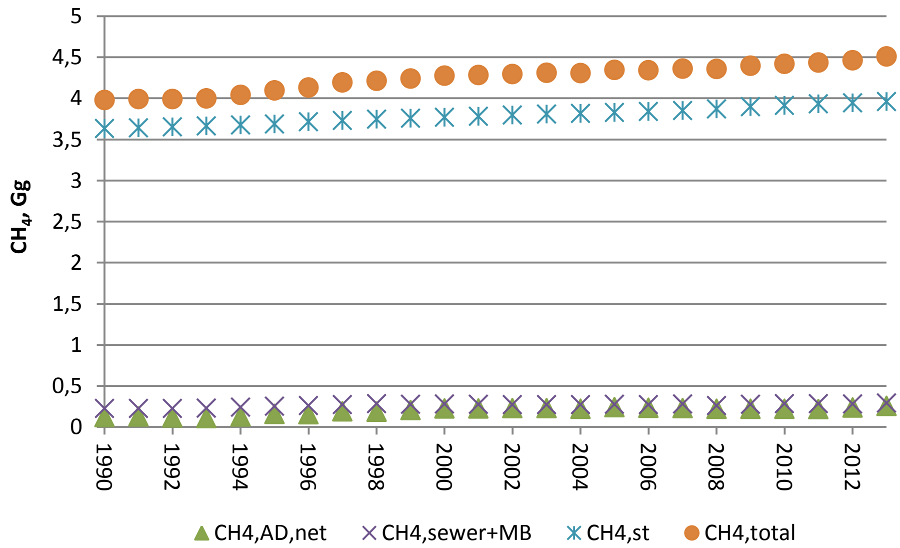

Figure 7.5.1 Time trends for net methane emission, methane emission from sewer systems, mechanical and biological treatment, from septic tanks and from anaerobic treatment processes.

The methane emission due to venting, i.e. $CH_{4,AD,net,}$ has increased by 112% from 1990 to 2013. The methane emission from the sewer system, mechanical and biological treatment, i.e. $CH_{4,sewer+MB}$, has increase by 28.9% from 1990 to 2013. The methane emission from scattered houses, i.e. $CH_{4,st}$, has increased by 9.1%.

The total methane emissions, i.e. $CH_{4,total}$, has increased from 3.97 Gg in 1990 to 4.51 Gg methane in 2013 corresponding to an increase in net methane emissions from wastewater handling of 13.3 %.

N_2O emissions from WWTPs

N_2O may be generated by nitrification (aerobic processes) and denitrification (anaerobic processes) during biological treatment. Starting material in the influent may be urea, ammonia and proteins, which are converted to nitrate by nitrification. Denitrification is an anaerobic biological conversion of nitrate into dinitrogen. N_2O is an intermediate of both processes. A Danish investigation indicates that N_2O is formed during aeration steps in the sludge treatment processes as well as during anaerobic treatments, the former contributing most to the N_2O emissions during sludge treatment (Gejlsberg et al., 1999, Thomsen et al., 2015). A review by Kampschreur et al. (2009) documents that around 90% of the emitted N_2O originates from activated sludge processes. Based on this review an average of two highest EF values, i.e. 0.6 % N_2O (Wicht et al., 1995) and 0.035 % (Czepiel et al., 1995), both reported in units of per cent N load in the influent wastewater was used to derive a national EF for the direct emission of nitrous oxide. The EF value has been verified in Thomsen et al., 2015)

The direct N_2O emission from wastewater treatment processes is calculated according to Equation 7.5.6:

$$E_{N_2O} = EF_{N_2O,direct} \cdot m_{N,\inf luent} \cdot \frac{M_{N_2O}}{2 \cdot M_N} \qquad \text{Eq. 7.5.6}$$

where

$EF_{N2O.direct}$ is set equal to a fraction of 0.0032 of the N load in the influent wastewater.

$m_{N.influent}$ is the annually reported N load in the Danish Water Quality Parameter Database provided in Table 7.5.4.

M_{N2O}/M_{N2} is the mass ratio i.e. 44/28 to convert the fraction of discharged N emitted as nitrous oxide from total N.

The country-specific EF value of 0.0032 may be expressed as $EF_{N2O.direct}$ = 4.99 g N_2O per kg N load in the influent wastewater by reducing eq. 7.5.6 to:

$$E_{N_2O} = EF_{N_2O,direct} \cdot m_{N,\inf luent} \qquad \text{Eq. 7.5.7}$$

The methodology here adopted for estimating the direct N_2O emission only relies on the influent N load as activity data.

<u>The indirect N_2O emission from WWTPs is calculated according to Equation 7.5.8</u>:

$$E_{N_2O,WWTP,effluent} = D_{N,WWTP} \cdot EF_{N_2O,WWTP,effluent} \cdot \frac{M_{N_2O}}{2 \cdot M_N} \qquad \text{Eq. 7.5.8}$$

where

$D_{N.WWTP}$ is the effluent discharged sewage nitrogen load consisting of contributions from municipal wastewater treatment plants, the separate industry. effluent from aquaculture, rainwater conditioned effluents and scattered houses not connected to the sewage system (cf. Table 7.5.4).

$EF_{N2O.WWTP.effluent}$ is the IPCC default emission factor of **0.01 kg N_2O-N per kg sewage-N** produced (IPCC, 1997, p 6.28)

M_{N2O}/M_{N2} is the mass ratio i.e. 44/28 to convert the fraction of discharged N emitted as nitrous oxide from total N.

Annual activity data and emission factors for calculating the nitrous oxide emission

Data on the N content in the influent and effluent wastewater flows are provided in Table 7.5.4. The effluent data provided in the table constitute a sum of the N content in effluent wastewater from municipal wastewater treatment plants, the separate industry, effluent from aquaculture, rainwater conditioned effluents and scattered houses. For the entire time series 1990-2013 cf. Annex 3G, Table 3G-5.4.

Table 7.5.4 Nitrogen content in the influent and effluent wastewater, Mg.

	1990	1995	2000	2005	2010	2011	2012	2013
Influent wastewater to WWTPs[1]	14,679[3]	22,340	26,952	32,288	27,357	30,049	26,316	29,557
Effluent wastewater from WWTP[2]	10,268	8,938	4,653	3,831	4,025	3,916	3,849	3,652
Effluent wastewater. Total[2]	16,884	15,152	10,005	7,038	6,960	6,770	6,597	6,399

[1]Data on the influent wastewater N load from municipal WWTPs are available from the Danish Water Quality Parameter Database held by the Agency for Spatial and Environmental Planning.

[2]Effluent wastewater, total includes separate industrial discharges, rainwater conditioned effluent, scattered houses, aquaculture farming and effluents from WWTPs (DEPA, 1994, 1996b, 1997, 1998b, 1999b, 2000, 2001c, 2002b, 2003b, 2004c, 2005b, 2005c and ASEP 2007, 2010, 2011, 2012, 2013).

[3]The significant lower number in 1990 compared to 1995 is due to step increase in the number of WWTPs above 30 PE after implementation of the first Water Action Plan in 1987 (Thomsen and Lyck. 2005, Annex 3G, Table 3G-5.4).

The reduction of N in the effluent wastewater from Danish WWTPs compared to in influent wastewater has increased from a reduction efficiency of 30% in 1990 to a reduction efficiency of around 88% in 2013. The significant reduction in the effluent wastewater content of nitrogen has been a driver for the increasing direct N_2O emission from WWTPs. However, emerging wastewater treatment technologies may cause an increased N capture in the sludge (Kristensen & Jørgensen, 2008).

Overall nitrous oxide emission trends

The trends in the direct N_2O emission from WWTPs, the indirect emission from wastewater effluent and the total nitrous oxide emissions, as summarised in Table 7.5.4, are presented graphically in Figure 7.5.2.

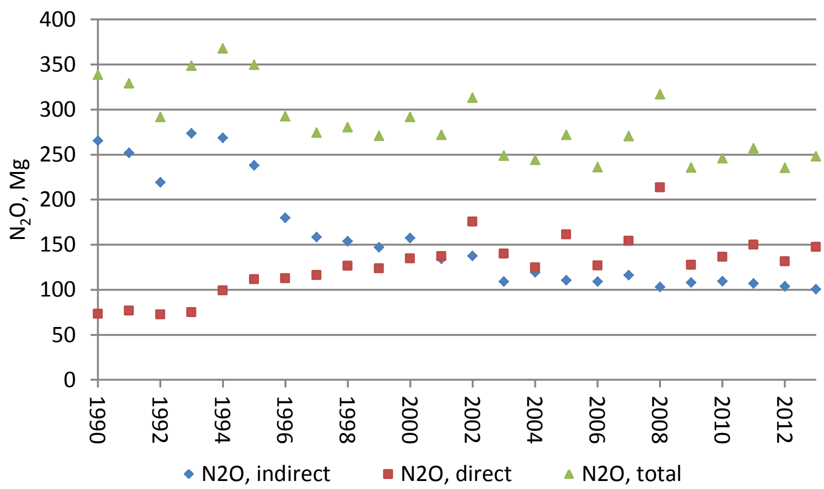

Figure 7.5.2 Time trends for the direct emission of N_2O, indirect emission of N_2O (from wastewater effluents) and total N_2O emission.

The annual fluctuations may be caused by several factors such as e.g. climatic condition such as variations in precipitation and as a result varying contributions to the influent N and varying characteristics of especially the industrial contributions to the influent. Furthermore, infiltration of groundwater, as well as exfiltration of overload rainwater and wastewater (DEPA, 1994, 1996b, 1997, 1998b, 1999b, 2000, 2001c, 2002b, 2003b, 2004c, 2005b, 2005c, ASEP 2007, 2010, 2011, Vollertsen et al., 2002), may contribute to the "noise" or fluctuation in the trend of the calculated indirect N_2O emission.

The direct emission shows an increasing trend from 73.2 ton in 1900 to 147.5 ton in 2013. Comparing 2013 with the base year 1990 an increase of 101.4 % is observed.

The decrease in the emission from effluent wastewater is due to the technical upgrade and centralisation of the Danish WWTPs following the adoption of the Action Plan on the Aquatic Environment in 1987. The indirect emission from wastewater effluent has decreased from 265.3 tonnes N_2O in 1990 to 100.6 tonnes N_2O in 2013 corresponding to a reduction of 62.1 %.

The indirect emission is the major contributor to the emission of nitrous oxide in the period 1990-1997. However, from around year 2000, the direct N_2O emission is the major contributor to the total N_2O emission. Overall, a net reduction of 26.7 % is observed for the total N_2O emission from wastewater handling.

7.6 Other, accidental fires)

The *CRF category 5.E. Other* is comprised by the subcategory accidental fires grouped into accidental building and vehicle fires as presented in subchapter 7.6.1 and 7.6.2. Greenhouse gasses that are emitted from these processes are CH_4, N_2O and CO_2 as presented in Table 7.6.1. The full time series for emissions related to composting are shown in Annex 3G, Table 3G-6.1.

Table 7.6.1 Overall emission of greenhouse gasses from accidental fires, 1990-2013.

		1990	1995	2000	2005	2010	2011	2012	2013
CO_2 emission from									
Accidental building fires	Gg	63.12	72.24	63.80	62.42	61.68	67.58	60.51	58.88
- of which non-biogenic	Gg	11.41	13.05	11.53	11.29	11.09	12.15	10.79	10.58
Accidental vehicle fires	Gg	6.13	6.54	6.87	6.86	7.26	6.30	5.56	5.41
Total. non-biogenic	Gg	17.54	19.60	18.40	18.14	18.35	18.45	16.36	15.99
CH_4 emission from									
Accidental building fires	Mg	64.15	73.35	64.87	63.77	64.61	68.46	61.67	60.62
Accidental vehicle fires	Mg	12.77	13.64	14.32	14.29	15.12	13.12	11.59	11.27
Total	Mg	12.77	86.99	79.2	78.1	79.7	81.6	73.3	71.9
5.E. Other									
CO_2-eqvivalents	Gg	17.86	21.77	20.38	20.10	20.34	20.49	18.19	17.78

7.6.1 Accidental building fires

Emissions that escape from building fires are CO_2 and CH_4.

Methodological issues

Emissions from building fires are calculated by multiplying the number of building fires with selected emission factors. Six types of buildings are distinguished with different emission factors: detached house, undetached houses, apartment buildings, industrial buildings, additional buildings and containers.

Activity data

In January 2005 it became mandatory for the local authorities to register every rescue assignment in the online data registration- and reporting system called ODIN. ODIN is developed and run by the Danish Emergency Management Agency (DEMA, 2007).

Activity data for accidental building fires are given by ODIN (DEMA. 2013). Fires are classified in four categories: full, large, medium and small. The emission factors comply for full scale fires and the activity data are therefore recalculated as a full scale equivalent where it is assumed that a full, large, medium and a small scale fire leads to 100 %, 75 %, 30 % and 5 % of a full scale fire respectively.

In practice, a full scale fire is defined as a fire where more than three fire hoses were needed for extinguishing the fire. A full scale fire is considered as a complete burnout. A large fire is in this context defined as a fire that involves the use of two or three fire hoses for fire extinguishing and is assumed to typically involve the majority of a house, an apartment, or at least part of an industrial complex. A medium size fire is in this context defined as a fire involving the use of only one fire hose for fire-fighting and will typically involve a part of a single room in an apartment or house. And a small size fire is in this context defined as a fire that was extinguished before the arrival of the fire service, extinguished by small tools or a chimney fire.

The total number of registered fires is known for the years 1990-2013. For the years 2007-2012 the total number of registered building fires is known with a very high degree of detail.

Table 7.6.2 shows the occurrence of all types of fires (registered for 1990-2013) and the occurrence of building fires (2007-2013) registered at DEMA. In 2007-2010 the average per cent of building fires, in relation to all fires, was 60 %. The total numbers of building fires 1990-2006 are calculated using this percentage. The full time series is presented in Annex 3G, Table 3G-6.2.

Table 7.6.2 Occurrence of all fires and building fires.

	1990	1995	2000	2005	2010	2011	2012	2013
All fires	17025	19543	17174	16551	16728	16157	14084	14546
Building fires	10187	11694	10276	9903	9325	11447	9932	9893

The building fires that occurred in the years 2007-2013 are sub-categorised into six building types, detached houses, undetached houses, apartment buildings, industrial buildings, additional buildings and container fires.

Table 7.6.3 presents the calculated averages of the registered activity data for building fires for the years 2007-2010, divided in both damage size and building type. These data describe the average share of building fires from 2007-2010 of a certain type and size. in relation to all building fires in the same four years period.

Table 7.6.3 Average registered occurrence of building fires for 2007-2010 (DEMA).

	Size	Detached	Undetached	Apartment	Industry	Additional	Container	All building fires
	full	2.46	0.50	0.31	0.73	0.44	0.17	4.61
	large	4.01	1.14	1.09	1.69	3.08	1.92	12.93
Average. %	medium	5.24	2.33	6.15	2.92	4.30	18.46	39.40
	small	11.77	4.24	12.64	5.36	4.79	4.27	43.06
	all	23.47	8.21	20.19	10.70	12.61	24.82	100.00

It is assumed that the average percentages provided by the years 2007-2010 shown in Table 7.6.3 are compliable for the years 1990-2006. Hereby, similar activity data for building fires can be estimated back to 1990.

By applying the damage rates of 100 %, 75 %, 30 % and 5 % corresponding to the damage sizes full, large, medium and small, a full scale equivalent can be determined. Table 7.6.4 shows the calculated full scale equivalents (FSE). The whole time series is shown in Annex 3G, Table 3G-6.3.

Table 7.6.4 Accidental building fires full scale equivalent activity data.

	1990	1995	2000	2005	2010	2011	2012	2013
Container fires	750	861	756	729	594	729	584	584
Detached house fires	777	892	784	755	833	818	742	761
Undetached house fires	231	265	233	224	194	206	181	162
Apartment building fires	367	421	370	357	348	362	327	316
Industry building fire	320	368	323	311	281	334	298	275
Additional building fires	437	501	440	424	429	740	610	619

Emission factors

For building fires, emissions are calculated by multiplying the number of full scale equivalent fires with the emission factors. The emission factors are produced from different measurements and assumptions from literature and expert judgements. When possible, emission factors are chosen that represent conditions that are comparable to Denmark. By comparable is meant countries that have similar building traditions, with respect to the materials used in building structure and interior.

In the process of selecting the best available emission factors for the calculation of the emissions from Danish accidental building fires, a range of different sources has been studied. Unfortunately it is difficult to perform an interrelated comparison of the different sources because they all establish emission factors on different assumptions and many of these assumptions are not fully accounted for.

Table 7.6.5 lists the emission factors that were chosen for 2013 as the best reliable and their respective references.

Table 7.6.5 Emission factors building fires, per FSE fire, 2013.

Compound	Unit /fire	Detached house	Undetached house	Apartment building	Industrial building	Additional building	Container	Reference
CO_2 - total	Mg	32.4	26.2	15.2	78.1	3.9	1.8	Blomqvist et al.. 2002
CO_2 - biogenic	Mg	26.4	21.4	12.4	67.6	3.2	0.2	Blomqvist et al.. 2002
CO_2 - non-biogenic	Mg	6.0	4.9	2.8	10.5	0.7	1.7	Blomqvist et al.. 2002
CH_4	kg	43.0	34.7	20.2	52.0	2.1	0.3*	NAEI. 2009

*Container fires have a different source of CH_4 emission factor than the other five categories, Blomqvist et al. 2002.

Emission factors for detached, undetached and apartment fires depend on the annual average floor space (cf. Table 7.6.6). Industrial, additional and container fires on the other hand are assumed to have a constant size/volume throughout the time series. Emission factors for detached, undetached and apartment fires for 1990-2013 are shown in Annex 3G, Table 3G-6.4a-c.

Emission factors from Aasestad (2008) are already specified for four of the six building types, detached houses, undetached houses, apartment buildings and industrial buildings (Aasestad, 2008) and all other sources considered were altered to match the six building types. This alternation was performed simply by adjusting the average floor space for each of the building types respectively, whereas factors like loss rate and mass of combustible contents per area are not altered.

The average floor space in Danish buildings is stated in Table 7.6.6. The data are collected from Statistics Denmark and takes into account possible multiple building floors but not attics and basements. For the whole time series see Annex 3G, Table 3G-6.5. The average floor space in industrial buildings, schools etc. is estimated to 500 square meters for all years and the average floor space for additional buildings, sheds etc. is estimated to 20 square meters for all years.

Table 7.6.6 Average floor space in building types (Statistics Denmark, 2013).

	1990	1995	2000	2005	2010	2011	2012	2013
Detached houses	156	155	156	162	163	164	165	165
Undetached houses	129	129	131	131	134	132	134	133
Apartment buildings	75	75	75	76	77	78	78	78

Some emission factors are delivered in mass emission per mass burned. In order to connect these emission factors to the activity data, the total combustible building masses are estimated using the data from Table 7.6.7.

Table 7.6.7 Building mass per building type.

	Unit	Detached house	Un-detached house	Apartment building	Industry building	Additional building	Container
Average floor area*	m^2	165	134	78	500	20	-
Building mass per floor area	kg per m^2	40	40	35	30	30	-
Total building mass	Mg per fire	6.6	5.4	2.7	15.0	0.6	1

* 2012 numbers

Emission factors for container fires cannot be calculated based on an average floor space but on an average mass. The average mass of a container is set to 1 Mg and covers all types of containers, from small residential garbage containers to large shipping containers and waste/goods in storage piles.

No data was available for N_2O.

For more information on the emission factors, please refer to Hjelgaard (2013).

7.6.2 Accidental vehicle fires

Emissions that escape from vehicle fires are CO_2 and CH_4.

Methodological issues

Emissions from vehicle fires are calculated by multiplying the mass of vehicle fires with selected emission factors. Emission factors are not available for different vehicle types, whereas it is assumed that all the different vehicle types leads to similar emissions. The activity data are calculated as an annual combusted mass by multiplying the number of different full scale vehicle fires with the Danish registered average weight of the given vehicle type.

Activity data

As with accidental building fires, data for accidental vehicle fires are available through the Danish Emergency Management Agency (DEMA). DEMA provides very detailed data for 2007-2013, the remaining years back to 1990 are estimated by using surrogate data.

Table 7.6.8 shows the occurrence of fires in general and vehicle fires registered at DEMA. In 2007-2010 the average per cent of vehicle fires, in relation to all fires, was 20 %. The total numbers of vehicle fires in 1990-2006 are calculated using this percentage. The full time series is presented in Annex 3G, Table 3G-6.5a-c.

Table 7.6.8 Occurrence of all fires and vehicle fires.

	1990	1995	2000	2005	2010	2011	2012	2013
All fires	17,025	19,543	17,174	16,551	16,728	16,157	14,084	14,060
Vehicle fires	3,354	3,850	3,383	3,260	3,459	3,255	2,889	2,841

There are fourteen different vehicle categories. The activity data are categorised in passenger cars (lighter than 3500 kg), buses, light duty vehicles (vans and motor homes), heavy duty vehicles (trucks and tankers), motorcycles/mopeds, other transport, caravans, trains, boats, airplanes, bicycles, tractors, combine harvesters and machines.

In the same manner as accidental building fires, the 2007-2013 data from DEMA can be divided in four categories according to damage size. It is assumed that a full scale fire is a complete burnout of the given vehicle, and that a large, medium and small scale fire corresponds to 75 %, 30 % and 5 % of a full scale fire respectively. The total number of full scale equivalent (FSE) fires can be calculated for each of the fourteen vehicle categories for 2007-2013.

The total number of registered vehicles is known from Jensen et al. (2013) and Statistics Denmark (2013). By assuming that the share of vehicle fires in relation to the total number of registered vehicles, of every category respectively, can be counted as constant, the number of vehicle fires is estimated for the years 1990-2006.

Table 7.6.9 states the total number of national registered vehicles and the number of full scale equivalent vehicle fires. The whole time series 1990-2013 is shown in Annex 3G, Table 3G-6.6a-c.

Table 7.6.9 Number of nationally registered vehicles and full scale equivalent vehicle fires.

	Passenger Cars		Buses		Light Duty Vehicles		Heavy Duty Vehicles	
	Registered	FSE fires	Registered	FSE fires	Registered	FSE fires	Registered	FSE fires
1990	1,645,454	479	8,109	12	192,317	19	45,664	58
1995	1,733,242	504	14,371	21	228,074	22	48,077	61
2000	1,916,364	557	15,051	22	272,386	27	50,227	64
2005	2,012,216	585	15,131	22	372,674	36	49,311	63
2010	2,246,675	646	14,577	23	362,385	38	44,813	60
2011	2,281,539	584	13,915	13	343,355	43	43,640	54
2012	2,326,778	514	13,177	11	318,668	32	42,326	53
2013	2,373,251	514	12,629	11	306,421	32	41,999	53

Continued

	Motorcycles/Mopeds		Caravans		Train		Ship	
	Registered	FSE fires	Registered	FSE fires	Registered	FSE fires	Registered	FSE fires
1990	163,133	58	86,257	24	7,156	9	2,324	26
1995	165,272	58	95,831	26	6,854	8	1,911	21
2000	233,309	82	106,935	29	4,907	6	1,759	19
2005	273,904	97	121,350	33	3,195	4	1,792	20
2010	301,562	83	142,354	37	2,740	2	1,773	16
2011	295,488	91	142,764	34	2,943	3	1,768	21
2012	295,798	82	142,654	33	3,055	2	1,772	14
2013	296,522	82	142,667	33	3,048	2	1,781	14

Continued

	Airplane		Tractor		Combined Harvester		Bicycle	Other transport	Machine
	Registered	FSE fires	Registered	FSE fires	Registered	FSE fires	FSE fires	FSE fires	FSE fires
1990	1,055	1	131,880	82	33,594	56			
1995	1,058	1	130,028	81	27,986	46			
2000	1,070	1	111,736	69	23,272	39			
2005	1,073	1	104,551	65	20,965	35			
2010	1,152	1	89,141	77	15,986	32	4	58	94
2011	1,132	0	85,776	59	14,990	21	3	50	111
2012	1,111	0	82,410	68	13,994	18	2	50	115
2013	1,069	0	79,045	68	12,998	18			

The average weights of a passenger car, bus, light commercial vehicle, truck and motorcycle/moped are known for every year back to 1993 (Statistics Denmark, 2012). The corresponding weights from 1990 to 1992 and the average weight of the units from the remaining categories are estimated by an expert judgment, see Table 7.6.10 and Annex 3G, Table 3G-6.7.

Table 7.6.10 Average weight of different vehicle categories, kg.

Year	Cars	Buses	Vans	Trucks	Motorcycles/ Mopeds
1990	850	10,000	2,000	15,000	86
1995	923	10,807	2,492	14,801	97
2000	999	11,195	3,103	15,214	103
2005	1,068	11,560	3,793	13,258	116
2010	1,144	11,804	4,498	11,883	133
2011	1,154	11,907	4,296	11,291	135
2012	1,160	11,625	4,150	10,844	136
2013	1,162	11,463	4,046	10,861	134

It is assumed that the average weight of a boat equals that of a bus. That tractors and vans weigh the same and that trains, airplanes and combine harvesters have the same average weight as trucks.

Bicycles, machines and other transport can only be calculated for the years 2007-2013 due to the lack of surrogate data (number of nationally registered vehicles). The average weight of a bicycle, caravan, machine and other transport is estimated as 12 kg, 90 % of a car, 50 % of a car and 40 % of a car respectively.

By multiplying the number of full scale fires with the average weight of the vehicles respectively, the total amount of combusted vehicle mass can be calculated. The result is shown in Table 7.6.11 and in Annex 3G, Table 3G-6.8a-c.

Table 7.6.11 Burnt mass of different vehicle categories, Mg.

Vehicle category	1990	1995	2000	2005	2010	2011	2012	2013
Passenger cars	407	466	557	625	739	674	592	555
Buses	116	223	242	251	266	160	130	121
Light duty vehicles	37	55	82	138	171	185	133	118
Heavy duty vehicles	869	902	969	829	715	606	579	455
Motorcycle. moped	5	6	8	11	11	12	11	11
Other transport	-	-	-	-	33	29	29	26
Caravan	30	36	44	53	63	59	57	59
Train	128	121	89	51	24	28	23	18
Ship	257	228	218	229	189	249	160	100
Airplane	12	11	12	10	7	3	5	5
Bicycle	-	-	-	-	0	0	0	0
Tractor	164	202	216	247	347	254	283	330
Combine harvester	530	476	425	409	398	271	236	402
Machine	-	-	-	-	43	51	53	53
Total	2,555	2,727	2,863	2,858	3,025	2,624	2,319	2,253

Emission factors

In the process of selecting the most reliable emission factors for the calculation of the emissions from Danish vehicle fires, a range of different sources have been studied. Unfortunately it is difficult to make an interrelated comparison of the different sources because they all establish emission factors on different assumptions and many of these assumptions are not fully accounted for. Table 7.6.12 lists the accepted emission factors and their respective references.

Table 7.6.12 Emission factors for vehicle fires. per Mg.

	Unit	Emission factor	Source
CO_2	Mg	2.4	Lönnermark et al., 2006
CH_4	kg	5	NAEI. 2009
N_2O	-	NAV	-

NAV = not available

7.6.3 Other

Other combustion sources included under Waste Other are the open burning of yard waste and bonfires.

Due to the cold and wet climatic conditions in Denmark wild fires very seldom occur. Controlled field burnings and the occasional wild fires are categorised under the Chapters on 6 Agriculture and 7 Land Use, Land Use Change and Forestry (LULUCF) respectively.

In Denmark, the open burning of private yard waste is under different restrictions according to the respective municipality. These restrictions involve what can be burned but also the quantity, how, when and where, or in some cases a complete ban is imposed. The burning of yard waste is not allowed within urban areas (DEPA. 2011b). There is no registration of private waste burning and the activity data on this subject are very difficult to estimate. Citizens are generally encouraged to compost their yard waste or to dispose of it through one of the many waste disposal/recycling sites.

The occurrences of bonfires at Midsummer's Eve, and in general, are likewise not registered, therefore it has not been possible to obtain activity data and consequently, bonfires are not included in this inventory.

7.7 Uncertainties and time series consistency

Two set of uncertainty estimates are made for the Danish emission inventory for greenhouse gases based on Tier 1 and Tier 2 methodology, respectively. The uncertainty models follow the methodology in the IPCC Good Practice Guidance (IPCC, 2000). Tier 1 is based on the simplified uncertainty analysis and Tier 2 is based on Monte Carlo simulations.

7.7.1 Input data

Solid Waste Disposal

The waste amounts for solid waste disposal are registered in a national database held by the Danish EPA and assessed to be of high quality resulting in the adoption of an uncertainty for reported waste amounts of 10 %.

Input parameter uncertainties for SWDS considered in the Tier 1 uncertainty analysis are based on the IPCC (IPCC 2000, page 5.12, Table 5.2) default values and provided in Table 7.7.1.

Table 7.7.1 Tier 1 input parameter uncertainty. %.

Parameter	Parameter ID	Uncertainty %	Note
The Waste amount sent to SWDS	*W*	10	Since the amounts are based on weighing at the SWDS the lower value in IPCC (2000) is used
Degradable Organic Carbon	DOC_i	50	Highest value, IPCC 2000. page 5.12, Table 5.2
Fraction of DOC dissimilated	DOC_f	30	Highest value, IPCC 2000. page 5.12, Table 5.2
Methane Correction Factor	*MCF*	10	IPCC. 2006
Fraction of CH_4 in landfill gas		10	Medium value, IPCC 2000. page 5.12, Table 5.2
Methane Generation Rate Constant	*k*	100	IPCC 2000, page 5.12,Table 5.2

The waste amounts for solid waste disposal on land are registered in a national database held by the Danish EPA and assessed to be of high quality resulting in the adoption of an uncertainty for reported waste amounts of 10 %. The default uncertainty range for the methane generation constant, k, is: -40 % to +300 %., for the Tier 1 uncertainty calculation it has been set to 100 % (Limpert et al., 2001). For the remaining parameters default uncertainties are used until country-specific parameters becomes available.

The uncertainty on the implied emission factor, U_{ief}, is based on uncertainty estimates in Table 7.7.1 and is approximated with IPCC (2000) Equation 6.4 equals

U_{ief} % = $SQRT(50^2+30^2+10^2+10^2+100^2)$ = 117.9 %

These uncertainties give the combined Tier 1 uncertainty on the emission from SWDS of: $SQRT(10^2+117.9^2)$ = 118.3 %.

Biological treatment of Solid waste - Composting

Activity data for composting are estimated for the years 1990-1994 and 2010-2013 resulting in a higher level of uncertainty these years, this is set at 40 %.

Table 7.7.2 lists the 95 % confidence interval uncertainties for activity data and emission factors used in this inventory and at the present level of available information. The uncertainties are assumed valid for all years 1990-2011.

Table 7.7.2 Estimated uncertainty rates for activity data and emission factors. %.

95 % confidence interval uncertainties	CO_2	CH_4	N_2O
Compost production			
Activity data	-	40	40
Emission factor	-	100	100

Waste Incineration

The uncertainty of the number of human cremations is miniscule, however for the purpose of uncertainty calculation it has been set to 1 %. The uncertainty of the activity data from animal cremations is also minimal for the most recent years (1998-2013) but is increasing back in time (to 67 % in 1990). The uncertainty is set to 67 % in 1990 and 5 % for 2012 and 2013 (Authors expert judgement).

Table 7.7.3 lists the 95 % confidence interval uncertainties for activity data and emission factors used in this inventory and at the present level of available information.

Table 7.7.3 Estimated uncertainty rates for activity data and emission factors. %.

95 % confidence interval uncertainties	CO_2	CH_4	N_2O
Human cremation			
Activity data	-	1	1
Emission factor	-	150	150
Animal cremation			
Activity data	-	5/67	5/67
Emission factor	-	150	150

Wastewater Handling

The uncertainty levels used in the Tier 1 and 2 uncertainty models are shown in Table 7.7.4.

Table 7.7.4 Estimated uncertainty rates for activity data and emission factors, %.

95 % confidence interval uncertainties	Activity data	Emission factor
N_2O, WWT, direct	20	53
N_2O,WWT, indirect	42	42
CH_4, Sewer system and WWTP processes	24	32
CH_4, Anaerobic digestion	24	39
CH_4,Septic tanks (scattered houses)	31	32

Default IPCC values are assumed to be given at 95 % confidence level. For the country-specific activity data, the standard deviation of different data sources has been used for deriving per cent uncertainty estimates. Annex 3G, Table 3G-5.5 elaborates on the different values and their references.

Uncertainties have been derived from IPCC default values and uncertainties in country-specific parameters, respectively (cf. Annex 3G, Table 3G-5.5).

Waste Other

The uncertainty of the total number of accidental fires is very small, but the division into building and transportation types and also the calculation of full scale equivalents will lead to some uncertainty, partly caused by the category "other". The uncertainty for both building and vehicle activity data is therefore set to 10 % for all years. The uncertainty is however lowest for the most recent years (2007-2013) (Authors expert judgement).

Table 7.7.5 lists the 95 % confidence interval uncertainties for activity data and emission factors used in this inventory and at the present level of available information. The uncertainties are assumed valid for all years 1990-2013.

Table 7.7.5 Estimated uncertainty rates for activity data and emission factors. %.

95 % confidence interval uncertainties	CO_2	CH_4	N_2O
Accidental building fires			
Activity data	10	10	-
Emission factor	300	500	-
Accidental vehicle fires			
Activity data	10	10	-
Emission factor	500	700	-

7.7.2 Tier 1 uncertainty results

The Tier 1 uncertainty estimates for the waste sector are calculated from 95 % confidence interval uncertainties, results are shown in Table 7.7.6.

The overall uncertainty interval for greenhouse gases (GHG) is estimated to be ±78.6 % and the trend in GHG emission, calculated as the per cent change in GHG emissions in 2013 compared to 1990, is -36.4 % ±19.6 %.

Table 7.7.6 National Tier 1 uncertainty estimates for the waste sector.

Pollutant	National emission. 2013, $GgCO_2$ eqv.	Total emission uncertainty, %	Trend* 1990-2013, %	Trend uncertainty,
GHG	1297.62	±78.6	-36.4	±19.6
CO_2	15.97	±300.2	-9.0	±12.9
CH_4	1084.17	±93.0	-43.2	±13.7
N_2O	197.48	±70.2	74.1	±119.0

*Per cent change in emission in 2013 with respect to the base year 1990.

**GHG emissions are calculated in units of CO_2 equivalents.

7.7.3 Tier 2 uncertainty results

The Tier 2 uncertainty estimates for the waste sector are calculated from the input data presented in Section 7.7.1, results are shown in Table 7.7.7. The calculations are based on a Monte Carlo approach as described in Chapter 1.7.

Table 7.7.7 National tier 2 uncertainty estimates for the waste sector, [Gg]

	1990 National emission, [Gg]			2012 National emission, [Gg]			1990-2012 Trend, [Gg]		
	median	Uncertainty interval, [%]		median	Uncertainty interval, [%]		mean	Uncertainty, [%]	
		lower (-)	upper (+)		lower (-)	upper (+)		lower (-)	upper (+)
GHG	2200	-55	156	2031	-47	121	156	-2518	3568
CO_2	27	-67	361	23	-67	364	3	0,3	18
CH_4	74	-64	183	41	-56	166	31	-45	169
N_2O	0,39	-38	72	0,70	-36	69	-0,31	-1	0.04

Greenhouse gas (GHG) emissions are calculated in CO_2 equivalents.

7.7.4 Time series consistency and completeness

Solid Waste Disposal

Registration of the amount of waste has been carried out since the beginning of the 1990s in order to measure the effects of action plans. The activity data are, therefore, considered to be consistent through the time series to make the activity data input to the FOD model reliable.

The consistency of the emissions and the implied emission factors is a result of the same methodology and the same model used for the whole time series. The parameters in the FOD model are the same for the whole time series. The use of a model of this type is recommended in IPCC (1997) and IPCC (2000).

As regards completeness, waste amounts for the whole time series, i.e. 1960-2013, have been allocated according to 18 waste types as described in Chapter 7.2.1. Corresponding annual fractional distributions of the total amount of deposited waste according to type, respecting mass conservation, is presented in units of mass fractions in Table 7.2.4 (for the whole time series the reader is referred to Annex 3G, Table 3G-2.6). The composition of these waste types is, according to Danish data, used to estimate DOC values for the waste types (refer IPCC 2000, page 5.10). Improvements regarding plant level data are ongoing and planned to increase the transparency and completeness (Thomsen & Hjelgaard, 2015).

Biological treatment of solid waste

For compost production, activity data are not consistent as data are only available for 1995-2009. Data for 1990-1994 and 2010-2013 along with data for home composting are estimated through linear regression and with surrogate data respectively. Emission factors and calculation method are consistent throughout the time series, except for the 2010-2013 in which period the data source used were the new waste reporting system.

Emissions from compost production are believed to be complete, calculations include composting at all nationally registered sites and best available estimated data for home composting.

Waste Incineration

Activity data for human cremation is considered to be consistent as these data have been collected by DKL throughout the time series. Activity data for animal cremation on the other hand is not fully consistent. Data for 1998-2013 are gathered directly from the crematoria and data for 1990-1997 are estimated by the author's expert judgement, no surrogate data or data regression is possible.

Emission factors and calculation method are consistent throughout the time series for both human and animal cremation.

Cremation of both corpses and carcasses is considered to be complete. Open burning of carcasses is illegal and therefore not occurring in Denmark, and small-scale incinerators are not known to be used at Danish farms.

Wastewater Handling

Consistency and completeness have been improved by integrating plant level data from the Danish Energy Statistics with plant level COD data from the Danish monitoring program and plant level environmental reports (Thomsen, 2015). Still, some work is needed before a COD mass balance is in place to verify the methane emission from anaerobic digestion as reported by the Danish Energy Agency.

Data regarding industrial on-site wastewater treatment processes have been achieved and will be included in the next NIR, allowing for the calculation of the on-site industrial contribution to CH_4 or N_2O emissions (Thomsen, 2015).

Waste Other

For accidental fires, DEMA provides detailed data for 2007-2013 and the total number of nationally registered fires for 1990-2013. Activity data for accidental fires are there for believed to be consistent. Both emission factors and calculation method are also consistent throughout the time series.

Emissions from accidental fires are believed to be complete. Field burning of agricultural residue is included in Chapter 5 Agriculture.

7.8 QA/QC and verification

In general terms, for this part of the inventory, the Data Storage (DS) Level 1, 2 and 4 and the Data Processing (DP) Level 1 can be described as follows.

7.8.1 Data Storage Level 1

The external data level refers to the placement of the original input data used for estimating annual activity and emission factors in the waste sector. Data references in terms of reports and databases used for deriving input for the emission calculations. Reports and a list of links to external data sources are stored in a common data storage system including all sectors of the annual NIR.

Table 7.8.1 Overview of annually stored external data sources at DS level1.

http, file or folder name	Description	AD or EF	Reference	Contact	Data agree-ment/ Comment
DCE data-exchange folder: U:\ST_ENVS-Luft-Emi\Inventory\2013\6_Waste\Level_1b_Processing	Inventory data storage system	AD and EF	DCE		
Report series published by the Agency for Spatial and Environmental Planning (ASEP) and available from the Danish Nature Agency (DNA): www.nst.dk			Report series: "*Point sources*" (2006-2013)	Naturstyrelsen Vestjylland Anna Gade Holm (angho@nst.dk) Marianne Thomsen (mth@dmu.dk)	Public available reports
Danish Water Quality parameter Database	Annually reported wastewater charac-teristics at plant level which includes all years 1990- 2013	AD	www.miljoeportalen.dk	Naturstyrelsen Vestjylland Anna Gade Holm (angho@nst.dk) Marianne Thomsen (mth@dmu.dk)	Authorised access
DCE data-exchange folder: U:\ST_ENVS-Luft-Emi\Inventory\2013\6_Waste\Level_1a_Storage	Raw data extracts from the Danish Waste Reporting System	AD	The Danish Environmental Protection Agency. Database on all registered Danish waste. Available at: http://www.mst.dk	Unit for Soil and Waste Eik Kristensen (eikri@mst.dk)	The amounts are regis-tered due to statuto-ry require-quire-ments
DCE data-exchange folder: U:\ST_ENVS-Luft-Emi\Inventory\2013\6_Waste\Level_1a_Storage	Integrated TOW-Energy recovery database		Thomsen, 2015	Marianne Thom-sen (mth@envs.au.dk)	-
DCE data-exchange folder: U:\ST_ENVS-Luft-Emi\Energy\2013	Basic data DS1 Dataset for energy-producing SWDS and WWTPs, CH_4 recovery data		The Danish Energy Agency (DEA)	Peter Dal (pd@ens.dk)	Prepared due to the obligation of DEA
DCE data-exchange folder: U:\ST_ENVS-Luft-Emi\Inventory\2013\6_Waste\Level_1b_Processing\5A Solid Waste Disposal	Excel file with the FOD model: swds_fod_model_2013_final_1940-2013.xls"	AD, EF, Model	IPCC 1997, 2000, 2006 Thomsen & Hjelgaard, 2015	Marianne Thomsen (mth@dmu.dk)	-
http://www.dkl.dk	Number for crema-tions	AD	Association of Danish Crematories	Hanne Ring hr@dkl.dk	Public access
http://www.statistikbanken.dk	Statistics for popula-tion. buildings and vehicles	AD	Statistics Denmark		Public access
DCE data-exchange folder: U:\ST_ENVS-Luft-Emi\Inventory\2013\6_Waste\Level_1a_Storage	Cremated animal carcasses	AD	Dansk Dyre-kremering ApS	Knud Ri-bergaard info@danskdyrekremering.dk	Personal contact
DCE data-exchange folder: U:\ST_ENVS-Luft-Emi\Inventory\2013\6_Waste\Level_1a_Storage	Cremated animal carcasses	AD	Ada's Kæledyrs-krematorium ApS	Anders Oxholm anders@adakrem.dk	Personal contact
DCE data-exchange folder: U:\ST_ENVS-Luft-Emi\Inventory\2013\6_Waste\Level_1a_Storage	Cremated animal carcasses	AD	Kæledyrskrematoriet	Annette Laur-sen dyrepension@skylinemail.dk	Personal contact
https://statistikbank.brs.dk	Categorized fires	AD	The Danish Emergency Management Agency	Steen Hjere Nonnemann shn@beredskabs styrelsen.dk	Public access
DCE data-exchange folder: U:\ST_ENVS-Luft-Emi\Inventory\2013\6_Waste\Level_1a_Storage	Waste categories for composting	AD	Danish Environmental Protection Agency (DEPA). Waste Statistics http://www2.mst.dk/udgiv/publikationer/2010/978-87-92668-21-9/pdf/978-87-92668-22-6.pdf		Public access

7.8.2 Data Processing Level 1

This level comprises a stage where the external data extracted from the waste data system (DEPA, 2013) are processed internally.

For CRF category 5.A, data are prepared for the DCE First Order of Decay model by allocation of the reported waste amounts according to the European Waste Codes (EWC) as presented in Chapter 7.2 and in Annex 3G, Table 3G-2.3 - Table 3G-2.6. The model runs in excel and the output are stored inside the excel file.

For the CRF categories 5.B, 5.C and 5.E, the activity data and emission factors are recalculated to match each other by using national average data like the average floor space in houses etc.

For CRF category 5.D, data are prepared for the input to the country-specific models. In this year´s inventory, the plant level data for WWTPs using anaerobic sludge digestion, i.e. biogas production, have been integrated with plant level energy recovery data from the Energy Statistics by purpose of performing a mass balance for the CH_4 potential in the influent TOW, the ingestate, the digestate, the amount of recovered and lost CH_4 by flaring and venting. Status for the improvements are presented Chapter 7.5 and in Thomsen, 2015. Calculations are carried out and the output stored in a not editable format each year. The DP at level 1 has been improved to fit into a more uniform and easily accessible data reporting format. Regarding the derivation of activity data and emission factors used in the model calculations, this year's improvements are documented in Chapter 7.5.

7.8.3 Data Storage Level 2

Data Storage Level 2 is the placement of selected output data from the calculation of emissions as inventory data on SNAP levels in the Access (CollectER) database.

7.8.4 Data Storage Level 4

Data Storage Level 4 is the placement of the calculated output data from the calculation of emissions as data on SNAP levels in the CRFs.

7.8.5 Points of measurement

The present stage of QA/QC for the Danish emission inventories for the waste sector is described below for DS level 1. 2 and 4 and DP level 1 Points of Measurement (PMs). This is to be seen in connection with the general QA/QC description in Section 1.6 and, especially, 1.6.10 on specific description of PMs common to all sectors, general to QA/QC.

Data Storage level 1	1. Accuracy	DS.1.1.1	General level of uncertainty for every dataset including the reasoning for the specific values

The sources of data described in the methodology sections and in DS.1.2.1 and DS.1.3.1 are used in this inventory. It is the accuracy of these data that define the uncertainty of the inventory calculations.

With regard to the general level of uncertainty for SWDS, the amounts in waste fractions/categories are reasonably certain (per cent uncertainty set equal to 10 %. cf. Table 7.7.1. Due to the statutory environment for these data, while the distribution of waste fractions according to waste type and their content of *DOC* are more uncertain (per cent uncertainty set equal to 50 %. cf. Table 7.7.1). It is generally accepted that FOD models for CH_4 emission estimates offer the best and the most certain way of estimation. The half-life in the FOD models is an important parameter with some uncertainty (cf. Table 7.7.1).

For the *CRF category 5.B Biological Treatment of Solid Waste, 5.C Incineration and open burning* and *5.E Other* the level of uncertainty is generally low for activity data but higher for emission factors. cf. Table 7.7.2, Table 7.7.3 and Table 7.7.5. Expert judgments are used whenever default uncertainties are not available.

The input parameter uncertainties *for CRF category 5.D Wastewater Treatment and Discharge* have been derived from standard deviations between activity data extracted from national databases and reported national statistics as shown in Table 7.7.4. Uncertainties on defaults numbers are taken from the IPCC (1997 and 2000). Uncertainty of activity data are based on simple standard deviations accompanying the annual reported monitoring data.

Data Storage level 1	2.Comparability	DS.1.2.1	Comparability of the emission factors/calculation parameters with data from international guidelines, and evaluation of major discrepancies.

Comparison of Danish data values from external data sources with corresponding data from other countries has been carried out in order to evaluate discrepancies.

Comparison of Danish data values with data sources from other countries has been carried out as presented in the national verification report by Fauser et al., 2007 and 2014 and in the methodology report by Thomsen & Lyck (2005), Thomsen (2015a, b) and Thomsen and Hjelgaard (2015).

Data Storage level 1	3.Completeness	DS.1.3.1	Ensuring that the best possible national data for all sources are included, by setting down the reasoning behind the selection of datasets.

SWDS

- Danish Environmental Protection Agency (DEPA). ISAG database and the new waste data system: amounts of the various waste fractions deposited (refer to Chapter 7.2).
- A Danish investigation and verification of the overall mass balance upon allocating waste fractions within the old ISAG and the new waste data system into 18 well-defined waste types as described in Chapter 7.2 and in Nielsen et al. (2014) and Thomsen and Hjelgaard (2015).
- Danish Energy Agency (DEA): Official Danish energy statistics: CH_4 recovery data.

The selection of sources is obvious. The ISAG database is based on statutory registrations and reporting from all Danish waste treatment plants for all waste entering or leaving the plants. Information concerning waste in the previous year must be reported to the DEPA no later than January 31 each year. Registration is made by mass according to EAK codes, which are automatically reallocated into 18 waste types of which 11 are characterised as inert. The individual waste type characteristics have been documented in Chapter 7.2 and Table 8.2.3 as well as in Annex 3G, Table G3-2.3 and G3-2.6.

For recovery data, the DEA registers the energy produced from plants where installations recover CH_4 in the national energy statistics. For the parameters of the FOD model, references are made to IPCC (1997, 2000 and 2006) (cf. Chapter 7.10 on planned improvements for the waste sector).

Composting

- ISAG Waste Statistics (DEPA, 1996, 1998, 1999, 2001a, 2001b, 2002, 2004a, 2004b, 2005, 2006a, 2006b, 2008, 2010a, 2011a)
- The New Danish Waste Reporting System (www.mst.dk)

All Danish waste treatment plants are obligated to statutory registration and reporting of all waste entering and leaving the plants. All waste streams are weighed, categorised with a waste type and a type of treatment and registered to the ISAG waste information system, which contain data for 1995-2009 (ISAG, 2010). For 201-2014 data from the new waste reporting system have been used and allocation according to the four compost types have been performed using the fractional distribution in 2009 to allocate the total amount of compost (cf. chapter 7.10 on planned improvements for the waste sector).

Waste Incineration

- Tables from Association of Danish Crematories available online
- Direct contact with the Danish animal crematories
- Emission factors from literature

Data from the Association of Danish Crematories is based on annual reporting from all Danish crematories. Specific reported data are available for the complete time series.

WWTP

- Integrated TOW-Energy recovery database
- The Danish Water Quality Parameter Database (www.miljoeportal.dk)

Data plant level on energy recovery have been integrated with plant level data on influent TOW, which have made it possible to quantify the amount of TOW in the influent at plants using anaerobic digestion as sludge management strategy as reported in Table 7.5.3. The COD-Energy recovery database have replaced the Danish sludge database, which were of low quality and high incompleteness regarding reporting statistics and time series coverage (Nielsen et al., 2014)
Knowledge of the amount of sludge treated at WWTPs with anaerobic sludge digestion has been used as input parameter for calculation the gross methane emission from anaerobic treatment and constitutes a major improvement of the activity data for CRF category 5.D, while the energy statistics have been used to quantify the amount of methane lost via venting and flaring (cf. chapter 7.10 on planned improvements for the waste sector).

Other

- Waste Statistics (DEPA, 1996, 1998, 1999, 2001a, 2001b, 2002, 2004a, 2004b, 2005, 2006a, 2006b, 2008, 2010a, 2011a)
- Danish Emergency Management Agency (DEMA) database
- Emission factors from literature

The waste statistics are based on data from the ISAG database, which is the only Danish registration of waste amounts. Also the DEMA database is the only provider of data on accidental fires, data for newer years (2007-2013) are extremely detailed.

Data Storage level 1	4.Consistency	DS.1.4.1	The original external data has to be archived with proper reference.

Data are predominantly extracted from the internet and databases (The Danish Waste Reporting System, the Water Quality Parameter database, Statistics Denmark, DEMA database, human cremation). The origin of external activity data has been preserved as much as possible by saving them as original copies in their original form. Files are saved for each year of reporting, in this way changes to previously received data and calculations is reflected and explanations are given. Specific information from reports, industries and experts are saved as e-mails and pdf files.

Data Storage level 1	6.Robustness	DS.1.6.1	Explicit agreements between the external institution holding the data and DCE about the conditions of delivery.

As stated in DS.1.4.1 most data are obtained from the internet. It is a statutory requirement that amounts of waste are reported annually to DEPA, no later than January 31 for the previous year. No explicit agreements have een made with external institutions.

Data Storage level 1	7.Transparency	DS.1.7.1	Listing of all archived datasets and external contacts.

Contact persons related to the delivery of specific data are provided in Table 8.7.1.

For a listing of all archived external datasets the reader is referred to DS 1.3.1.

Data Processing level 1	1. Accuracy	DP.1.1.1	Uncertainty assessment for every data source not part of DS.1.1.1 as input to Data Storage level 2 in relation to type and scale of variability.

No data are used in addition to those included in DS.1.1.1. Uncertainties are reported in Section 7.7 and Annex 3G-7.

Data Processing level 1	2.Comparability	DP.1.2.1	The methodologies have to follow the international guidelines suggested by UNFCCC and IPCC.

The methodological approach is based on the detailed methodology as outlined in the Emission Inventory Guidebook. The calculation used for SWDS is a Tier 2 methodology from IPCC (1997, 2000 and 2006). For WWTP the calculations follow the IPCC (1997, 2000 and 2006). Exemptions have been documented whenever occurring. The inventory calculations for Waste Incineration and Waste Other are a simple multiplication of activity data and emission factors (See also DS.1.3.1).

Data Processing level 1	3.Completeness	DP.1.3.1	Identification of data gaps with regard to data sources that could improve quantitative knowledge.

For SWDS there is no quantitative knowledge in the methodology on either (1) the shift in waste fractions within waste categories for 1960-1984 and 1986-1993, (2) the development over time of the DOC content in individual waste fractions or (3) possible individual conditions relating to the SWD sites (cf. chapter 7.10 on planned improvements for the waste sector).

Data on separate industrial WWTPs. Information on methane emissions for separate industries may be of importance (cf. chapter 7.10 on planned improvements for the waste sector).

Emission factors for cremation and accidental fires are gathered from literature studies. There is no Danish literature or measurements available on greenhouse gas emissions from these categories.

Activity data for accidental fires for the years 1990-2006 are not sub categorised into vehicles, buildings or sizes.

Data Processing level 1	4.Consistency	DP.1.4.1	Documentation and reasoning of methodological changes during the time series and the qualitative assessment of the impact on time series consistency.

There is no change in calculation procedure during the time series and the activity data are, as far as possible, kept consistent for the calculation of the time series. Any changes in calculation procedures are noted for each year's inventory in the individual chapters for each CRF category.

Data Processing level 1	5.Correctness	DP.1.5.1	Verification of calculation results using time series

The time series of activities and emissions from the model output in the SNAP source categories and in the CRF format have been prepared. The time series are examined and significant changes are checked and explained. Comparison is made with the previous year's estimate and any major changes are verified.

Data Processing level 1	5.Correctness	DP.1.5.2	Verification of calculation results using other measures

The correct interpretation in the model/calculation of the methodology and the parameterisation has been checked as far as possible.

Data Processing level 1	7.Transparency	DP.1.7.1	The calculation principle. the equations used and the assumptions made must be described.

The calculation principle and equations are described in Chapter 7.2 to 7.6 for each CRF category in the waste sector.

Data Processing level 1	7.Transparency	DP.1.7.2	Clear reference to dataset at Data Storage level 1

Refer to the table at the start of this Section and DS.1.1.1 (Table 8.7.1).

The calculation principle and equations are described in Chapter 7.2 to 7.6 for each CRF category in the waste sector.

Data Processing level 1	7.Transparency	DP.1.7.3	A manual log to collect information about recalculations.

Recalculation and changes in the emission inventories are described in the NIR whenever occurring. The logging of the changes takes place in the annual model file.

Data Storage level 2	5.Correctness	DS.2.5.1	Check if a correct data import to level 2 has been made

The transfer of emission data from level 1, storage and processing, to data storage level 2 is manually checked. This check is performed, comparing model output and report files made by the CollectER database system.

Data Storage level 4	4. Consistency	DS.4.4.3	The IEFs from the CRF are checked both regarding level and trend. The level is compared to relevant emission factors to ensure correctness. Large dips/jumps in the time series are explained.

See DP.1.5.1 and DP.1.5.2.

7.9 Source specific recalculations

Table 7.9.1 presents the recalculations to the waste sector for this year's inventory. Tables with the full time series 1990-2013 are shown in Annex 3G-7.

Table 7.9.1. Changes in emissions from the waste sector compared with last year´s submission.

	Unit	1990	1995	2000	2005	2010	2011	2012	2013
5.A. Solid Waste Disposal									
CH_4, previous inventory	Gg	65.0	57.6	49.87	41.1	34.3	34.8	33.2	
CH_4, recalculated	Gg	71.0	62.2	51.04	44.0	37.2	37.0	35.1	33.8
Change, CO_2-equivalents	Gg	148.2	116.1	29.33	72.6	73.4	54.4	47.7	
Change	%	9.1	8.1	2.35	7.1	8.6	6.3	5.7	
5.B. Biological treatment of Solid Waste									
CH_4, previous inventory	Mg	1,386.1	1,860.2	3,240.0	3,419.9	4,094.6	4,204.3	4,306.3	
CH_4, recalculated	Mg	1,386.1	1,860.2	3,240.0	3,419.9	3,072.9	3,861.7	3,554.1	5,026.9
N_2O, previous inventory	Mg	41.5	72.8	515.7	200.2	355.2	381.4	409.1	
N_2O, recalculated	Mg	41.5	72.8	515.7	200.2	253.1	317.9	293.0	413.8
Change, CO_2-equivalents	Mg	0.0	0.0	0.0	0.0	-56.0	-27.5	-53.4	
Change	%	0.0	0.0	0.0	0.0	-26.9	-12.6	-23.3	
5.C. Incineration and open burning of waste									
CH_4, previous inventory	Mg	0.51	0.55	0.57	0.62	0.76	0.71	0.70	
CH_4, recalculated	Mg	0.51	0.55	0.57	0.62	0.76	0.71	0.70	0.71
N_2O, previous inventory	Mg	0.64	0.69	0.71	0.77	0.95	0.88	0.88	
N_2O, recalculated	Mg	0.64	0.69	0.71	0.77	0.95	0.88	0.88	0.88
Change, CO_2-equivalents	Mg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
Change	%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
5.D. Wastewater treatment and discharge									
CH_4, previous inventory	Gg	3.12	3.23	3.48	3.45	3.53	3.56	3.52	
CH_4, recalculated	Gg	3.98	4.10	4.28	4.35	4.42	4.44	4.46	4.51
N_2O, previous inventory	Gg	0.34	0.35	0.29	0.27	0.25	0.26	0.23	
N_2O, recalculated	Gg	0.34	0.35	0.29	0.27	0.25	0.26	0.23	0.25
Change, CO_2-equivalents	Gg	21.50	21.81	20.03	22.49	22.35	22.01	23.53	
Change	%	12.02	11.80	11.53	13.46	13.84	13.30	14.88	
5.E. Other									
CO_2, previous inventory	Gg	17.5	19.6	18.4	18.1	18.3	18.4	16.4	
CO_2, recalculated	Gg	17.5	19.6	18.4	18.1	18.3	18.3	16.3	16.0
CH_4, previous inventory	Gg	0.1	0.1	0.1	0.1	0.1	0.1	0.1	
CH_4, recalculated	Gg	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Change, CO_2-equivalents	Gg	0.0	0.0	0.0	0.0	0.0	-0.1	-0.1	
Change	%	0.0	0.0	0.0	-0.1	-0.2	-0.5	-0.4	0.0

7.9.1 Solid waste disposal on land recalculations

The recalculation of emissions from Solid Waste Disposal on Land is caused by extension of the historical part of the time series by 20 years, the starting year of the solid waste disposal set equal to 1940. The deposited amount of waste has been held constant equal to the data for 1960.

7.9.2 Biological treatment of Solid Waste

Data on the total amount of composted biowaste in the period 2010 to 2013 have been received from the Danish EPA, extracted from the new waste reporting system. The total amount of composted biowaste reported in the new waste database results in a drop in the time series when moving from 2009 to 2010. Communication with the DEPA on this aspect is ongoing (cf. chapter 7.10 on planned improvements).

7.9.3 Waste Incineration and open burning

No recalculations were made for Waste Incineration.

7.9.4 Wastewater treatment and discharge

For Wastewater treatment and discharge recalculations have been due to methodological changes in the calculation of methane lost by venting, replacement of the sludge statistics with plant level data on influent COD integrated with plant level data on WWTPs with biogas production. The main reason for the increase in the methane emission is however due to an increase in the default TOW data for Denmark (IPCC, 2006, Vol. 5, Table 6.4) used for quantifying the methane emission from scattered houses as described in detail in Chapter 7.5.

7.9.5 Other

For sector 5.E recalculations are due to smaller corrections in the activity data.

The joint effect of these recalculations is an increase in the GHG emissions between 9.1 % (1990) and 5.7 % (2013).

7.10 Source specific planned improvements

For the category 5.A. Solid Waste Disposal, plant specific data was made available from the new waste reporting system in November 2013, which has initiated plant level integration of information from the Danish Energy Agency on methane collection with time trend data on the deposited amount of waste according to waste types. Site specific modelling are compared to monitoring data seeking to verify a plant level model approach with the aim of estimating plant level methane potentials remaining at the individual landfill sites.

Regarding 5.B. Wastewater treatment and discharge, a methodology report is under publication, describing status for the methodological approach with focus on verifying the CH_4 emission from anaerobic sludge digestion.

Data on industrial wastewater treatment have been realized (Thomsen, 2015) and will be included in the next NIR.

The methodology report documents that it is not justifiable to reduce the number of people not connected to the collective sewer system.

Still, alternative solutions to the treatment of wastewater from scattered houses as well as development in aquaculture and marine fish farming activities in Denmark will influence indirect N_2O emissions, why improvements are expected. However, these improvements are long-term aspects implemented ad hoc as the necessary documentation becomes available.

There are no other planned improvements for the waste sector.

7.11 References

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8 Other

In CRF Sector 6, there are no activities and emissions for the inventories of Denmark.

9 Recalculations and improvements

Explanations for the recalculations of the Danish inventory are included in Chapter 9.1.1.

The overall impact of recalculations is shown in Table 9.1.

Information on recalculations for the aggregated submission of Denmark and Greenland under the Kyoto Protocol are included in Chapter 17.

9.1 Explanations and justifications for recalculations

Explanations and justifications for the recalculations performed in this submission, since submission of data to the UNFCCC due April 15, 2013 for Denmark, are given in the following sector chapters:

Energy:	
• Stationary Combustion	Chapter 3.2.8
• Transport	Chapter 3.3.7
• Fugitive emissions	Chapter 3.5.8
Industrial processes and product use:	
• Mineral industry	Chapter 4.2.10
• Chemical industry	Chapter 4.3.5
• Metal industry	Chapter 4.4.6
• Non-energy products from fuels	Chapter 4.5.8
• Electronics industry	Chapter 4.6.4
• Substitutes for ODS	Chapter 4.7.9
• Other product use	Chapter 4.8.8
Agriculture	Chapter 5.14
LULUCF	
• Forest Land	Chapter 6.2.8, 6.3.7
• Cropland	Chapter 6.4
• Grassland	Chapter 6.5
• Wetlands	Chapter 6.6
• Settlements	Chapter 6.7
Waste	Chapter 7.9
KP-LULUCF	
• ARD	Chapter 10.3.5
• FM	Chapter 10.4.5
• CM	Chapter 10.6.5
• GM	Chapter 10.7.4

The main recalculations since the 2014 submission are:

9.1.1 Energy

Stationary Combustion

For stationary combustion plants, the emission estimates for the years 1990-2012 have been updated according to the latest energy statistics published by the Danish Energy Agency. The update included both end use and transformation sectors as well as a source category update. The changes in the energy statistics are largest for the years 2010, 2011 and 2012.

A time series for the CH_4 emission factor for residential wood combustion have been added for 1990-2000. This cause an increased CH_4 emission estimated for residential plants in 1990-2000.

The consumption of wood in residential plants in 2012 is 4% lower in the revised energy statistics than in the energy statistics applied last year. This causes a lower emission of CH_4 reported for 2012 this year.

The increased CO_2 emission from residential plants is related to improved fuel data disaggregation between the transport sector and stationary combustion plants.

Mobile sources

The following recalculations and improvements of the emission inventories have been made since the emission reporting in 2014.

Road transport

Based on the updated version of COPERT IV version 11 launched in 2014, fuel consumption and NO_x , VOC, CO and PM emission factors for euro 5 and 6 gasoline and diesel passenger cars and light duty vehicles have been updated in the model. Updated Euro V and VI fuel consumption and NO_x, VOC, CO and PM emission factors for heavy duty vehicles have been included in the calculations also.

For N_2O and NH_3, Euro 5/6 and V/VI emission factors are also updated for passenger cars/light duty vehicles (only N_2O) and heavy duty vehicles.

Further a new Euro 6c technology class has been added for diesel passenger cars and light duty vehicles.

The amount of diesel sold for road transport reported by the Danish Energy Agency has been slightly changed in 2012.

Very small changes in mileage data has been made for the years 1985-2012 based on new information from DTU Transport.

The percentage emission change interval and year of largest percentage differences (low %; high %, year) for the different emission components are: CO_2 (0 %; 0.2 %, 2011), CH_4 (-0.1 %; 0.4 %, 2012) and N_2O (-21.7 %; 0 %, 2006).

Navigation

Recreational craft have been regrouped in the Danish inventory. These vessels have now been removed from the navigation sector and included under Other (1A5b), the latter sector according to its sector subtitle also comprise recreational craft. Further, small amounts of LPG and kerosene previously included in the navigation sector has now been transferred to stationary sources.

The following largest percentage differences (in brackets) for domestic navigation are noted for: CO_2 (-20 %), CH_4 (-72 % and N_2O (-12 %).

Agriculture/forestry

The baseline emission factors of NO_x, TSP, CO and VOC and the transient factors for fuel consumption, NO_x, TSP, CO and VOC for diesel machinery has been slightly changed in the calculation model used to estimate the emissions from Danish non road mobile machinery. Further, the CH_4 fraction of VOC has been updated. The changes are made based on new emission knowledge published by IFEU (1999) for baseline emission factors and CH_4 fractions, and IFEU (2014) for transient factors.

The number of agricultural tractors has been regrouped into finer engine size intervals for all inventory years. The total number of agricultural tractors and harvesters has been updated for the years 2006-2012 based on new stock data from Statistics Denmark for the year 2013.

The following largest percentage differences (in brackets) for agriculture/forestry are noted for: The following largest percentage differences (in brackets) are noted for: CO_2 (0.5 %), CH_4 (100 % and N_2O (0.6 %).

Fisheries

Small amounts of LPG and kerosene previously included in the navigation sector has now been transferred to stationary sources.

The following largest percentage differences (in brackets) for fisheries are noted for: CO_2 (-0.8 %), CH_4 (-8.9 % and N_2O (0.1 %).

Industry

The baseline emission factors of NOx, TSP, CO and VOC and the transient factors for fuel consumption, NOx, TSP, CO and VOC for diesel machinery has been slightly changed in the calculation model used to estimate the emissions from Danish non road mobile machinery. Further, the CH_4 fraction of VOC has been updated. The changes are made based on new emission knowledge published by IFEU (1999) for baseline emission factors and CH_4 fractions, and IFEU (2014) for transient factors.

The following largest percentage differences (in brackets) for industrial non road machinery are noted for: CO_2 (0.6 %), CH_4 (14 % and N_2O (0.1 %).

Civil aviation

The model used for calculating civil aviation emissions has been updated by replacing the previous fuel consumption and emission factors for representative aircraft types (46 types) with a new and more comprehensive list of aircraft types (79 types) provided by Eurocontrol and published in the EMEP/EEA guidebook (EMEP/EEA, 2014).

The following largest percentage differences (in brackets) for civil aviation are noted for: CO_2 (32 %), CH_4 (44 % and N_2O (-8.9 %).

Military

Recreational craft have been regrouped in the Danish inventory. These vessels have now been removed from the navigation sector and included under

Other (1A5b), the latter sector according to its sector subtitle also comprises recreational craft.

The following largest percentage differences (in brackets) for military are noted for: CO_2 (108 %), CH_4 (1780 %) and N_2O (93 %).

Fugitive emissions

In the emission inventory reported in 2015 for the years 1990-2013 the following recalculations regarding fugitive emissions from fuels have been applied:

Exploration of oil and natural gas

Exploration has been included as a new source in the emission inventory as activity data has now been made available by the Danish Energy Agency. Emissions only occur in years with exploration and appraisal wells (E/A wells) (1990-2000, 2002, 2005, 2009 and 2013). The largest E/A productions occurred in 1990 and 2002, contributing 3.8 % and 4.0 % to the fugitive CO_2 emission, 0.6 % and 1.0 % to the fugitive CH_4 emission, and 2.6 % and 3.9 % to the fugitive N2O emission.

Refineries

The methodology for estimating CH_4 from one refinery has been changed, resulting in an increase of the CH_4 emissions for the years 1994-2003 and a decrease for the years 2004-2012. The refinery report annual VOC emissions based on results from measurement campaigns, the last in carried out in 2006. In previous inventories, the split between CH_4 and NMVOC given by the refinery has been use. This methodology has been changed, as the CH4 share was much higher than for the other Danish refinery, and also much higher than corresponding shares found in a literature study. The CH_4 share of VOC has been changed to 10 % for all years, as given by the other Danish refinery and supported by shares of 10-20 % found for Swedish refineries. Previously, the shares were 1 % (1994-2003), 20 % (2004-2005), and 44 % (2006-2012). The largest decrease of the CH_4 emissions is estimated for the years 2006-2012 (1 611 tonnes per year), corresponding 17 % - 35 % of the total fugitive CH_4 emissions (17 % in 2006 and 35 % in 2012).

Gas transmission and distribution

Activity data has been updated for one town gas distribution company for the year 2012. The change of 0.22 tonnes CH_4 has insignificant impact on the total fugitive emissions (< 0.01%).

Venting

Activity data and direct CH_4 emission has been corrected for one gas storage plant for 2012 according to the annual environmental report. The change of 0.002 tonnes CH_4 is insignificant for the total fugitive CH_4 emissions (< 0.01%).

Flaring in refineries

The CO_2 emission factor has been updated for 1994-2006 to the average of first five years with ETS data available (2007-2011) for two refineries. For a third refinery that was closed down in 1996 the CO_2 emission factor has been updated for the years 1994-1996 according to the 2013 EMEP/EEA Guidebook. The changes of the emissions are largest in 1994 with an increase of 3 kt CO_2, corresponding 0.5 % of the total fugitive emission.

Flaring in oil and gas extraction
The implied emission factor for CO_2 has been updated for the years 1990-2007 to the average of ETS data for the years 2008-2012 instead of the previously applied average of the years 2008-2010. The increase of the CO_2 emission factor is 1 %, and the increase of the emissions is 2.9 kt CO_2 (1990) to 10.4 kt CO_2 (1999), corresponding to 0.6 % and 0.9 % of the total fugitive CO_2 emissions, respectively.

Flaring in gas storage and treatment plants
CH_4 emissions are updated according to the environmental report for the gas treatment plant for 2012. CH_4 has been changed from 0.502 tonnes to 0.027 tonnes. The decrease of the CH_4 emissions accounts for 0.01 % of the total fugitive emissions.

Flaring in gas transmission and distribution
Flaring in gas transmission and distribution has been included as a new source in the emission inventory, only occurring in the years 2011-2013. The gas transmission company inform that they have started using a mobile flare in large construction works, and also one distribution company is flaring gas. The largest emissions occur in 2012 with 0.1 kt CO_2 and 0.7 ktonnes CH_4, corresponding 0.05 % and 0.02 % of the total fugitive emissions.

9.1.2 Industrial Processes

Lime production
The activity data for lime no longer includes slaked lime and imported burnt lime. Personal communication with the industry made it clear that the inclusion of slacked lime resulted in a double counting, because statistical data on the production of burned lime also includes lime that is later slacked. Also, imported burned lime was by mistake included for 2010-2011 for Faxe Kalk. This recalculation related to slacked lime results in a decreased emission of between 5 % (1999) and 18 % (1991). The double counting of hydrated lime was only a problem for the years 1990-2010 (where EU-ETS data was not available/used) and the inclusion of imported burned lime only affected 2011-2012 (where EU-ETS data was used). The result of these recalculations has been an increase of the implied emission factor, and that the implied emission factors for 1990-2010 now matches the level of those for 2011-2013.

The EU-ETS data from Faxe Kalk for 2006-2010 have been included in this year's inventory; this change has only caused minor recalculation.

The stoichiometric emission factor for lime production has been corrected from 0.7857 to 0.7850 kg CO_2 per kg CaO for the entire time series.

The CO_2 emissions from lime production in the sugar industry have been moved from the CRF category "2H2 Food and Beverages Industry" (previously "2D2 Food and Drink"; IPCC, 1997), to the CRF category "2A2 Lime Production" (IPCC, 2006).

Glass production
A new methodology for calculating emissions from container glass production for 1990-2005 was used in this year's inventory. The resulting recalculations are between -1 % (1995) and +22 % (1998); average for 1990-2005 is an increase of 2 %. More detailed data was found for dolomite in 2006-2007, causing a decrease in emissions of 22 % and 25 % for the two years respectively.

Better estimates for the activity data for container glass in 1998-2012 were calculated for this year's inventory. This change has no influence on the emission but creates more stable implied emission factor.

The consumption of dolomite in the production of glass wool in 1990-2005 has been added as a raw material carbonate; as a result emissions from this production have increased with between 16 % (1999) and 37 % (2000); average for 1990-2005 is 29 %.

In last year's submission, the CO_2 emission from glass wool production in 2009 was mistakenly reported as 2977 Mg, this has now been corrected to 1428 Mg causing a 52 % decrease from this production in 2009.

Ceramics
The methodologies for calculating emissions from both bricks and expanded clay products have been changed for 1990-2005 in this year's inventory. Previously, emissions were based on a number of unverifiable assumptions. Now the historical years are based on the actual implied emission factors provided by EU-ETS (2006-2013).

This recalculation has resulted in increased emissions from brickworks of 3-10 % (8 % in average) and from expanded clay producers of 9 %.

Other uses of soda ash
The source category of other uses of soda ash is new in this year's inventory.

Flue gas desulphurisation
All activity data from this source category were reassessed and multiple recalculations were performed. Some recalculations were simple corrections of typing errors and some were more general. During the reassessment of flue gas desulphurisation at waste incineration plants, four facilities were removed from this part of the inventory because their desulphurisation is dry or semi-dry technology. It was also discovered that waste incineration plants (being power and gypsum producing) are included in the data from Energinet.dk (2014) and have therefore previously been double counted.

Mineral wool production
The CO_2 emission from mineral wool production was reassessed and found to be underestimated in last year's inventory. The surrogate data used to extrapolate emissions back in time was changed from energy consumption to raw material consumption. Emissions are now also calculated for 1995-2002 based on surrogate data instead of kept constant. Emissions have more than doubled for some years.

Chemical industry
The process related CO_2 emission from production of catalysts/fertilisers was recalculated for the years 1990-1996 leading to a small increase; the production for these years is now calculated as the average production for 1997-2001.

Metal industry
A correction was made for the activity data for steel production in 1992, this recalculation has resulted in small increases in emissions for 1992 and the extrapolated/interpolated years 1990-1991 and 1993.

For magnesium production, activity data are now calculated from the consumption of SF_6 and the default IPCC (2006) emission factor is applied, however this change has no influence on the emission.

CO_2 emissions related to the production of secondary lead are new in this year's inventory.

Non-energy products from fuels and solvent use

The amount of solvent, which is added to the asphalt in "cutback", is comprised in Solvent use (CRF 2D3 Other), with an emission factor of approximately unity. This amount was previously included in Road paving with asphalt (CRF 2D3 Other) as "cutback". In the improved inventory NMVOC emissions from "cutback" asphalt in Road paving (CRF 2D3 Other) only include emissions from the asphalt fraction.

A change in allocation of amounts from Statistics Denmark (2014) has caused an increase in activity data for Asphalt roofing (CRF 2D3 Other), e.g. 2012: from 75.5 kt to 131 kt, and a relatively small increase for Road paving (CRF 2D3 Other), e.g. for 2012: from 3223 kt to 3233 kt.

CH_4 emissions from Road paving with asphalt (CRF 2D3 Other) have been included.

CH_4 emissions from use of candles (CRF 2D2 Paraffin wax use) have been included.

CO_2 emissions from the use of urea in fuel consumption has been included in Urea used in catalysts (CRF 2D3 Other).

Other product manufacture and use

For "Medical applications of N_2O" emissions have been extrapolated back to 1990. A recalculation of the activity data for 2000-2004 has caused the emission for these years to increase drastically because last year's submission only included 1-2 distributors (out of four) for these years. Minor corrections were made for 2005-2012.

The category of "N_2O used as propellant for pressure and aerosol products" is new in this year's inventory.

CH_4 emissions have been included for use of fireworks, tobacco and charcoal for barbeques.

9.1.3 Agriculture

Changes have been made in the number of animals due to updated numbers in the statistics. These changes are of minor importance compared to the changes caused by the change to the 2006 IPCC Guidelines.

9.1.4 LULUCF

In the updated land use matrix that now includes mapping of three years: 1990, 2005 and 2011, significant changes have been noted related to land use and land use changes. This includes increased afforestation in areas without support from public funds. This includes establishment of minor forests areas, to improve hunting options and to produce biomass. Some forest areas have been established through natural succession, a method now approved by the Forest Act (from 2005). In the previous reporting, mainly afforestation based on subsidies were expected and included in the reporting.

Recalculations have been made due to the update to the IPCC 2006 Guidelines. Furthermore was there, by a mistake used a wrong EF for organic soils. Elsgaard et al. (2012) is used for documentation of the EF. In the previous submission was by mistake the Net Ecosystem Exchange (NEE) figures used instead of the net ecosystem carbon balances (NECB) figures. Overall has the recalculations increased the emission from CL.

9.1.5 Waste

A review of plant specific data was initiated with the purpose of identifying process emissions from the biogas production at wastewater treatment plants. Data on biogas lost via venting is scarce but based on a review of plant level environmental account data reported voluntary by the WWTPs an EF value of 1.3 % of the gross energy production were applied in this year´s inventory. This has led to a small decrease in the methane lost by venting ranging between 2.9-6.4 %.

The main reason for the increase in the methane emission from sector 5.D. Wastewater treatment and discharge are to be found in the change in the default COD value for the 10 % of the population not connected to the collective sewer system from 45.625 to 56.575 kg COD/person/year (IPCC, 1996; IPCC, 2006), which results in an increase in the methane emission from septic tanks of 29.2%. Likewise, the use of COD data in place of BOD data for the influent organic matter (TOW) have resulted in an increase in the methane emission from the sewer system and biotanks of 0-30 %.

Only a minor update in the influent N for the year 2011 resulting in a small increase in the N_2O emission of 0.24 %, while no methodological changes have occurred.

9.1.6 KP-LULUCF

A recalculation for KP-LULUCF has been performed for all areas as a consequence of the new land area matrix, see the section on LULUCF.

9.2 Implications for emission levels

For the national total CO_2 equivalent emissions without Land-Use, Land-Use Change and Forestry, the general impact of the improvements and recalculations performed is larger than usual due to the implementation of the 2006 IPCC Guidelines and the changes for the whole time-series are between 0.88 % (1990) and 2.22 % (2002). The implications of the recalculations on the level and on the trend, 1990-2012, of the national total are still relatively small, see Table 9.1.

For the national total CO_2 equivalent emissions with Land-Use, Land-Use Change and Forestry, the general impact of the recalculations is larger due to recalculations in the LULUCF sector. The changes vary between 2.80 % (1990) and 13.66 % (2009), see Table 9.1.

Table 9.1 Recalculation performed in the 2015 submission for 1990-2012. Differences in pct. of CO_2 equivalents between this submission and the April 2014 submission for Denmark, excluding Greenland and the Faroe Islands.

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Total CO_2 eqv. Emissions with Land-Use Change and Forestry	0.88	0.90	1.33	0.91	1.00	1.40	1.38	1.69	1.38	1.75	1.80
Total CO_2 eqv. Emissions without Land-Use Change and Forestry	2.80	2.86	3.45	2.80	2.83	3.07	2.90	3.41	3.56	4.06	3.85
Continued	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Total CO_2 eqv. Emissions with Land-Use Change and Forestry	1.96	2.22	2.11	2.09	2.18	1.90	1.81	1.73	1.75	1.69	1.56
Total CO_2 eqv. Emissions without Land-Use Change and Forestry	4.18	4.47	4.09	4.36	4.42	3.97	3.97	4.02	13.66	7.23	8.21
Continued	2012										
Total CO_2 eqv. Emissions with Land-Use Change and Forestry	1.86										
Total CO_2 eqv. Emissions without Land-Use Change and Forestry	8.00										

9.3 Implications for emission trends, including time series consistency

It is a high general priority in the considerations leading to recalculations back to 1990 to have and preserve the consistency of the activity data and emissions time-series. As a consequence activity data, emission factors and methodologies are carefully chosen to represent the emissions for the time-series correctly. Often considerations regarding the consistency of the time-series have led to recalculations for single years when activity data and/or emission factors have been changed or corrected. Furthermore, when new sources are considered, activity data and emissions are as far as possible introduced to the inventories for the whole time-series based on preferably the same methodology.

Due to the change in the UNFCCC reporting guidelines the 2015 inventory submission is not comparable to the 2014 submission. Hence, the detailed comparison of recalculations has not been carried out.

9.4 Recalculations, including those in response to the review process, and planned improvements to the inventory (e.g. institutional arrangements. inventory preparations)

The review on the submissions in 2007 and 2008 was finalised and the report was published April 15, 2009. For the 2009 submission the review report was finalised and published April 15 2010. The review report of the in-country review of the 2010 submission was published March 3 2011. The draft review report for the review of the 2011 submission was available February 9, 2012. The final review report was published April 30 2012. The draft review report of the 2012 submission was made available April 30 2013 and the final review report was dated August 2 2013. The draft review report of the 2013 submission was made available April 28 2014 and the final review report was dated June 23 2014.

Denmark received the draft of the review report from the centralised review carried out in September 2014 on December 9 2014. The final report was published on February 4 2015. The main recommendations from the reviews of the 2008 to 2014 submissions are listed in Table 9.2.

To keep the table transparent the recommendations that have been completed from the review of the 2008 to 2013 submissions have been deleted.

Table 9.2 Main recommendations from the reviews of the 2008, 2009, 2010, 2011, 2012, 2013 and 2014 submissions.

CRF	ERT Comment	Denmark's response	Reference
2008 submission (Review report: http://unfccc.int/resource/docs/2009/arr/dnk.pdf)			
Energy, road transport – Paragraph 41	The change of non-CO_2 EFs associated with the use of bioethanol in gasoline blends has not been taken into account when estimating the corresponding emissions. The ERT suggests that Denmark assess probable changes to these EFs in its next annual submission.	No data has previously been available indicating different CH_4 and N_2O emission factors for blends of fossil and biogenic fuels. This issue is being followed in case new research indicates otherwise.	Chapter 3.3.2.
2009 submission (Review report: http://unfccc.int/resource/docs/2010/arr/dnk.pdf)			
CRF	ERT Comment	Denmark's response	Reference
Solvent and other product use, use of N_2O – Paragraph 64	The ERT encourages the Party to provide estimates of emissions of N_2O from use as anaesthesia for the period 1990–2004 in order to complete the time-series.	The producers and distributors of N_2O will be contacted again and if data cannot be given for 1990-2004 this will be clearly explained in the report. 2013 update: Based on contact with the industry, data for 2000-2004 have been obtained and included in the inventory. 2015 update: The time-series has been completed by extrapolation.	
2010 submission (Review report: http://unfccc.int/resource/docs/2011/arr/dnk.pdf)			
2011 submission (Review report: http://unfccc.int/resource/docs/2012/arr/dnk.pdf)			
2012 submission (Review report: http://unfccc.int/resource/docs/2013/arr/dnk.pdf)			
2013 submission (Review report: http://unfccc.int/resource/docs/2014/arr/dnk.pdf)			
2014 submission (Review report: http://unfccc.int/resource/docs/2015/arr/dnk.pdf)			
CRF	ERT Comment	Denmark's response	Reference
Cross-cutting – Paragraph 11	Enhance QC activities to avoid inconsistencies	Denmark always strives to avoid errors in the reporting. However, it is inevitable that no matter how stringent QC procedures are elaborated there will be an error that goes undetected. We continue to refine and improve our QC system taking into account findings during the QA procedures.	
Energy, Stationary combustion: gaseous fuels – N_2O – Paragraph 24	Describe the trend in the N_2O IEF for manufacture of solid fuels and other energy	The trend in N_2O emission and hence the IEF is discussed in the NIR	Chapter 3.2.3
Energy, Stationary combustion: gaseous fuels – N_2O – Paragraph 24	Improve QA/QC procedures and follow up on the recommendations made in previous review reports	Denmark always strives to avoid errors in the reporting. However, it is inevitable that no matter how stringent QC procedures are elaborated there will be an error that goes undetected. We continue to refine and improve our QC system taking into account findings during the QA procedures.	
Industrial processes and solvent and	Provide detailed explanations in the NIR re-	The NIR describes how the methodology for estimating emissions from	Chapter 4.2.3

Table 9.2 Main recommendations from the reviews of the 2008, 2009, 2010, 2011, 2012, 2013 and 2014 submissions.

CRF	ERT Comment	Denmark's response	Reference
other product use, Cement production – CO_2 – Paragraph 29	garding the inclusion of emissions from cement kiln dust	cement production takes into account cement kiln dust.	
Industrial processes and solvent and other product use, Cement production – CO_2 – Paragraph 30	Improve QA/QC procedures	Denmark always strives to avoid errors in the reporting. However, it is inevitable that no matter how stringent QC procedures are elaborated there will be an error that goes undetected. We continue to refine and improve our QC system taking into account findings during the QA procedures.	
Industrial processes and solvent and other product use, Consumption of halocarbons and SF_6 – HFCs, PFCs and SF_6 – Paragraph 31	Report the emissions from disposal from refrigerators, air-conditioning equipment and aerosols/metered dose inhalers as "NO", provide a detailed explanation to improve transparency and improve the QA/QC checks for the use of notation keys for the entire time series	The use of notation keys has been revised in accordance with the ERT recommendation and the general restructuring required by the new reporting guidelines.	NIR Chapter 4.6, 4.7 and 4.8 CRF tables
Industrial processes and solvent and other product use, Consumption of halocarbons and SF_6 – HFCs, PFCs and SF_6 – Paragraph 32	Estimate the AD for HFCs remaining in hard foam	The AD have been reported where applicable	CRF tables
Industrial processes and solvent and other product use, Consumption of halocarbons and SF_6 – HFCs, PFCs and SF_6 – Paragraph 32	Verify that, consistent with Danish law, emissions from disposal are not occurring	It has been verified that Danish law requires f-gases in products to be collected and reused or destroyed upon decommissioning.	Chapter 4.7.4, 4.7.5
Industrial processes and solvent and other product use, Lime production – CO_2 – Paragraph 33	Correct the AD for lime production and improve QA/QC procedures	The error has been corrected. Denmark always strives to avoid errors in the reporting. However, it is inevitable that no matter how stringent QC procedures are elaborated there will be an error that goes undetected. We continue to refine and improve our QC system taking into account findings during the QA procedures.	CRF tables
Industrial processes and solvent and other product use, Consumption of halocarbons and SF6 – SF_6 - Paragraph 35	Report the SF_6 emissions remaining in double-glazed windows at decommissioning separately from the emissions from stocks, and if not possible, change the notation key from "NO" to "IE"	The emissions from decommissioning have been reallocated.	CRF tables
Industrial processes and solvent and	Correct the amount of SF_6 accumulated as	The error has been corrected.	CRF tables

Table 9.2 Main recommendations from the reviews of the 2008, 2009, 2010, 2011, 2012, 2013 and 2014 submissions.

CRF	ERT Comment	Denmark's response	Reference
other product use, Consumption of halocarbons and SF6 – SF_6 - Paragraph 36	stock in double-glazed windows and improve QA/QC procedures to avoid such errors	Denmark always strives to avoid errors in the reporting. However, it is inevitable that no matter how stringent QC procedures are elaborated there will be an error that goes undetected. We continue to refine and improve our QC system taking into account findings during the QA procedures.	
Agriculture, Sector overview - Paragraph 41	Report the results of the check and comparison of total N excretion in the 2016 annual submission, to the extent possible	We still work continuously to obtain the data series from DCA - Danish Centre for Food and Agriculture, which is responsible for producing the Danish Normative data for feed intake, manure production and N-excretion. A first rough estimate indicating that the two data sets correlated well, but we still need the more detailed data for the different animal categories.	
Agriculture, Enteric fermentation – CH_4 – Paragraph 42	Provide the explanations provided during the review to explain the declining population of dairy and non-dairy cattle	Increasing feed efficiency has resulted in higher milk production per cow, which means that fewer dairy cattle are needed to produce the amount of milk allowed by the EU milk quota. The production of non-dairy cattle follows the trend of dairy cattle. The explanation is added in NIR.	Chapter 5.3.5
Agriculture, Enteric fermentation – CH_4 – Paragraph 43	Include a description in the NIR of the interpolation method and parameters used for the average gross energy intake for non-dairy cattle	Explanation due to interpolation of GE for heifers is included in NIR.	Chapter 5.3.2
Agriculture, Direct soil emissions – N_2O – Paragraph 45	Provide information on crop yield for the complete time series	The N_2O emissions from N-fixing crops were estimated based on the crop yield, but according to the IPCC 2006 Guidelines this emission source is no longer estimated separately. Denmark still use national data for crop yield when emission from crop residue are estimated and these are given in form of dry matter content for each crop type each year from 1990 - 2013	Annex 3D, Table 3D-14
LULUCF, Sector overview - Paragraph 47	Elaborate on the explanation of any recalculations in the NIR	The discussion on recalculations has been expanded.	Chapter 6.2.8, 6.3.7, 6.4, 6.5, 6.6 and 6.7
LULUCF, Sector overview - Paragraph 48	Improve the transparency of reporting on how data sources have been combined and used to construct the land-use and land-use change matrices by summarizing the information provided during the review on the methodology for estimating land use and land-use change for	We continue to improve the transparency. Further Improvements will be made in the 2016 submission.	Chapter 6.1

Table 9.2 Main recommendations from the reviews of the 2008, 2009, 2010, 2011, 2012, 2013 and 2014 submissions.

CRF	ERT Comment	Denmark's response	Reference
	the period between 1990 and 2011 and 2011 to 2012 in section 7.1.4 of the NIR		
LULUCF, Forest land remaining forest land – CO_2 – Paragraph 50	Improve the transparency of the NIR by including information to explain the large inter-annual variations in the carbon stock changes in living biomass	We have discussed this issue to see if we can come up with more smooth estimates but we have not made any decision yet. Improvements will be made in the next submission.	
LULUCF, Forest land remaining forest land – CO_2 – Paragraph 51	Provide additional information on the area and volume of clear cutting and the area subject to destructive disturbance, subject to the availability of data	We will try to find more data on clear cutting for the 2016 submission. However, it may be difficult as both thinning and clear cuttings takes place inside the forest area. Combined with the fact that the Danish forests are small there will be many small areas.	
LULUCF, Cropland remaining cropland – CO_2 – Paragraph 52	Increase the transparency of the NIR by including information on the rationale for, and application of, the methods used to estimate emissions from areas previously classified as organic soils that do not qualify as organic by definition	More information will be provided in the 2016 submission.	
LULUCF, Cropland remaining cropland – CO_2 – Paragraph 52	Improve the accuracy of the emission estimates for this category by incorporating the results of the university research and mapping in future annual submissions	Continuously, efforts are made to include the latest research in the inventory. In many cases, recalculations are performed and reported based on new knowledge becoming available. For this specific issue of a map of soils with 6-12 % organic matter, the results of the research will be included once the project is finalised and the results published.	
LULUCF, Cropland remaining cropland – CO_2 – Paragraph 53	Accurately report figures on the area of cultivated organic soil reported in the agriculture and LULUCF sectors and improve the implementation of QC measures	More information on the link between the area of organic soils reported in the LULUCF sector and the area of histosols reported in the agricultural sector will be provided in the 2016 submission.	
LULUCF, Cropland remaining cropland – CO_2 – Paragraph 54	Provide additional information on the large variations in the areas of set-aside to help explain the estimates associated with cropland management practices	More information will be provided in the 2016 submission.	
LULUCF, Settlements – CO_2, CH_4 and N_2O – Paragraph 55	Enhance QA/QC procedures and accurately report the total area estimates in both the NIR and the CRF tables	We have corrected the error in total area of settlements.	Chapter 6.7 and CRF tables
LULUCF, Biomass burning – CO_2,	Enhance QA/QC procedures and accurately	We had some unfortunate issues related to aggregation of the Danish	CRF tables

Table 9.2 Main recommendations from the reviews of the 2008, 2009, 2010, 2011, 2012, 2013 and 2014 submissions.

CRF	ERT Comment	Denmark's response	Reference
CH_4 and N_2O – Paragraph 56	report the AD associated with biomass burning in the CRF tables	and Greenlandic submission that caused problems with the reporting of the unit for the AD for biomass burning. This should be easier to avoid when the new CRF Reported software is functioning.	
Waste, Sector overview – Paragraph 58	Provide all necessary explanations for the recalculations in the NIR	The discussion on recalculations has been expanded	Chapter 7.9
Waste, Sector overview – Paragraph 59	Enhance the category-specific QC procedures in order to avoid discrepancies between the NIR and the CRF data	Denmark always strives to avoid errors in the reporting. However, it is inevitable that no matter how stringent QC procedures are elaborated there will be an error that goes undetected. We continue to refine and improve our QC system taking into account findings during the QA procedures.	
Waste, Solid waste disposal on land – CH_4 and CO_2 – Paragraph 61	Use the notation key "NA" to report CO_2 emissions in CRF table 6.A	Denmark has reported CO_2 emissions as NA as recommended.	CRF tables
Waste, Other (waste) – CO_2, CH_4 and N_2O – Paragraph 66	Increase the transparency of reporting on sludge spreading, fugitive emissions from biological waste, sludge and manure during biogas production, and flaring and venting	Regarding emissions from sludge spreading, these are included in the agricultural sector. Fugitive emissions from composting of biological waste are due to the new reporting guidelines reported separately in sector 5.B.1 Composting. As part of the methodological improvement of sub-sector 5.D a separation of plant level processes into respectively wastewater and sludge treatment processes have been performed. This allows for a separate reporting of the methane emission from sludge-based biogas production which will be transferred from sector 5.D to sector 5.B in the next NIR. Similarly, documentation of the methane emission factor from manure-based biogas plants in Denmark have allowed for a first time reporting of such emission in sector 5.D in the next NIR.	Chapter 7 and CRF tables
Waste, Wastewater handling – CH_4 and N_2O – Paragraph 70	Improve the transparency of the NIR by documenting the data available and studies used to develop the country-specific factors	Improved transparency of the rationale behind changes, in terms of improved completeness in activity data (data availability) used to develop the country-specific factors and related changes in the methodology have been introduced in the NIR in section 7.5.2 and is furthermore documented in depth in a methodology report which is currently subjected to a review process prior to publication.	Chapter 7.5

More information on the specific responses to the review has been given in the sectoral chapters of this report.

9.5 Explanations, justifications and implications of recalculations for KP-LULUCF inventory

9.5.1 Recalculations

Almost all sectors in the KP-LULUCF have been recalculated.

This is due to:

- A revision of the land use matrix for the entire period 1990 to 2013
- Updated data from the Danish National Forest Inventory (NFI) for carbon stock changes in above/below ground, dead wood and litter

For more information on KP-LULUCF recalculations please refer to Chapter 10.

9.5.2 Review recommendations

The main recommendations for KP-LULUCF are included in Table 9.3.

Table 9.3 Recommendations from the UNFCCC review process concerning KP-LULUCF.			
CRF	ERT Comment	Denmark's response	Reference
2010 submission (Review report: http://unfccc.int/resource/docs/2011/arr/dnk.pdf)			
2011 submission (Review report: http://unfccc.int/resource/docs/2012/arr/dnk.pdf)			
2012 submission (Review report: http://unfccc.int/resource/docs/2013/arr/dnk.pdf)			
2013 submission (Review report: http://unfccc.int/resource/docs/2014/arr/dnk.pdf)			
2014 submission (Review report: http://unfccc.int/resource/docs/2015/arr/dnk.pdf)			
KP-LULUCF, Deforestation - Paragraph 76	Enhance QC procedures	Denmark always strives to avoid errors in the reporting. However, it is inevitable that no matter how stringent QC procedures are elaborated there will be an error that goes undetected. We continue to refine and improve our QC system taking into account findings during the QA procedures.	
KP-LULUCF, Deforestation - Paragraph 77	Increase the transparency of the NIR by including information in the NIR to explain the choice of transition periods that are different from the IPCC default transition periods, and perform a QA assessment of the approach used through independent model verification based on country-specific data relevant to deforestation	More information will be provided in the 2016 submission.	
KP-LULUCF, Cropland management - Paragraph 79	Increase the transparency of the NIR by explaining how the AD for cropland management ensures that the national territory is covered, and validate the model results based on country-specific data	More information will be provided in the 2016 submission.	

10 KP-LULUCF

10.1 General information

In the following text the abbreviations is used in accordance with definitions in the IPCC guidelines:

A:	Afforestation
R:	Reforestation
D:	Deforestation
FF:	Forest remaining Forest, areas remaining forest after 1990
FL:	Forest Land meeting the Danish definition of forests
CL:	Cropland
GL:	Grassland
WE:	Wetlands
SE:	Settlements
OL:	Other land, unclassified land
FM:	Forest Management, areas managed under article 3.4
HWP:	Harvested Wood Product
CM:	Cropland Management, areas managed under article 3.4
GM:	Grazing land Management, areas managed under article 3.4
RV:	Revegation
WDR:	Wetland Drainage and Rewetting
CP:	Commitment Period

10.1.1 Definition of forest and any other criteria

For the estimation of anthropogenic emissions by sources and removals by sinks associated with afforestation (A), reforestation (R) and deforestation (D) since 1990 under Article 3.3 and forest management (FM) under Article 3.4 of the Kyoto Protocol, the following forest definition will be applied:

- Minimum values for tree crown cover: 10 % tree crown cover for forests.
- Minimum values for land area: 0.5 ha.
- Minimum value for tree height: trees must be able to reach a minimum height of 5 m in the site.

In addition, the forest area includes temporarily unstocked areas, smaller open areas in the forest needed for management purposes and fire breaks. Forests in national parks, reserves, or areas under special protection are included. Windbreaks and groves covering more than 0.5 ha and with a minimum width of 20 m are also considered as forests. Farmlands, fruit plantations for commercial purposes, orchards, gardens (houses and summer houses) are NOT included in the forest area. Willow plantations on agricultural soils for bioenergy purposes are included in Cropland (CL).

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

As regards the possibility of including in the first commitment period emissions and removals associated with land use, land-use change and forestry activities under Article 3.4 of the Kyoto Protocol, it has been decided to include emissions and removals from forest management (FM), cropland management (CM) and grazing land management (GM). Revegetation and

Wetland Drainage and Rewetting (WDR) is not elected by Denmark in the second Commitment Period (CP).

Natural disturbances are very seldom in Denmark it has not been elected. Hence this is not reported.

Reporting is required by Parties that apply the provision in decision 2/CMP.7, annex, and paragraphs 37-39 on Carbon Equivalent Forests. Denmark has decided not to use this in its accounting.

The Danish territory covers mainland Denmark and Greenland and not the Faroe Islands.

The tables given below covers only the Danish territory and not data from Greenland and thus only data, which shall be included in the submission to the European Union (EU). The Danish CRF and KP tables are named: DNM

For Greenland separate CRF and KP tables are produced, see Chapter 15. The Greenlandic tables are named: **GRL.**

The Greenlandic impact on the overall estimates is very low: <0,01 % and thus the figures given below can be regarded as very proximate values for both Denmark and Greenland.

The Danish and the Greenlandic CRF and KP tables are merged into one set of CRF and KP tables and named: **DKE**.

The Faroe Islands has not signed the Kyoto-Protocol and has therefore not submitted KP tables or been included in the Danish and the Greenlandic submission.

The national system has identified land areas associated with the activities under Article 3.4 of the Kyoto Protocol in accordance with definitions, modalities, rules and guidelines relating to land use, land-use change and forestry activities under the protocol by satellite monitoring, use of Land Parcel Information System (LPIS) from the EU subsidiary system as well as the Greenlandic subsidiary system, detailed crop information data on field level, soil mapping and sample plots from the national forest inventory (NFI).

Inventories of emissions and removals under Article 3.3 and Article 3.4 are prepared for 2013, and reported annually together with the other greenhouse gas inventory information.

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

The definition of afforestation, reforestation and deforestation is in accordance with the Supplementary GPG (IPCC 2014).

Afforestation or reforestation is identified when areas have wooded tree cover and fulfils the forest definition given above. The time of the A is given by the time of action - i.e. planting of trees. For R the time is given by the first spontaneous regeneration of tress, typically either by absence of management or by management inducing natural regeneration. All types of es-

tablishment of forest (A or R) is considered human induced, as all land area of Denmark is under management or as minimum specifically left for spontaneous revegetation. Regulations and support for A and R include natural revegetation as a specific method, often supplementing already existing forest areas. (Danish Forest and Nature Agency, Support for Sustainable Forestry - active until 2010.
http://www.skovognatur.dk/Skov/Privat/Tilskud/Baeredygtig/)

Deforestation is identified where areas in 1990 were covered by forest and where subsequent information (through remote sensing or NFI) is recorded to have another land use. Deforestation occurs for a number of reasons, e.g. nature restoration which in the period 1990 - 2011 have been the predominant reason. Other reasons can be urban or infrastructure development.

Temporarily unstocked areas - as integral part of forest management or as result of windthrow - which is expected to continue in forest management is not considered deforestation.

As for the forest management (Article 3.4) - the forest areas fulfilling the definition given above are included under this activity. All forest areas are considered managed due to the intense utilisation of the land area of Denmark. All inventories apply this approach. The Forest Act in Denmark gives the frame for most of the forest area ('Fredskov') - thereby ensuring continued forest cover - or by deforestation at least afforestation of a similar area or in most cases the double area. As described in Chapter 6 the changes in forest floor and mineral soils pools are not significant in the period observed (1990-2011) and are hence not considered being a source of emissions.

For Cropland and Grassland the area accounted for under Art. 3.4 has been estimated with the EO mapping combined with agricultural data from Statistics Denmark, Statistics Greenland and the EU agricultural subsidiary system. Only areas which are reported as CL and GL are included in the accounted area.

10.1.4 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

All Forest activities have precedence, after this Cropland activities and then Grassland activities.

Afforestation has precedence. All land converted to forest are included as afforested area. Deforestated areas are reported under D. The following categories in the Convention reporting are included under afforestation:

- 5A21 CL to A
- 5A22 GL to A
- 5A23 WE to A
- 5A24 SE to A
- 5A25 OL to A

Deforestation is estimated as:
- 5B21 to CL
- 5C21 to GL
- 5D21 to WE
- 5E21 to SE

- 5F21 to OL

FM activities are only related to:
- 5A1 Forest remaining Forest

CM activities are related to:
- 5B1 CL remaining CL
- 5B22 GL to CL
- 5B23 WE to CL (not occurring)
- 5B24 SE to CL
- 5B25 OL to CL
- 5D22 CL to WE
- 5E22 CL to SE
- 5F22 CL to OL (not occurring)

GM activities are related to:
- 5C1 GL remaining GL
- 5C22 CL to GL
- 5C23 WE to GL (not occurring)
- 5C24 SE to GL
- 5C25 OL to GL
- 5D23 GL to WE
- 5E23 GL to SE
- 5F23 GL to OL (not occurring)

No elected land has left land, which is accounted for. Land conversion between elected activities (FM, CM and GM) has been allowed. FL, CL and GM, which has been converted to WE and SE is still included in the accounted area. No land elected under 3.4 activities has been converted to Other Land. No Other land has been converted to land included in Art. 3.3 and 3.4 activities. As a consequence there has been a small increase in land, which is accounted for under Art. 3.3 and Art. 3.4 (Table 10.1) with 384 hectares from 2008 to 2013.

Table 10.1 The development in the different KP classes, which are included in the accounting (only Denmark) 1990 to 2013.

	1990	2008	2009	2010	2011	2012	2013
AF	4 187	79 787	84 033	88 279	92 525	94 358	99 420
D	116	3 776	4 284	4 791	5 299	5 662	5 803
FM	543 856	540 124	539 600	539 076	538 553	538 189	538 048
CM	2 715 019	2 625 021	2 627 224	2 629 428	2 631 632	2 638 035	2 633 478
GM	401 414	315 123	308 248	301 373	294 498	285 900	285 288
Total area, Ha	3 664 592	3 563 830	3 563 389	3 562 947	3 562 506	3 562 144	3 562 038

The Land Use matrix developed for the purpose of reporting Art. 3.3 and 3.4 activities for 2012 are shown in Table 10.2.

Table 10.2 Land Use matrix for art. 3.3 and 3.4 activities in 2013, in 1000 hectares.

	ARTICLE 3.3 ACTIVITIES		ARTICLE 3.4 ACTIVITIES					Other(6)	Total area at the end of the previous inventory year(7)
	Afforestation and reforestation	Deforestation	Forest management(5)	Cropland management (if elected)	Grazing land management (if elected)	Revegetation (if elected)	Wetland drainage and rewetting (if elected)		
	(kha)								
Article 3.3 activities									
Afforestation and reforestation	94.36	NO							94.36
Deforestation		5.78							5.78
Article 3.4 activities									
Forest management		0.14	538.05						538.19
Cropland management(3) (if elected)	4.04		NO	2,613.60	2.83	NA	NA		2,620.47
Grazing land management(3) (if elected)	1.02		NO	1.12	314.54	NA	NA		316.67
Revegetation(3) (if elected)	NA		NA	NA	NA	NA	NA		NA
Wetland drainage and rewetting(3) (if elected)	NA		NA	NA	NA	NA	NA		NA
Other(4)	NO	NO	NO	1.31	0.78	NA	NA	NO	2.08
Total area at the end of the current inventory year	99.42	5.92	538.05	2,616.02	318.14	NA	NA	NO	99.42

The above given information in the hierarchy between the Contention and the KP-LULUCF activities ensures that emission from activities under article 3.4 are not double counted under both article 3.3 and 3.4 activities.

10.2 Land-related information

10.2.1 Spatial assessment unit used for determining the areas of the units of land under Article 3.3

Afforestation and reforestation is identified where areas in 1990 were not covered by forest and where subsequent information (through remote sensing or NFI) is recorded to have forest cover fulfilling the forest definition. Even though the definition for A and R refers to the time of establishment, there may be a slight time delay in the actual recording of the A/AR. This will be improved through more frequent land use mapping and improved methods for mapping in the coming years.

Deforestation is identified where areas at the beginning of the commitment period were covered by forest and where subsequent information (through remote sensing or NFI) is recorded to have another land use. The identification of the areas is in most cases supported by reports on e.g. nature restoration or establishment of settlements.

10.2.2 Methodology used to develop the land transition matrix

A land use/land cover map was produced for the Kyoto reference year 1990, 2005 and 2011 based on EO data for the forest land use. For mostly all other land uses the main data comes from detailed vector maps. These include data such as different vector layers from cadastral maps, road maps, wetland areas, agricultural land use data, vector layers of established wetlands, gravel maps etc. as well as aerial photos. The primary data used for the forest land use mapping is Landsat imagery mainly Landsat 5 (TM) and 7 (ETM+) data to classify and estimate the area and in combination with NFI data and other sources of data, including LiDAR data. The product is specified by a Minimum Mapping Unit (MMU) of 0.5 ha, a geometric accuracy of < 15 m RMS and a thematic accuracy of 90% +/- 5%.

The land use was allocated to the six major Kyoto classes: Forest, Cropland, Grassland, Wetland, Settlements, and Other. Highest priority was given to maps having the highest reliability in the production of the land use matrix. To avoid transition artefacts due minor updates in the precision of the vector maps a Minimum Mapping Unit (MMU) for land use change has been set to 0.5 ha which is the same as the elected Danish minimum MMU for forests in the Initial Report under the Kyoto protocol: Initial Report

In Chapter 6, Table 6.1 shows the overall development from 1990 to 2013. The preliminary result is an increase in the afforested area of 99 420 hectares, but also that deforestation has taken place of approximately 5 924 ha. Afforestation is mainly taking place on CL and GL. Areas, which are deforestated, are mainly converted to CL and GL as the far major part of D is a conversion of existing Christmas tree fields to agricultural crops in rotation or permanent grass. Only to a little extend is forest converted to SE.

Since 1990 almost 33 335 hectares have been changed into SE and other infrastructures. No FF, CL and GL are converted into OL by definition.

Based upon the combination of the satellite image classified land use map and the combined vector layer of know information a full land use map for 1990, 2005, 2011, 2012 and 2013 was produced.

10.2.3 Maps and/or database to identify the geographical locations, and the system of identification codes for the geographical locations

The entire Danish territory except the Faroe Islands is included. This chapter includes only the territory of Denmark without Greenland. Denmark is reported as one unit and no sub-geographical locations are used.

Greenland is submitting a full separate NIR and CRF to be included in the submission to UNFCCC (Chapter 16).

10.3 Afforestation, Reforestation & Deforestation (ARD)

10.3.1 Methods for carbon stock change and GHG emission and removal estimates

For afforestation the carbon stock change in the period 1990 - 2011 is based both on the area of afforestation, the information on species composition from the Forest Census 2000 and from the NFI.

In the afforestation a steady increase in carbon stock is found. The species composition is based on the information from the 2000 Forest Census for the period 1990-2000. Subsequently the NFI provides information on the afforestation area and the carbon pools in these areas - up till 2007. The estimates for the carbon pools in the afforestation are similar to previous estimates, with a slight increase due to the new knowledge on species composition and average carbon stock in those areas based on the NFI data.

Carbon stock change caused by deforestation is estimated based on the deforested area and the mean values of carbon stock in the total forest area in the period 1990-2005. Based on analysis by aerial photographs and LiDAR data of the deforested areas in the period 2005-2011 is it estimated that 50 pct. of this deforestation is happening in very young forests or forests with low biomass (e.g. Christmas tree plantations or small open forests on the edge of agricultural land). This biomass carbon removed from these areas is estimated to be 15 t C/ha whereas the remaining deforested areas is assumed to have average carbon pools as the remaining forest area.

Where deforestation is taking place is the living and dead biomass removed and oxidized instantly. This includes also the litter layer in the forest. For the litter layer is further more included a N_2O-emission from nitrogen in the litter layer as well as changes in the C stock in mineral soils multiplied with a C:N ratio of 10 and a EF of 0.01. A large part of the deforestation is conversion of forest to create wetlands by removing the forest and closing the drainage system. For land converted to wetlands is assumed an average increase in the soil carbon stock of 0.5 ton C per ha per year which are and reported under mineral soils.

Further details are available in Johannsen et al. 2009.

10.3.2 Description of the methodologies and the underlying assumptions used

The climate in Denmark is cold and wet, which gives limitations to the growth of the forests and therefore afforestation in Denmark are on long rotations (>50 years) to give a reasonable amount of wood and wood products. Furthermore, the afforested areas are in many cases protected against deforestation. Therefore, afforested areas under article 3.3. will seldom be harvested during the commitment period.

The basic information utilised to give the data for the emission estimates for units of land subjected to afforestation/reforestation is based on National Forest Inventory (NFI) observations of stock change, specific related to the afforestated areas. This will include all changes in carbon pools - also if affected by harvest - including thinnings of young stands.

Based on the NFI it will be possible - for the next reporting also to give some indications of the frequency of harvesting/thinning occurring on the afforestated areas. Given the fact that the afforestated area still is a relatively small part of the full forest area - there will be more uncertainty on the estimate related to afforestated areas compared to the area of forest remaining forest.

10.3.3 Justification when omitting any carbon pool or GHG emissions/removals from ARD

When deforestation occurs it is assumed that all dead organic matter will be cleared. The actual amount depends on which type of forest is converted.

10.3.4 Information on whether or not indirect and natural GHG emissions and removals have been factored out

No factoring out has been performed in the emission and removal estimates.

10.3.5 Changes in data and methods since the previous submission (recalculations)

Minor recalculations have been made as updated values from the NFI have become available; also minor changes in the Land Use Matrix have occurred. See more in Chapter 6.3.7.

10.3.6 Uncertainty estimates

Not estimated under KP for this year. Please look in chapter 6 for the whole LULUCF sector.

10.3.7 Information on other methodological issues

See Chapter 6.

10.3.8 The year of the onset of an activity, if after 2008

Not applicable.

10.4 Forest Management (FM)

10.4.1 Methods for carbon stock change and GHG emission and removal estimates

See Chapter 6 in LULUCF on "Forest remaining forest (4.A.1)".

10.4.2 Methodologies and the underlying assumptions

See Chapter 6 in LULUCF on "Forest remaining forest (4.A.1)".

10.4.3 Omission of pools from FM

No pools omitted.

10.4.4 Factoring out

No factoring out has been made.

10.4.5 Recalculations

A recalculation has been made for the living biomass for the years 2009 to 2012 due to a change in the Biomass Expansion Factor (BEF) factor.

10.4.6 Uncertainty estimates

Not estimated under KP for this year. Please look in chapter 6 for the whole LULUCF sector.

10.4.7 Information on other methodological issues

See Chapter 6 in LULUCF on "Forest remaining forest (6.A.1)".

10.4.8 The year of the onset of an activity, if after 2008

Not applicable.

10.5 Forest Management Reference level (FMRL)

The value inscribed in the appendix to the annex of decision 2/CMP.7 is reported to 409 kt CO_2 eq/yr in the second commitment period. For the year 2013 a technical correction has been calculated to -474 kt. The technical correction is documented in the following report (Schou *et al.* 2015).

For the accounting of emissions a FMRL is constructed specifying the expected average annual net emissions from the HWP pool for the second commitment period. Due to the data corrections it was decided to correct the original FMRL reported in 2011 (Johansen et al. 2011). This correction also entailed a change in the reference period used to project the inflow to the HWP pool – from 2005-2009 to 2008-2012 – in order to provide a more accurate reference level using the most recently collected data. Had the reference period not been changed, the FMRL would have significantly underestimated the inflow for 2013 and thus caused a significant gap between the reported net emissions and the projected net emissions by the FMRL. This means that the HWP pool would actually have been projected to decrease as opposed to the expected increase in the pool during the second commitment period.

The corrected FMRL has projected the inflow in 2013 to about 132.000 ton carbon (61.000 ton from sawnwood and 71.000 tonnes from wood-based panels) and the outflow to about 110.000 ton carbon in 2013 (65.000 ton from sawnwood and 45.000 ton from wood -based panels). The projected net sequestration is about 22.000 ton carbon. For the entire second commitment period the corrected FMRL projects an average annual net emission of -65 kt CO_2 equivalents/year. I.e. the HWP pool is projected to increase over the period.

Table 10.3 Values inscribed in the appendix to the annex of decision 2/CMP.7 for FMRL for instant oxidation and first order decay and the performed technical correction.

	Forest Management Reference Level kt CO_2 eq/year	Forest Management Reference Level applying first order decay function for HWP kt CO_2 eq/year
Decision 2/CMP.7	334	409
Technical correction		-474
Sum		-65

10.6 Cropland Management (CM)

10.6.1 Methods for carbon stock change and GHG emission and removal estimates

CL is subdivided in four classes: agricultural CL, wooded perennial fruit plantations, hedgerows and "other agricultural CL".

10.6.2 Methodologies and the underlying assumptions used

The area with agricultural CL are given as the agricultural area in Statistics Denmark for cereals, fodder crops, grass for seed, sugar beets, potatoes and other root crops.

Land converted from other Land use categories to CL is included under CL. Land converted to forest is reported under forest (AR). Land which according to the land use matrix is converted to WE and SE are still included in CM. Land conversion to OL is not allowed.

The same methodology as used in the Convention reporting, is used in the KP reporting.

10.6.3 Omission of pool from CM

Aboveground and belowground living biomass, litter and dead organic are only reported for perennial woody crops in accordance with IPCC Supplementary GPG 2014. No litter and dead organic matter are reported under CM as this is seen as not occurring or as very insignificant as it is only related to the small area with fruit plantations and hedges. Only above- and belowground living biomasses for perennial fruit plantations, hedgerows and willow plantations for bioenergy purposes on agricultural land are therefore reported under CM. CL converted to other land uses such as WE and SE is assumed not to store litter and other dead organic matter. Christmas trees are reported under Forest Management.

10.6.4 Factoring out

The dramatic increase in the temperature in the latter years results in a higher turn-over rate of organic matter in soils leading to an increased emission from soils compared to pre 1990. For agricultural soils Denmark is using a dynamical temperature dependent model (Tier 3), which is expected to give the best estimate of the actual emission from soils compared to most other methods. If Denmark had used the default IPCC Tier 1 or 2 there would likely have been a *negative* factoring out, because the emission factor (EF) in these methods are based on long-term scientific data and thus not having the recent increase in temperatures included. Therefore by using the actual temperature in the Tier 3 no factoring out has been made.

10.6.5 Recalculations

Recalculations have been made due to the update to the 2006 GL, implementation of the 2013 Wetland Supplement and an error correction in the EF for agricultural organic soils. The recalculations have increased the overall emission from CM.

10.6.6 Uncertainty estimates

Not estimated under KP for this year. Please look in chapter 6 for the whole LULUCF sector.

10.6.7 Information on other methodological issues

None.

10.6.8 The year of the onset of an activity. if after 2008

Not applicable.

10.7 Grazing land management (GM)

10.7.1 Methods for carbon stock change and GHG emission and removal estimates

Grazing land is defined as land used for permanent grazing as well as dry land not meeting the definitions for FF, CL, WE or SE. GL is subdivided into two types: Land strictly used for grazing and other grassland. Land used for grazing has no wooden vegetation whereas other grassland may have some wooden vegetation that does not meet the forest definition. The area with strict grazing land is remaining area between the grazing area and the grassland area in the land use matrix.

10.7.2 Description of the methodologies and the underlying assumptions used

As all the grazed grassland is more or less unimproved without fertiliser or limited fertilisation no changes in management practice has been applied. This is in accordance with IPCC 2006 Chapter 6 and IPCC Supplementary GPG Chapter 2.10.

For land converted to GL and not purely free of wooden trees/bushes it is assumed that there is a living biomass of 2.200 kg DM per ha in above ground biomass and 6.160 kg DM per ha in below ground biomass (IPCC 2006). In Grassland it is assumed that no changes in soil carbon stock in mineral soils are occurring. For organic soils is assumed an emission as reported in Section 6.

10.7.3 Factoring out

No factoring out has been made.

10.7.4 Recalculations

See section 10.5.5 as this also affect GM.

10.7.5 Uncertainty estimates

Not estimated under KP for this year. Please look in chapter 6 for the whole LULUCF sector.

10.7.6 Information on other methodological issues

None.

10.7.7 The year of the onset of an activity, if after 2008

Not applicable.

10.8 Article 3.3

10.8.1 Information that demonstrates that activities under Article 3.3 began on or after 1 January 1990 and before 31 December 2012 and are direct human-induced

The land use mapping in 1990, 2005, 2011, 2012 and 2013 is the documentation that activities under Article 3.3 began after 1.1.1990. As all land area is under management all changes are evaluated as direct human induced. This also includes A and R, which are based on approved methods of establishing new forest - both planting and natural revegetation. In some cases the absence of removal of tree growth is an easy and cheap method for establishing new forest. Hence this method has also been supported through public support for establishment of new forest areas.

10.8.2 Information on how harvesting or forest disturbance that is followed by the re-establishment of forest is distinguished from deforestation

Deforestation is detected by analysis of satellite images. Furthermore deforestation of larger areas is confirmed by e.g. projects on nature restoration. Temporarily unstocked areas are typically located within larger forest areas and will in most cases be reforestated within a period of 10 years as according to the Forest Act of Denmark, which applies to all Legal Forest Reserves (Fredsskov) and equals approximately 70 % of the total forest area. Clearcuts outside forests - e.g. small plantations of conifers on former cropland - is considered deforestation.

Most forest areas - including new forest areas - are subject to intermediate thinnings - harvesting of small trees. This is done with the purpose of reducing stem number and often to produce firewood or wood chips. Clearcuts of new forest areas occurs in most cases first at maturity of the stand – after 50-100 years. A subset of the new forest area are managed as coppice like management. e.g. for production of Christmas trees.

10.8.3 Information on the size and geographical location of forest areas that have lost forest cover but which are not yet classified as deforested

This information will be available after the QA/QC analysis of the land use maps of 1990, 2005, 2011, 2012 and 2013, which will be performed during 2015.

10.8.4 Uncertainty on article 3.3 activities

Not estimated under KP for this year. Please look in chapter 6 for the whole LULUCF sector.

10.9 Article 3.4

10.9.1 Information that demonstrates that activities under Article 3.4 have occurred since 1 January 1990 and are human-induced

Forest Management

In FM all forest area is under management and changes in carbon stock are hence seen as human induced. The baseline for 1990 is estimated as documented in Johannsen et al. 2009.

Cropland Management

Since 1990 major changes in Danish Agriculture has taken place. Due to environmental demands for "green crops during winter" the previous major crop, spring barley, has been replaced by primarily winter wheat. Furthermore, a ban on field burning was implemented in January 1990 (Executive order NO. 142 of 08/03/1989). This has reduced the burning of field residues, which were widely occurring until then. Furthermore, as part of reducing the leaching of nitrogen, executive order NO. 624 of 15/07/1997 demands of the farmers that a certain percentage of the area shall be grown with an extra crop after harvest of annual crops. Currently about eight per cent of the agricultural area is having an extra crop. From 2003 agricultural areas has been taken out of rotation due to demanded borders along watersheds to protect the watersheds.

Grassland Management

No specific activities have taken place in Grassland to increase or decrease the carbon stock. GM was elected so that all human induced activities affecting the carbon stock in the landscape are included in the Danish commitments under the Kyoto Protocol. Furthermore, it is very difficult to distinguish between activities in CM and GM in the heterogenic patchy Danish landscape.

10.9.2 Information relating to Cropland Management. Grazing Land Management and Revegetation, if elected, for the base year

No further information is available.

10.9.3 Information relating to Forest Management

No further information is available.

10.9.4 Uncertainty on article 3.4 activities

Not estimated under KP for this year. Please look in chapter 6 for the whole LULUCF sector.

10.10 Harvested Wood Products

Table 4(KP-I)C

Carbon in the HWP pool is accounted for based on the semi-finished wood product categories: sawnwood, wood-based panels and paper and paper products with default half-lives of 35, 25 and 2 years, respectively, stipulated by the Intergovernmental Panel on Climate Change (IPCC). HWP originating from imported wood is excluded from the accounting. HWP originating from deforestation activities is accounted for on the basis of instantaneous oxidation.

For calculating carbon stocks in HWP, Denmark has applied the default first order decay (FOD) model stipulated by the IPCC Supplementary GPG 2013, with the default half-lives (IPCC Tier 2 methodology). Activity data has been collected from international databases as well as from surveying the Danish wood industry (IPCC Tier 2 and 3 methodologies). Carbon conversion factors have been derived from national forest inventory data (IPCC Tier 3 methodology).

As of 2013 the HWP pool originating from domestic harvest and domestic consumption consisted of about 5 million tonnes carbon (67 % from sawnwood and 33% from wood-based panels – the paper pool was insignificant). This is equivalent to 13 % of the carbon stock in live forest biomass. If imported wood were also included, the pool increases to about 29 million tonnes carbon equivalent to 75 % of the carbon stock in live forest biomass. The total inflow of carbon to the HWP pool in 2013 is reported to about 144.000 tonnes carbon - 63.000 tonnes from sawnwood and 81.000 tonnes from wood-based panels. The outflow from the pool is reported to about 110.000 tonnes carbon in 2013 - 65.000 tonnes from sawnwood and 45.000

tonnes carbon from wood-based panels. Thus there has been a net carbon sequestration in HWP of about 34.000 tonnes carbon in 2013. This corresponds to 0,13 % of Denmark's total CO_2 emissions for 2013.

10.11 Other information

10.11.1 Key category analysis for Article 3.3 activities and any elected activities under Article 3.4

According to the 2013 Revised Supplementary GPG (Chapter 2.3.6) for LULUCF a category that is identified as key in the UNFCCC inventory should also be considered key under the Kyoto Protocol.

In 2013 the following LULUCF categories were identified as key categories at the level in the UNFCCC reporting:

- Forest land remaining forest land.
- Cropland remaining cropland – living biomass
- Cropland remaining cropland – organic soils
- Cropland remaining cropland – mineral soils
- Grassland remaining grassland – living biomass

According to Table 5.4.4 in the IPCC GPG for LULUCF this means that the following Kyoto Protocol activities are initially considered key.

Table 10.4 Relationship between activities in the UNFCCC LULUCF and the KP-LULUCF.

LULUCF activity	KP-LULUCF activities
Forest land remaining forest land	FM, GM, CM
Land converted to forest land	AR
Cropland remaining cropland	CM
Grassland remaining grassland	GM

For Denmark the relevant KP-LULUCF activity corresponding to forest land remaining forest land identified as being a key category in the UNFCCC reporting is FM. For land converted to forest afforestation/reforestation is a key category. For cropland remaining cropland the relevant KP-LULUCF activity is CM. For grassland remaining grassland the relevant KP-LULUCF activity is GM.

Therefore AR, FM, CM and GM are considered key categories in the Danish KP-LULUCF inventory.

For the full list of identified key categories please refer to Annex 1.

10.12 Information relating to Article 6

There are no Article 6 projects (Joint Implementation) on the Danish territory.

10.13 Literature

Johannsen, V.K., Nord-Larsen T., and K. Suadicani, 2011. Submission of information on forest management reference levels by Denmark. Forest & Landscape Working Papers No. 58-2011, 34 pp. Forest & Landscape Den-

mark, Frederiksberg. Can be found at:
https://unfccc.int/files/home/application/pdf/awgkp_denmark_2011.pdf

11 Indirect CO_2 and N_2O emissions

11.1 Description of sources of indirect emissions in GHG inventory

The estimation of indirect CO_2 and N_2O emissions is based on the official Danish inventories for the precursor gases (CO, NMVOC, NH_3 and NO_x) reported under the United Nations Economic Commission for Europe (UNECE) Convention on Long-Range Transboundary Air Pollution (CLRTAP) and the CH_4 emissions reported to the UNFCCC.

For an in-depth description of the Danish inventories for the precursor gases, please see the Danish Informative Inventory Report submitted to the UNECE (Nielsen et al., 2015).

11.2 Methodological issues

Indirect emissions are generally calculated using the methodology described in the 2006 IPCC Guidelines (IPCC, 2006). However, for some sources a more detailed calculation is performed.

In order for consistency with the reporting done by Denmark under the first commitment period of the Kyoto Protocol, the indirect CO_2 emissions from solvent use, road paving with asphalt and asphalt roofing are reported in category 2D3 of the CRF tables in accordance with the reporting guidelines (UNFCCC, 2013) that allows for the use of these categories in a drop-down list within this category. For other sources of indirect CO_2, the emissions are reported in CRF Table6. In the calculation of indirect CO_2, only fossil carbon has been considered, hence indirect CO_2 is not calculated for precursors originating from biomass combustion, nor from other biogenic sources, e.g. agriculture and waste disposal on land.

For indirect N_2O the emissions from resulting from ammonia emissions in agriculture and LULUCF are covered in the sectoral tables for agriculture and LULUCF. The indirect N_2O emissions resulting from NO_x emissions in these sectors are included in CRF Table6. Emissions for the other sectors are calculated using the default emission factor of 0.1 kg N_2O-N per kg NH_3-N or NO_x-N emitted.

11.3 Uncertainties and time-series consistency

Please see Nielsen et al. (2015) for further information on the uncertainties and time-series consistency for the Danish inventories of indirect greenhouse gases.

11.4 Category-specific QA/QC and verification

Please see Nielsen et al. (2015) for further information on the QA/QC for the Danish inventories of indirect greenhouse gases.

11.5 Category-specific recalculations

Please see Nielsen et al. (2015) for further information on the recalculations for the Danish inventories of indirect greenhouse gases.

11.6 Category-specific planned improvements

Please see Nielsen et al. (2015) for further information on the planned improvements for the Danish inventories of indirect greenhouse gases.

11.7 References

IPCC, 2006: 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Prepared by the National Greenhouse Gas Inventories Programme, Eggleston H.S., Buendia L., Miwa K., Ngara T. & Tanabe K. (eds). Published: IGES, Japan. Available at: http://www.ipcc-nggip.iges.or.jp/public/2006gl/index.html (11-03-2015).

Nielsen, O.-K., Plejdrup, M.S., Winther, M., Mikkelsen, M.H., Nielsen, M., Gyldenkærne, S., Fauser, P., Albrektsen, R., Hjelgaard, K., Bruun, H.G. & Thomsen, M., 2015: Annual Danish Informative Inventory Report to UNECE. Emission inventories from the base year of the protocols to year 2013. Aarhus University, DCE – Danish Centre for Environment and Energy, 482 pp. Scientific Report from DCE – Danish Centre for Environment and Energy No. 145 http://dce2.au.dk/pub/SR145.pdf

UNFCCC, 2013: Decision 24/CP.19 – Revision of the UNFCCC reporting guidelines on annual inventories for Parties included in Annex I to the Convention.

12 Information on accounting of Kyoto units

Referring to Decision 15/CMP.1 on Guidelines for the preparation of the information required under Articles 7 of the Kyoto Protocol (UNFCCC, 2006), this chapter and chapters 13, 14 and 15 include information and references to Denmark's and Greenland's annual non-inventory information under the Kyoto Protocol.

12.1 Background information

In accordance with paragraph 10 of the annex to Decision 15/CMP.1 information on emission reduction units, certified emission reductions, temporary certified emission reductions, long-term certified emission reductions, assigned amount units and removal units will be reported for the first calendar year in which these units will be transferred or acquired.

12.2 Summary of information reported in the SEF tables

The information required is contained in the UNFCCC Standard Electronic Format (SEF) application version 1.2.1.

12.3 Discrepancies and notifications

Annex 1 parties are also required to submit four reports according to paragraphs 12 to 16 of the annex to decision 15/CMP.1. These reports are:

- Paragraph 12 – List of discrepancies identified by the ITL.
- Paragraph 13/14 – List of notifications from the CDM Executive Board regarding lCERs.
- Paragraph 15 – List of non-replacement identified by the ITL.
- Paragraph 16 – List of invalid Kyoto units.

The list described in paragraph 12 is contained in Annex 6 as "Report – List of discrepancies identified by the ITL according to paragraph 12 of the annex to decision 15/CMP.1".

The lists described in paragraph 13-15 are not included in this NIR, as there are no tCERs or lCERs in the Danish Registry. For paragraph 16, the Danish Registry has yet to receive invalid Kyoto units. This also renders this list unnecessary to submit. The discrepancies have been found in the daily reconciliation and have all been solved by manual intervention by either the Danish Registry or the CITL/ITL depending on which stage the transaction was in.

12.4 Publicly accessible information

Information to be publically available from the SEF will be included in SEF 2013 Denmark. The SEF report will also be publically available on the Danish Business Authority website (http://danishbusinessauthority.dk/public_information).

Other information that is required to be publically available can be found on the EUTL website: http://ec.europa.eu/environment/ets/.

The public reports can be found under at the ETS registry without logging in:

UK: https://ets-registry.webgate.ec.europa.eu/euregistry/DK/public/reports/publicReports.xhtml

and

DK: https://ets-registry.webgate.ec.europa.eu/euregistry/DK/public/reports/publicReports.xhtml

And can also be found at The Danish Business Authority website:

UK: http://danishbusinessauthority.dk/public_information
DK: http://erhvervsstyrelsen.dk/offentlig_information

The files are updated every month.

This information includes information on each account as required in paragraph 45 of the annex to Decision 13/CMP.1. Please note that the contact information (paragraph 45 (d) and (e)) requires the consent of the account holder according to EU law. Thus, all of this information is not publically available.

Information required in paragraph 45 (c) of the annex to Decision 13/CMP.1 can be found at the Danish Business Authority webpage:
http://danishbusinessauthority.dk/eu-ets-registry-kyoto

Information on article 6 projects is not available as Denmark to this date has not approved any Joint Implementation projects in Denmark.

12.5 Calculation of the commitment period reserve

For the first commitment period, the calculation of the Commitment Period Reserve (CPR) is based on the assigned amount of 276 838 955 tonnes of CO_2 equivalents (UNFCCC, 2007). Subsequently, the CPR calculated as 90 % of the assigned amount is 249 155 060 tonnes CO_2 equivalent, during the commitment period and has not changed since the Report of the review of the initial report of Denmark published on 2 November 2007 (UNFCCC, 2007). The commitment period reserve has not changed since the previous submission, as 100 % times the most recent inventory times five would amount to a higher value.

Since the assigned amount has not been established for the second commitment period, it is not yet possible to calculate the CPR.

12.6 KP-LULUCF accounting

At the time of preparation for this report Denmark has issued 8.920.413 RMUs and net-source cancelled 1.635.242 units (1.590.143 RMUs and 45 099 AAUs) for the first commitment period.
Referring to the KP-LULUCF inventory the accounting quantity is 8 609 424 tonnes CO_2 equivalent as RMUs on the basis of activities in 2008-2012 under Articles 3.3 and 3.4 of the Kyoto Protocol.

The accounting of RMUs based on the 2015 submission will not begin until after publication of the review report from the review of the submission.

Table 12.1 Information on accounting for activities under articles 3.3 and 3.4 of the Kyoto Protocol.

Greenhouse gas source and sink activities	Base year	Net emissions/-removals									Accounting Parameters	Accounting Quantity
		2013	2014	2015	2016	2017	2018	2019	2020	Total		
	(kt CO_2 equivalent)											
A. Article 3.3 activities												79.28
A.1. Afforestation and Reforestation		40.02								40.02		40.02
A.2. Deforestation		37.95								37.95		39.27
B. Article 3.4 activities												2414.53
B.1. Forest Management		-2384.50								-2384.50		-2350.06
Net emissions/removals												
Forest management reference level (FMRL)												
Technical corrections to FMRL												
Forest management cap												
B.2. Cropland Management	5443.64	4161.73								4161.73		-4162,82.80
B.3. Grazing Land Management	796.36	593.80								593.80		601.76
Total												2493.82

12.1 References

EC, 2004: COMMISSION REGULATION (EC) No 2216/2004 of 21 December 2004 for a standardised and secured system of registries pursuant to Directive 2003/87/EC of the European Parliament and of the Council and Decision No 280/2004/EC of the European Parliament and of the Council. Available at:
http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2004:386:0001:0077:EN:PDF

UNFCCC, 2006: Report of the Conference of the Parties serving as the meeting of the Parties to the Kyoto Protocol on its first session, held at Montreal from 28 November to 10 December 2005. Available at:
http://unfccc.int/resource/docs/2005/cmp1/eng/08a02.pdf

UNFCCC, 2007: Report of the review of the initial report of Denmark. Available at:
http://unfccc.int/resource/docs/2007/irr/dnk.pdf

13 Information on changes in the national system

Since the 2014 submission no changes have been made to the national system.

14 Information on changes in the national registry

The ETS operates in the EU Member States plus Iceland, Liechtenstein and Norway. It covers CO_2 emissions from installations such as power stations, combustion plants, oil refineries and iron and steel works, as well as factories making cement, glass, lime, bricks, ceramics, pulp, paper and board.

The following changes to the national registry of Denmark have occurred in 2014:

Reporting Item	Description
15/CMP.1 annex II.E paragraph 32.(a) Change of name or contact	The Danish Business Authority The Danish Kyoto Registry Dahlerups Pakhus Langelinie Allé 17 DK-2100 København Ø Telephone 1: +45 3529 1000 Telephone 2: +45 7220 0038 E-mail: co2register@erst.dk www.erhvervsstyrelsen.dk/kvoteregisteret http://danishbusinessauthority.dk/eu-ets-registry-kyoto The registry Staff has changed to: Registry Manager Ms. Susanne Petersen Phone: +45 3529 1884 e-mail: susbod@erst.dk Registry staff: Mr. Peter W. Bentzen Phone: +45 3529 1883 e-mail: petben@erst.dk Ms. Hanne Paulli Phone: +45 3529 1881 e-mail: hanpau@erst.dk Ms. Anita Smed Phone: +45 3529 1622 e-mail: anisme@erst.dk Mr. Ulrik Barkentin Overby Phone: +45 3529 1636 e-mail: Ulrove@erst.dk Ms. Astrid Dahl Phone: +45 3529 1684 e-mail: astdah@erst.dk

Continued…	
	Mr. Jacob Meibom Hansen Phone: +45 35291624 e-mail: jachan@erst.dk
15/CMP.1 annex II.E paragraph 32.(b) Change regarding cooperation arrangement	No changes
15/CMP.1 annex II.E paragraph 32.(c) Change to database structure or the capacity of national registry	An updated diagram of the database structure is attached as Annex A. Versions of the CSEUR released after 6.1.7.1 (the production version at the time of the last Chapter 14 submission) introduced changes in the structure of the database. These changes were limited and only affected EU ETS functionality. No change was required to the database and 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	Changes introduced since version 6.1.7.1 of the national registry were limited and only affected EU ETS functionality. However, 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 were successfully carried out prior to the relevant major release of the version to Production (see Annex B). Annex H testing will be carried out in February 2015 and the test report will be submitted thereafter 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 Danish Registry staff has implemented a new case handling system called REMA. The system documents all processes and ensures that the same process is used every time. REMA is also used in other EU countries, however the processes might differ from country to country. As we are hosting this system inside the organisation a consult firm has made a penetration test on our intern network. The recommendations from the test have been taken into account. We have implemented a new filing system in the agency. From autumn 2014 all case handling in the registry is digital Other security changes in the Danish registry reported former years remain unchanged. All security changes regarding the EU ETS is reported by EC: No change of security measures occurred during the reporting period 1.
15/CMP.1 annex II.E paragraph 32.(g) Change to list of publicly available information	EC: No change to the list of publicly available information occurred during the reporting period. DK: UK: http://danishbusinessauthority.dk/public_information http://danishbusinessauthority.dk/danish_emission_trading_registry DK: http://www.erhvervsstyrelsen.dk/offentlig_information http://www.erhvervsstyrelsen.dk/kyoto-registeret The publicly available information is updated on a monthly basis and confidential

Continued…	
	information is clearly marked as confidential. The information is available in English and Danish. Publicly available information concerning transactions, holdings and total volumes via the EUTL is concerned confidential, this information is not publicly available before year x+5, where "x" is the year of the transaction. Furthermore the following information is considered confidential: • Account identifier, • Representative's identifier, name, and contact information • Holdings of all accounts, • All transactions made, • The unique unit identification code of the allowances • The unique numeric value of the unit serial number of the Kyoto units held or affected by a transaction No public information is available concerning article-6 projects. Denmark has not approved any joint implementation projects in Denmark.
15/CMP.1 annex II.E paragraph 32.(h) Change of Internet address	The internet address of the Danish registry is: https://ets-registry.webgate.ec.europa.eu/euregistry/DK/index.xhtml
15/CMP.1 annex II.E paragraph 32.(i) Change regarding data integrity measures	No change of data integrity measures occurred during the reporting period.
15/CMP.1 annex II.E paragraph 32.(j) Change regarding test results	Changes introduced since version 6.1.7.1 of the national registry were limited and only affected EU ETS functionality. Both regression testing and tests on the new functionality were successfully carried out prior to release of the version to Production. The site acceptance test was carried out by quality assurance consultants on behalf of and assisted by the European Commission; the report is attached as Annex B. Annex H testing will were carried out in February 2015 and is attached as annex B1
The previous Annual Review recommendations	The 2013 assessment report included no recommendations for Denmark.

The mentioned Annex A and Annex B contains confidential information and is therefore not part of the NIR. The information has been submitted to the UNFCCC as confidential.

15 Information on the minimization of adverse impacts in accordance with Article 3, paragraph 14

No changes have occurred since the information reported in NIR 2011.

16 Methodology applied for the greenhouse gas inventory for Greenland

16.1 Introduction

The following sections contain a report of Greenland's part of the National Inventory Report (NIR) 2015. The structure of the report follows the UNFCCC guidelines on reporting and review (UNFCCC, 2002).

The report is to a far extent structured according to the recommended outline provided by the UNFCCC secretariat.

Previous to 2010 the greenhouse gas (GHG) inventory and this report were completed exclusively by The Danish Centre for Environment and Energy, Aarhus University (DCE), with input from the Environmental and Nature Protection Agency (APA), Ministry of Domestic Affairs, Nature and Environment (current Ministry of Environment and Nature).

In 2008 an energy statistic was officially initiated at Statistics Greenland with the intention to "… create an important tool, which in regard to political and economical priorities, can contribute to the identification of efforts on energy matters…" and which "… in regard to environmental aspects will create a basis for assessing the development in regard to Greenland's meetings of the Kyoto protocol …". The first results on the new energy statistics, covering the period 2004-2007, were published in November 2008.

The GHG inventory submitted in 2015 is completed by Statistics Greenland and the Ministry of Environment and Nature, Greenland Government, with technical support from DCE. This report on methodology is written by Statistics Greenland with assistance from the Ministry of Environment and Nature and documental support by DCE.

The annual emission inventories for Greenland for the years 1990-2013, are reported in the full CRF format.

The GHG's reported are:

- Carbon dioxide CO_2
- Methane CH_4
- Nitrous Oxide N_2O
- Hydrofluorocarbons HFCs
- Perfluorocarbons PFCs
- Sulphur hexafluoride SF_6

16.1.1 A description of the institutional arrangement for inventory preparation

Statistics Greenland and The Greenland Ministry of Environment and Nature are responsible for the annual preparation of the Greenlandic contribution to the National Inventory Report and the GHG inventories in the Common Reporting Format in accordance with the UNFCCC Guidelines. Statistics Greenland provides the data to DCE. DCE is responsible for aggregating the Danish and Greenlandic CRF submissions and reporting the aggregated CRF and the National Inventory Report to the UNFCCC.

The inventory for LULUCF and KP-LULUCF is carried out by DCE and the documentation of the inventory (Sections 16.6 and 16.10) is completed by the Danish LULUCF experts.

Formerly, the provision of data was on a voluntary basis, but a formal contract between DCE and the Greenland Government came in place for the 2009 GHG inventory report.

The work concerning the annual GHG emission inventory is carried out in co-operation with other Greenlandic ministries, research institutes, organisations and companies:

Statistics Greenland (Ministry of Finance)
Annual energy statistics in a format suitable for the emission inventory work and fuel-use data for the large combustion plants. Since 2009 annual survey on emissions of F-gases.

Agricultural Advisory Service (Ministry of Fisheries, Hunting and Agriculture)
Background data on cropland and grassland, and statistics on livestock (sheep and reindeer).

Ministry of Domestic Affairs, Nature and Environment
Data on waste and emissions of F-gases. Annual Survey carried out by the Ministry of Domestic Affairs, Nature and Environment until 2008 and by Statistics Greenland from 2009 and onwards.

Ministry of Fisheries, Hunting and Agriculture and the Greenlandic Arboretum
Background data on forestry.

Greenland Airport Authority (Ministry of Health and Infrastructure)
Statistics on domestic flights and foreign flights to and from Greenland.

16.1.2 Brief description of the process of inventory preparation - data collection, data processing, data storage

The background data (activity data and emission factors) for estimation of the Greenlandic emission inventories is collected and stored in central databases at Statistics Greenland. The databases are in SAS format and handled with software from the SAS Institute Inc. The SAS programs are designed by Statistics Greenland. The methodologies and data sources used for the different sectors are described briefly in Section 16.1.4 and more in depth in Sections 16.3 to 16.7 and Section 16.10.

The material is placed on servers at Statistics Greenland. The servers are subject to routine backup services. Material, which have been backed up is archived safely.

16.1.3 General description of methodologies and data sources used

The GHG inventory for Greenland includes the following sectors:

- Energy
- Industrial Processes and Product Use
- Agriculture

- Land Use, Land-use Change and Forestry
- Waste
- KP LULUCF

The applied methodologies follow the IPCC Guidelines and IPCC Good Practice Guidance. In some cases the methodology is identical to the methodology applied in the Danish inventory, however, the availability of data – especially site specific data – do not allow the same methodology to be used for all the sectors. The brief methodological description is included below for the different sectors. More thorough descriptions are included in Sections 16.3-16.7 and 16.10.

Energy

Fuel Combustion

The Greenlandic emission inventory for fuel combustion has been performed according to the IPCC tier 1 methodology. The inventory is based on activity data from the Greenlandic energy statistics and on emission factors for different fuels, plants and sectors.

Total fuel combustion is based on data from Polaroil, Statoil and Malik Supply A/S. Polaroil imports fuel and distributes fuel in all parts of Greenland. Statoil imports and distributes fuel in Kangerlussuaq. Malik Supply A/S, a Danish company, re-distributes fuel bought from Polaroil to Greenlandic trawlers, ships etc. By using detailed data from Polaroil, Statoil and Malik Supply A/S it is possible to determine total import, total export, total international bunkers and total domestic fuel combustion.

Total domestic fuel combustion is divided into sectors and private households by using data from a survey on energy consumption, company specific sales data from Polaroil and local fuel distributors, company tax accountings, municipality and the Government of Greenland accountings, and by estimation.

Fuel combustion in private households is estimated using detailed information from a number of local fuel distributors. Fuel deliveries are registered by buildings. In Greenland each building has a unique number registered in the Greenlandic Area Register (NIN). By combining the NIN-register and the Greenlandic Business Register (GER) with statistics on housing and population each building is labelled *private household* or located to a sector describing the main activity in the building. This new building-sector register, completed annually, is used extensively to determine the buyer of fuel delivered by Polaroil or local fuel distributors.

Fuel combustion in road traffic is based on a model designed by Statistics Greenland. The model contains data on the vehicle stock obtained from the Greenland Police Department's register on engine data. The vehicles are divided into broad categories of type i.e. personal car, lorry, taxi, truck, ambulance, motorbike etc. Each category is assigned with ratios on fuel type and mileage. Input data on mileage is derived from an annual survey among businesses and private road traffic since 2008. Each vehicle is divided in business categories or labelled *private vehicle* according to the owner. For each group the emissions are estimated by combining vehicle and annual mileage numbers with standard emission factors according to the type of fuel. The model does not take cold start or hot engines into account.

For air traffic annual emissions are based on activity data from Air Greenland A/S and sales data from the Greenland Airport Authority. For navigation, ferries and freight, annual emissions are based on activity data from Royal Arctic Line A/S (freight), Royal Arctic Tankers A/S (freight), Royal Arctic Bygdeservice A/S (freight/passengers), and Arctic Umiaq Line A/S (passengers) and the liquidated Assartuivik A/S (passengers).

For further information please refer to Section 16.3.

Memo Items

International Aviation Bunkers

Emissions from international aviation bunkers are considered to be of neglible importance. The Greenland Airport Authority has reported the annual amount of jet fuel loaded into foreign aircrafts including Danish aircrafts. However, it is not possible to distinguish between Danish aircrafts and other aircrafts. Since most foreign aircrafts by far are Danish the annual amount of jet fuel loaded into foreign aircrafts are therefore included as part of the IPCC category 1A3a Domestic Aviation.

International Navigation Bunkers

Emissions from international marine bunkers are included from 2004 and onwards. Before 2004 international marine bunkers are considered to be of negligible importance.

Fugitive emission

Greenland has no coal mines, no off-shore activities, no oil refineries, no natural gas transmission or distribution. For that reason there have been no fugitive emissions from such activities in 1990-2009. However in 2010 a scotish company initiated a search for oil along the westcoast of Greenland. Three wells were drilled and tested in 2010. Five wells in 2011. There were no oil exploration activities in 2012 and 2013.

In the 2014 National Inventory Report calculation of fugitive emission was based on the annual number of drilled and tested wells and IPCC Guideline emission factors.

In this 2015 National Inventory report fugitive emission is to be based on the amount of drilled oil and gas and IPCC Guideline emission factors.

However, the scotish company has not been able to provide the Greenland Government with any information on the amount of oil and gas picked up during drillings in 2010 and 2011. To our knowledge the scotish company only discovered a few minor kicks with some minor inflow of water or gas during drillings.

With no data available, activity data in 2010 and 2011 has been marked with the notation key Not Applicable (NA). Since no amounts could be estimated, all fugitive emissions are assumed to be zeo, and also marked with the notation key Not Applicable (NA). This decision has been made in agreement with the DCE.

Besides from energy production, some fugitive emission occurs in the distribution of fuel e.g. when refuelling from ships to on-shore tanks, onshore loading of fuel to ships and offshore loading of ships. The emission would only be in the form of NMVOC. The fugitive emission from loading/unloading of ships is currently not estimated.

Industrial Processes and Product Use

Mineral Industry

CO_2 emissions occur from limestone and dolomite use. Import statistics of limestone are used as activity data for estimating the emissions.

Chemical Industry

Greenland has no chemical industry.

Metal Industry

Greenland has no metal industry.

Non-energy Products from Fuels and Solvent Use

CO_2 emissions occur from paraffin wax use, road paving with asphalt and asphalt roofing. Import statistics of paraffin wax and asphalt are used as activity data for estimating the emissions.

The emission estimates for solvent use are also prepared by using import statistics of pure chemicals that fits the criteria for being considered a NMVOC compound. Additionally import statistics are used for products containing NMVOC's. The NMVOC emission is then calculated in to a CO_2 emission by using a standard value for carbon content in the NMVOC's. For further information see Section 16.4.

Electronics Industry

Greenland has no electronics industry.

Product Uses ...

Greenland has no production of halocarbons or SF_6. Data on consumption of F-gases (HFCs and SF_6) are obtained from an annual survey on consumption of halocarbons and SF_6 conducted by Statistics Greenland. Information on emission of industrial gases is available from 1995 onwards. Greenland has no consumption of PFCs.

Product Uses as Substitutes for ODS

Consumption of halocarbons for refrigeration

Other Product Manufacture and Use

Consumption of SF_6 in electrical equipment.

Other Production

There are several manufacturers of fish products and one tannery. Emissions of NMVOC are estimated, but there are no emissions of greenhouse gases occurring.

For further information on the methodology for calculating emissions from industrial processes please refer to Section 16.4.

Agriculture

Livestock, Enteric Fermentation and Manure Management

Agriculture is sparse in Greenland due to climatic conditions. However sheep and reindeer are considered to contribute to emission of greenhouse gases. Enteric fermentation and manure management is assumed to contribute to emission of CH_4, and nitrogen excretion is assumed to contribute to emission of N_2O.

Activity data for livestock is on a one year average basis from the agriculture statistics published by Statistics Greenland. Data concerning the land use and crop yield is obtained from the Agricultural Advisory Service.

Data concerning the feed consumption and nitrogen excretion from sheep is based on information from the Agricultural Advisory Service supplemented by data on imported feed. Data concerning the feed consumption and nitrogen excretion from reindeer is based on information from the Agricultural Advisory Service and information from an article on reindeer management in Greenland.

Emission of N_2O is closely related to the nitrogen balance. Thus, quite a lot of the activity data is related to the calculation of ammonia emission. National standards are used to estimate the amount of ammonia emission. When estimating the N_2O emission the IPCC standard value is used for all emission sources. The emission of CO_2 from Agricultural Soils is included in the LULUCF sector.

For a more thorough description of the methodology for the agricultural sector please refer to Section 16.5.

Land Use, Land-Use Change and Forestry

Greenland is the world's largest non-continental island on the northern American continent between the Arctic Ocean and the North Atlantic Ocean, northeast of Canada. The northernmost point of Greenland, Cape Morris Jesup, is only 740 km from then North Pole. The southernmost point is Cape Farewell, which lies at about the same latitude as Oslo in Norway. Greenland is covering approx. 2,166,086 km^2. It has been estimated that 81 % is covered permanently with ice leaving only 410,449 km^2 ice free. The climate is Arctic to sub arctic with cool winters and cold summers. The capitol Nuuk is having an average temperature of 1.4°C.

Due to its cold climate the LULUCF sector is of minor importance in relation to the emission of green house gases. Only a very minor area is covered by forest of which the major part has been planted within the last 40 years. Cropland was introduced in year 2000 and grassland management within the last 30 years. The cold climate slows down the biological processes making all growth rates very low.

In total the emission from the LULUC sector in 2013 has been estimated to a net source of 1.12 kt CO_2 equivalent or 0.2 % of the total Greenlandic emission.

Forest land

Greenland has a few forests, which may qualify to the FAO criteria of forest definitions. The major forest areas are:

A natural forest in the Qinngua valley of 45 ha consisting mainly of *Betula Pubescens ssp. czerepanovii* which in the period 1990 to 2013 has had an average height of six meters and approx. 100 trees per ha. It is thus assumed that it has had the same biomass for the whole period.

187 ha other planted forest. The largest of this is an arboretum (a research area) where different species and origins of trees are investigated which are adaptable to the harsh climate.

Cropland

In 1990 no annual crops were grown in Greenland. In 2013 10.5 ha of cropland was used for annual crops. The primary production is potatoes. Potato fields are mainly managed by hand and primarily fens with a high content of organic matter which is used for this purpose. It is thus assumed that the IPCC standard emission factor for boreal/cold areas of five tonnes C pr ha can be used although it is probably an overestimation due to the cold climate and the current management practice.

Grassland

In total is 242,000 hectare reported as grassland. The grassland is located in mountainous areas used for grazing of sheep. Due to the global warming are there some smaller areas which have become improved fertilised grassland. The total area with improved grassland has increased from 490 ha in 1990 to 1,069 ha in 2013.

Wetlands

Reported area with wetlands consists only of water-reservoirs. Due to lack of methodology for methane emissions under arctic conditions has no emission estimates has been made which is in accordance with the IPCC GPG 2003 guidelines.

Settlements

The few settlements are mainly built on cliffs with very sparse vegetation. Hence it is assumed that no changes in C stock occur.

Other land

No emission estimates has been made since no data is available which is in accordance with IPCC GPG 2003 guidelines.

Harvested wood products

Due to the very low area with slowgrowing forests is it assumed that no national changes in the carbon stock in Harwested Wood Products (HWP) are taking place.

For a more thorough description of the methodology applied for LULUCF and KP-LULUCF please refer to Section 16.6 and 16.10.

Waste

Solid Waste Disposal

The solid waste disposal in Greenland can be divided in the following processes:

- Managed waste disposal sites, anaerobic.
- Unmanaged waste disposal sites.

Biological Treatment of Solid waste

Greenland has no biological treatment of solid waste.

Incineration and Open Burning of Waste

Waste incineration with or without energy recovery and open burning of waste is both divided in the following processes:

- Waste incineration/Open burning, biogenic.
- Waste incineration/Open burning, non-biogenic.

Waste incineration with energy recovery is according to IPCC Guidelines included under the energy sector.

Information on amount of waste produced per year, amount of waste treated in the different processes, distribution between household and commercial waste, composition of the household waste and commercial waste, respectively, are provided by the Ministry of Environment and Nature.

Wastewater Treatment and Discharge

N_2O emission from human sewage is estimated. The calculation of the N_2O emission uses population data from Statistics Greenland and an estimate for average protein consumption combined with default values from the IPCC Guidelines. No emissions of CH_4 are assumed to occur.

For more information please refer to Section 16.7.

KP-LULUCF

Regarding the possibility of including in the first commitment period emissions and removals associated with land use, land-use change and forestry activities under Article 3.4 of the Kyoto Protocol, Greenland as part of the Kingdom of Denmark has included emissions and removals from forest management (FM), cropland management (CM) and grazing land management (GM).

The national system has identified land areas associated with the activities under Article 3.4 of the Kyoto Protocol in accordance with definitions, modalities, rules and guidelines relating to land use, land-use change and forestry activities under the protocol. All land converted from other activities into Cropland and Grassland is accounted for. No land has been allowed to leave elected areas under Article 3.4, see Section 16.10 for further details.

In 2013 has the emissions undet KP-LULUCF not been estimated due to the technical problems with the CRF-Reporter.

16.1.4 Brief description of key categories

A key category analysis (KCA) for year 1990 and 2013 has been carried out in accordance with the IPCC Good Practice Guidance.

The categorisation used results in a total of 33 categories. In the level KCA for the inventory for 1990, five key categories were identified. In the KCA for 2013, six categories were identified as key categories due to both level and trend. Further, two categories were key categories due to the trend.

Of the six key sources due to level for the reporting year 2013 five are in the energy sector, of which CO_2 from liquid fuels excluding transport in the analysis contributes most with 74.0 % of the national total (this contribution and the percentage contributions in the following are results from the level KCA based on the absolute values of the emissions; this contribution as percentages may differ somewhat from the percentage used in the sectoral chapters). Of the remaining level key categories in the energy sector three are CO_2 from the transport sector and one is CO_2 from combustion of other fuels excluding transportation. Domestic aviation, domestic navigation and road transportation comprise respectively 7.1 %, 5.8 % and

5.6 % of the national total. The last key categories are HFCs from the consumption of HFCs.

The trend assessment shows that CO_2 from from Grassland remaining grassland and CO_2 emission from waste ncineration and open burning of waste are key categories to the trend.

The categorisation used, results, etc. are included in Section 16.11 (Annex 1).

16.1.5 Information on QA/QC plan including verification

A number of measures are in place to ensure the quality of the Greenlandic greenhouse gas inventory.

The general QC activities include:

- Check that data are correctly moved between data processing steps, e.g. it is ensured that the data are imported correctly from the emission spreadsheets/databases to the CRF Reporter.
- The time-series are analysed. Any large fluctuations are investigated and explained/corrected.
- The recalculations are analysed and the consistency of the emission estimates are verified.
- The completeness of the inventory is checked utilising the completeness checker incorporated in the CRF Reporter as well as expert knowledge from the inventory compilers.
- All references are checked and it is ensured that the citations are correct.

These types of QC checks are recommended as tier 1 QC checks in the IPCC Good Practice Guidance (IPCC, 2000).

The Greenlandic emission inventory is reviewed by Danish emission experts, who provide input to the Greenlandic inventory compilers on necessary improvements etc. This is done as a QA procedure. When the emission estimates are transferred to DCE, the quality control system of the Danish emission inventory is applied to the Greenlandic data.

All information related to the Greenlandic emission estimates are documented and archived securely annually. This is done in order to ensure that any part of the inventory can be reproduced at a later stage if necessary.

In addition source specific QA/QC activities are conducted; please see the associated paragraphs in the sectoral chapters.

16.1.6 General uncertainty evaluation

The uncertainty estimates are based on the Tier 1 methodology in the IPCC 2006 Guidelines (IPCC, 2006). Uncertainty estimates for the following sectors are included in the current year: fuel combustion, industrial processes and product use, solid waste, wastewater treatment and waste incineration, agriculture and LULUCF.

The uncertainties for the activity rates and emission factors are shown in Table 16.1.4. The estimated uncertainties for total GHG and for CO_2, CH_4,

N_2O and F-gases are shown in Table 16.1.3. The base year for F-gases is 1995 and for all other sources the base year is 1990. The total Greenlandic GHG emission is estimated with an uncertainty of ± 4.3 % and the trend in GHG emission since 1990 has been estimated to be -8.7 % ± 3.7 %-age points. The GHG uncertainty estimates do not take into account the uncertainty of the GWP factors.

The uncertainty on CO_2 and N_2O from liquid fuels in fuel combustion, N_2O emission from waste water treatment and CH_4 emission from enteric fermentation are the largest sources of uncertainty for the Greenlandic GHG inventory. The result is skewed by the fact that more than 90 % of the Greenlandic Greenhouse gas emission is from fuel combustion of liquid fuels.

Table 16.1.3 Uncertainties 1990-2013.

	Uncertainty [%]	Trend [%]	Uncertainty in trend [%-age points]
GHG	± 4.3	-8.7	± 3.7
CO_2	± 3.5	-9.9	± 3.8
CH_4	± 57	-7.9	± 8.7
N_2O	± 123	-16	± 25.8
F-gases	± 51	+13 480	± 5 674

Table 16.1.4 Uncertainty rates for each emission source.

IPCC Source category	Gas	Base year emission	Year t emission	Activity data uncertainty	Emission factor uncertainty
		Gg CO_2 eqv	Gg CO_2 eqv	%	%
1A Liquid fuels	CO_2	619	551	3	2
1A Municipal waste	CO_2	2	7	3	25
1A Liquid fuels	CH_4	1	1	3	100
1A Municipal waste	CH_4	0	0	3	100
1A Biomass	CH_4	0	0	3	100
1A Liquid fuels	N_2O	2	2	3	500
1A Municipal waste	N_2O	0	0	3	500
1A Biomass	N_2O	0	0	3	200
1B2 Oil exploration	CO_2	0	0	3	1 000
1B2 Oil exploration	CH_4	0	0	3	1 000
1B2 Oil exploration	N_2O	0	0	3	1 000
2A4 Limestone and dolomite use	CO_2	0	0	5	5
2D2 Paraffin wax use	CO_2	0	0	5	25
2D3 Solvent use	CO_2	0	0	5	25
2D3 Road paving with asphalt	CO_2	0	0	5	25
2D3 Asphalt roofing	CO_2	0	0	5	25
2F Consumption of HFC	HFC	0	8	10	50
2G Consumption of SF_6	SF_6	0	0	10	50
3A Enteric fermentation	CH_4	8	7	10	100
3B Manure management	CH_4	0	0	10	100
3B Manure management	N_2O	1	1	10	100
3D Agricultural soils	N_2O	1	2	20	50
3G Liming	CO_2	0	0	5	50
4A Forest	CO_2	0	0	5	50
4B Cropland	CO_2	0	0	5	50
4C Grassland	CO_2	0	1	5	50
5A Solid waste disposal	CH_4	4	5	10	100
5C Incineration and open burning of waste	CO_2	3	3	10	25
5C Incineration and open burning of waste	CH_4	3	2	10	50
5C Incineration and open burning of waste	N_2O	1	1	10	100
5D Wastewater treatment and discharge	N_2O	7	5	30	100

16.1.7 General assessment of completeness

The present Greenlandic greenhouse gas emission inventory includes all major sources identified by the Revised IPCC Guidelines.

16.1.8 References

Ministry of Environment and Nature: Data on waste and ozone depleting substances and greenhouse gases HFCs, PFCs and SF_6.

Agricultural Advisory Service: Statistics on livestock (sheep and reindeer) and background data on land use (cropland and grassland).

Ministry of Fisheries, Hunting and Agriculture: Background data for Forestry.

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http://www.ipcc-nggip.iges.or.jp/public/gp/english/ (15-04-2007).

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http://www.stat.gl/publ/da/EN/201403/pdf/2013%20Gr%C3%B8nlands%20energiforbrug.pdf as "Grønlands energiforbrug 2013" (01-12-2014).

Statistics Greenland, 2014: The Greenlandic energy statistics aggregated to SINK categories. Not published.

16.2 Trends in Greenhouse Gas Emissions

16.2.1 Description and interpretation of emission trends for aggregated greenhouse gas emission

The GHG emissions are estimated according to the IPCC guidelines and are aggregated into five main sectors; Energy incl. Transport, Industrial Processes and Product Use, Agriculture, LULUCF, and Waste, See Figure 16.2.3 and Figure 16.2.4.

The greenhouse gases include CO_2, CH_4, N_2O, HFCs, PFCs and SF_6. However, Greenland has no consumption of PFC. In 2013 total emission of greenhouse gases excluding LULUCF was 594.45 Gg CO_2 equivalent, and 595.57 Gg CO_2 equivalent including LULUCF.

Figure 16.2.1 shows total greenhouse gas emission in CO_2 equivalents from 1990 to 2013. The emissions are not corrected for temperature variations. CO_2 is the most important greenhouse gas. In 2013 CO_2 contributed to the total emission in CO_2 equivalent excluding LULUCF with 94.4 %, followed by CH_4 2.5 %, N_2O 1.7 % and F-gases (HFCs and SF_6) with 1.4 %. Since 1990 these percentages have been increasing for F-gases, and falling for CO_2, N_2O and CH_4.

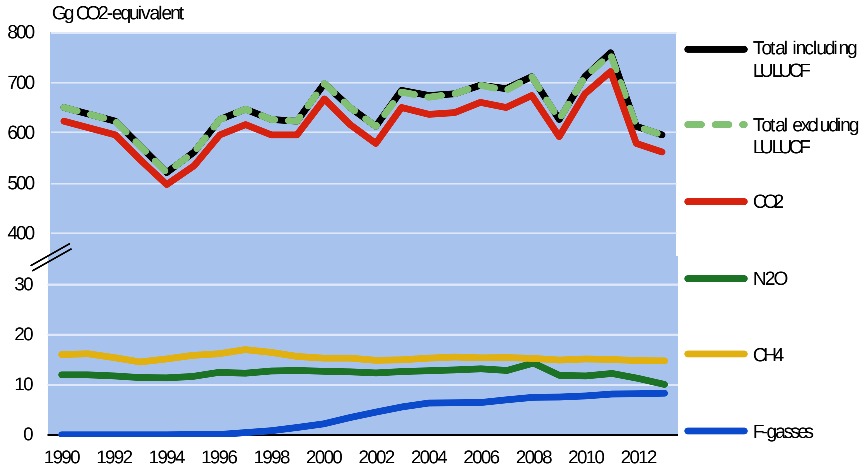

Figure 16.2.1 Greenhouse gas emission in CO_2 equivalents, time-series 1990-2013.

Stationary combustion plants and transport represent the largest categories. Energy excluding transport contributed to the total emission in CO_2 equivalents excluding LULUCF with 76 % in 2013; see Figure 16.2.2. Transport contributed with 19 %. Industrial processes and product use, agriculture and waste contributed to the total emission in CO_2 equivalents with 5.5 %.

The net CO_2 emission forestry etc. is 0.2 % of the total emission in CO_2 equivalents in 2013. Total GHG emission in CO_2 equivalents excluding LULUCF has decreased by 8.8 % from 1990 to 2013 and decreased 8.6% including LULUCF. Comments on the overall trends etc. seen in Figure 16.2.1 and Figure 16.2.2 are given in the sections below on the individual greenhouse gases.

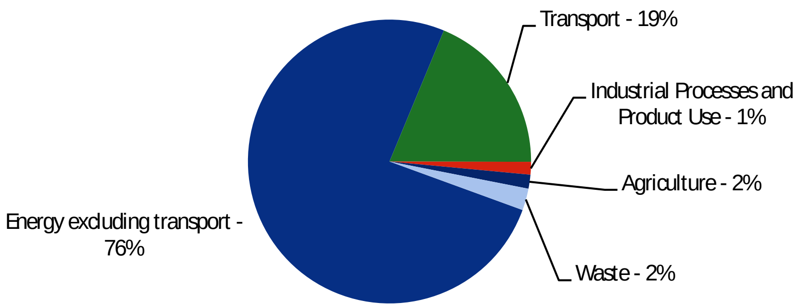

Figure 16.2.2 Greenhouse gas emission in CO_2 equivalents distributed on main sectors for 2013.

16.2.2 Description and interpretation of emission trends by gas

Carbon Dioxide

Emission of CO_2 accounted for 94.4 % of the total GHG emission in 2013. The largest source to the emission of CO_2 is the energy sector comprising Fuel Combustion (Sectoral Approach). In 2013 the energy sector contributed to 99.4 % of the total CO_2 emission.

In Figure 16.2.3 and Figure 16.2.4 CO_2 emissions are split into several subcategories i.e. Energy Industries, Manufacturing Industries and Construction, Transport, Other energy sectors consisting of the subcategories Commercial and Institutional, Residential, Agriculture and Fishing. All remaining sectors are included in the subcategory Other including Agriculture, Industrial Processes and Product Use, and Incineration and Open Burning of waste.

The largest source to the emission of CO_2; the energy sector includes combustion of fossil fuels like gasoil, gasoline, jet kerosene etc. From this sector Agriculture and Fishing (AFF) contributes with 24 % making AFF the largest contributor in 2013 followed by Residental and Transport both sharing 20 %, and Energy Industries with 17 % of the total CO_2 emission in 2013.

Emissions from Energy Industries have been reduced a great deal in later years due to massive investments in hydro power plants. However, in 2010 and 2011 oil explorations were initiated along the west coast increasing fuel combustion and thus emissions in the Energy Industries to rise to the highest point ever. In 2012 and 2013 oil exploration activities came to a standstill, which send energy combustion in Energy Industries to the lowest level ever in the time series since 1990.

Commercial and Institutions contributes with 10 % of the total CO_2 emission and Manufacturing Industries and Construction with 7 %. The category *Other* (containing the remaining sectors) contributed with 1 % of the CO_2 emissions in 2013.

Overall CO_2 emissions excluding LULUCF decreased by 3 % from 2012 to 2013. The main reason for this decrease was the introduction of the fifth hydropower plant, which lead to a decrease in the use of gasoil in the energy industry in 2013. In 2013, the actual CO_2 emission was 10 % lower than the emission in 1990 excluding LULUCF.

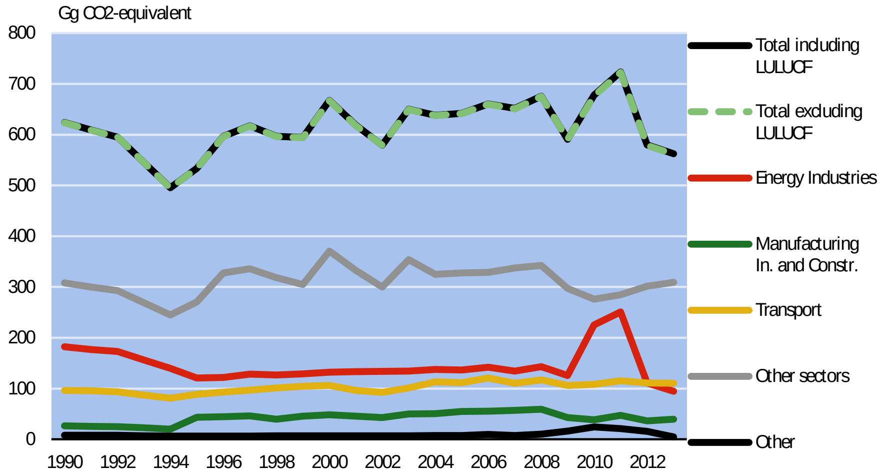

Figure 16.2.3 CO_2 emissions, time-series for 1990-2013.

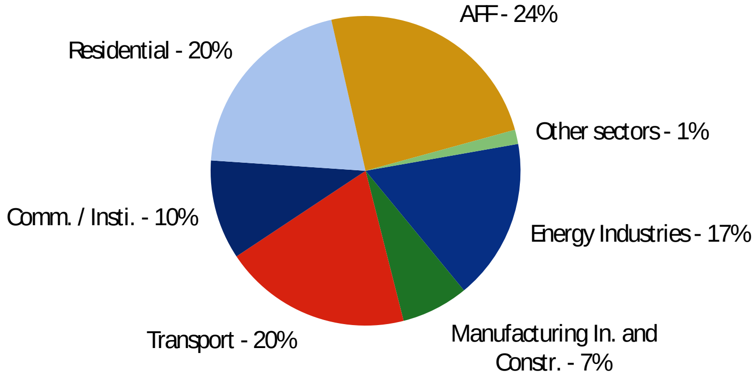

Figure 16.2.4 CO_2 emissions, distribution according to the main sectors for 2013.

Nitrous oxide

Waste, particularly waste water treatment and discharge is the most important N_2O emission source in 2013 contributing 50.8 % to the total N_2O emissions, see Figure 16.2.6. Agricultural activities contributed 24.4 % to the total N_2O emissions in 2013. Fuel combustion including transport contributed 24.8 %. Since 1990 total emission of N_2O has decreased by 16.0 %.

Besides from a temporary increase in 2011 total N_2O emission has been reduced in later years, 2009-2010 and 2011-2013 due to a fall in the amount of waste water from industrial fishing plants and reduced use of inorganic fertilizers in agricultural activities, see Figure 16.2.5.

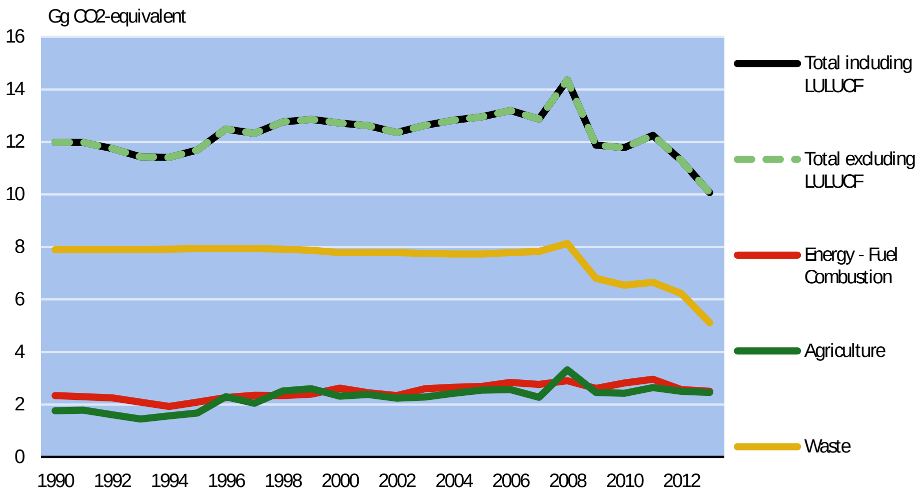

Figure 16.2.5 N_2O emissions, time-series for 1990-2013.

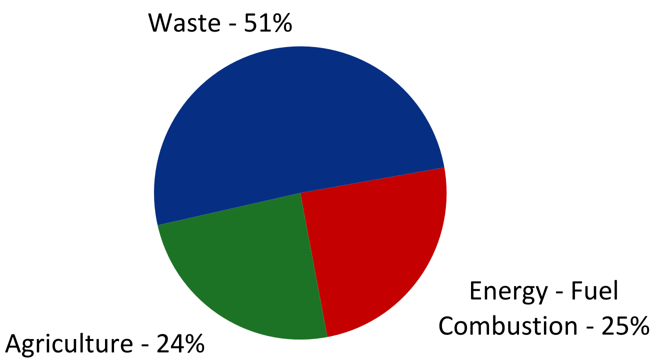

Figure 16.2.6 N_2O emissions, distribution according to the main sectors in 2013.

Methane

The largest sources of anthropogenic CH_4 emissions are agricultural activities contributing with 47 % of total CH_4 emission in 2013; see Figure 16.2.8. Waste handling contributes to 44 % of total emission and the energy sector to 9.0 % of total CH_4 emission in 2013. The emission from agriculture derives from enteric fermentation (98 %) and management of animal manure (2 %).

Since 1990 the overall number of sheep has increased, while the overall number of reindeer has decreased. From 1990 to 2013 the emission of CH_4 from agricultural activities has decreased by 10.3 %.

The emission of CH_4 from waste derives from solid waste disposal (71 %) and incineration and open burning (29 %). From 1990 to 2013 the emission of CH_4 from solid waste disposal has increased by 6.3 %, while emissions from waste incineration have decreased by 29.6 %. Overall emission of CH_4 from waste handling has decreased by 7.5 % from 1990 to 2013.

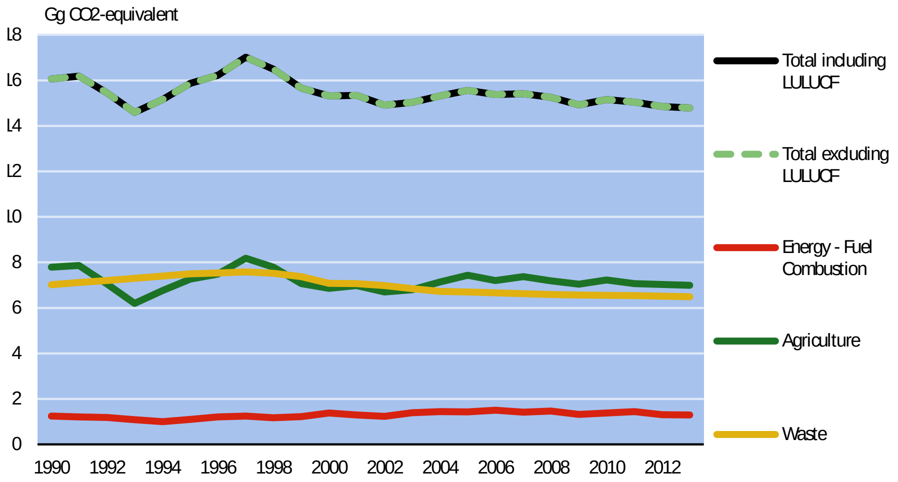

Figure 16.2.7 CH_4 emissions, time-series for 1990-2013.

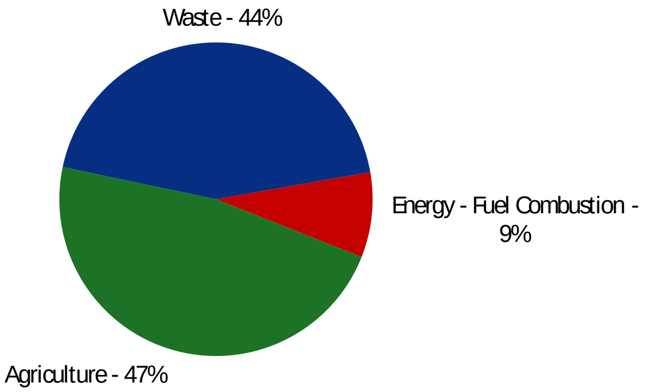

Figure 16.2.8 CH_4 emissions, distribution according to the main sectors in 2013.

HFCs, PFCs and SF_6

This part of the Greenlandic inventory only comprises a full data set for HFCs and SF_6 from 1995. Greenland has no consumption that leads to emission of PFCs. From 1995 to 2013 there has been a continuous and substantial increase in the contribution from F-gases calculated as the sum of emissions in CO_2 equivalents, see Figure 16.2.9. This increase is caused by an increase in the emission of HFCs. For the time series 2004-2013 the increase is lower than for the years 1995 to 2004. The increase from 1995 to 2004 is 10,290 %. From 2004 to 2013 total emission increased by 30.7 %. SF_6 contributed to the F-gas sum in 1995 with 55.9 %. Environmental awareness and regulation of this gas under Danish law has reduced its use considerably since 1995. In 2013 the contribution from SF_6 to the emission of F-gases was only 0.03 %.

The use of HFCs has increased to a great extent. Today HFCs are by far the dominant F-gas, comprising 44.1 % in 1995, but 99.97 % in 2013. HFCs are mainly used as a refrigerant.

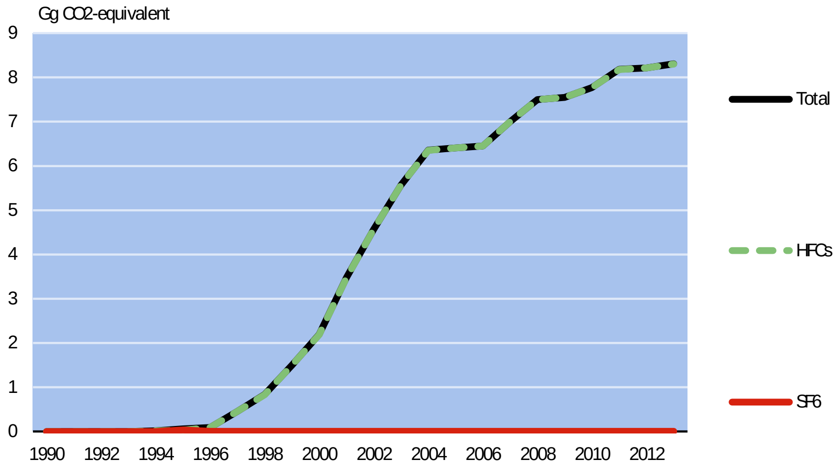

Figure 16.2.9 F-gas emissions, time-series for 1990-2013.

16.2.3 Description and interpretation of emission trends by category

Energy

The emission of CO_2 from energy has decreased by 10.1 % from 1990 to 2013. Emissions decreased from 1990 until 1994 due to the implementation of the first hydro power plant. However, since 1994 combustion of fuel increased continuously causing emissions to increase as well. The reason for this increase was primarily higher demand for transportation and heating. Combustion of fuel may decrease in certain years due to milder temperatures. In 2010 and 2011 emissions increased significantly due to a significant increase in fuel conbustion due to the initation of oil exploration, which caused CO_2 emission from energy to rise by 14.6 % in 2010 and by 6.9 % in 2011. However, in 2012 and 2013 oil exploration activities came to a standstill, while Greenlands fifth hydro power plant went into operation. This caused CO_2 emissions from energy to decrease by 20 % in 2012 and 3 % I 2013.

Emission of CH_4 has increased by 4.6 % from 1990 to 2013 primarily due to an increase in the use of fuel for transportation as well as in the energy recovery from waste. The CH_4 emission from the transport sector has increased by 84.0 % from 1990 to 2013, mainly due to increasing domestic aviation.

Emission of N_2O has increased by 6.8 % from 1990 to 2013.

Industrial processes and product use

Emissions from industrial processes and product use (consumption of halocarbons and SF_6) other than fuel combustion amount to 1.5 % of the total emission in CO_2 equivalents excluding LULUCF in 2013. The main source is consumptions of HFCs. Emission of F-gases have increased considerable since 1990.

Agriculture

The agricultural sector contributes with 1.6 % of the total GHG emissions excluding LULUCF in 2013, 47.3 % of the total CH_4 emission and 24.4 % of the total N_2O emission. The total emission from the sector has decreased by 1.1 % from 1990 to 2013. This decrease is due to a fall in the number of reindeer from 6,000 heads in 1990 til 3,000 heads in 2013. In later years the number of sheep has decreased to a level that is almost the same as in 1990 with 19,929 heads in 1990 to 19,994 heads in 2013. The use of inorganic fertilizers has increased since 1990. The CH_4 emission has decreased by 10.3 % from 1990 to 2013 primarily due to the fall in the number of reindeers. In the same period N_2O emission has increased by 39.8 % due to a significantly increase in the use of fertilizers.

LULUCF

Emissions from the LULUCF sector amount to just 0.2 % of the total emission in CO_2 equivalents in 2013. Forests are assumed to be a sink for the whole period increasing from approximately zero in 1990 to 45.0 tonnes CO_2 in 2013. The emission from cropland is estimated to zero in 1990 as there were no cropland in Greenland in 1990 and a net source in 2013 of 48.1 tonnes CO_2. The emission from grassland has been estimated to 206 tonnes CO_2 in 1990 increasing to 1,117 tonnes CO_2 in 2013.

Waste

The waste sector contributes with 2.5 % of the total greenhouse gas emissions in 2013, 44.1 % of the total CH_4 emission and 50.8 % of the total N_2O emission. The total emission from the sector has decreased by 15.6 % from 1990 to 2013. This decrease is caused by a drop in the CH_4 emission from incineration and open burning by 29.6 % and a decrease in N_2O emission from waste water handling by 24.6 %.

Total GHG emission from waste incineration without energy recovery has decreased by 6.5 % from 1990 to 2013 due to an increasing amount of waste incineration with energy recovery and a continuously decrease in waste water from industrial fishing plants in 2013. Emission from incinerated waste used for heat production is included in the 1A1 IPCC category Energy Industries.

16.2.4 Description and interpretation of emission trends for indirect greenhouse gases and SO_2

NO_X

The largest sources to emission of NOx are AFF (Agriculture, Forestry and Fisheries) followed by Transport and combustion in Energy Industries (public power and district heating plants). The AFF-sector is the most contributing sector to the emission of NO_X. In 2013, 53.4 % of the Greenlandic emission of NO_X came from AFF-related activities. The emission of NO_X from AFF varies from year to year. The emissions from transport obtain 28.8 % of total emissions in 2013.

From 1990 to 2013 emission of NO_X from AFF has increased by 30.9 %, while emissions from transport have increased by 23.6 %. In the same period total emission of NO_X has increased by 11.7 %.

The emissions from energy industries obtain 6.3 % of total emission in 2013. The emission from energy industries have decreased by 47.1 % from 1990 to 2013. The decrease is due to a continuous substitution of fossil fuels with hydro power.

Emission of NO_X from waste handling obtains 1 % of total emission, see Figure 16.2.10.

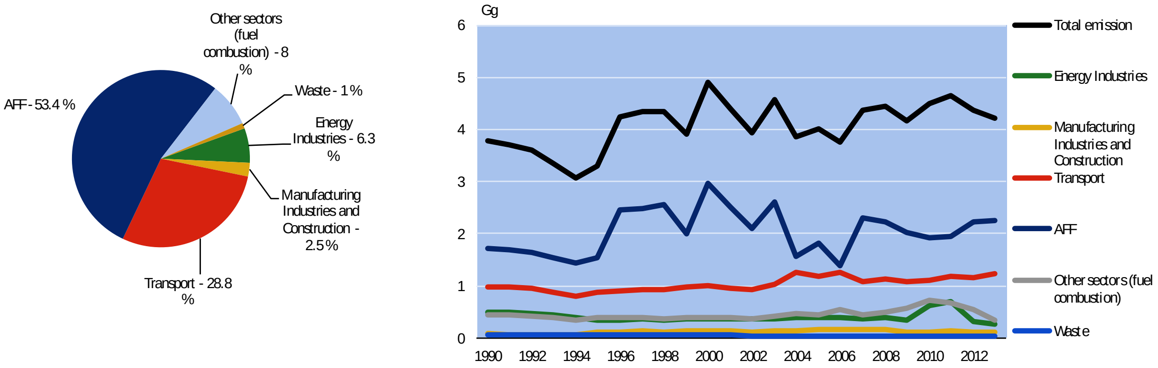

Figure 16.2.10 NO_X emissions. Distribution according to the main sectors (2013) and time series (1990-2013).

CO

Mobile sources like transport and AFF (agriculture, forestry and fisheries) contribute significantly to the total emission of this pollutant. Transport is the largest contributor to the total CO emission, see Figure 16.2.11.

Total CO emission has increased by 33.1 % from 1990 to 2013, largely due to increasing emissions from road transportation and civil aviation. Emissions from energy industries have been cut to half from 1990 to 2013, while emissions from transport have more than doubled since 1990.

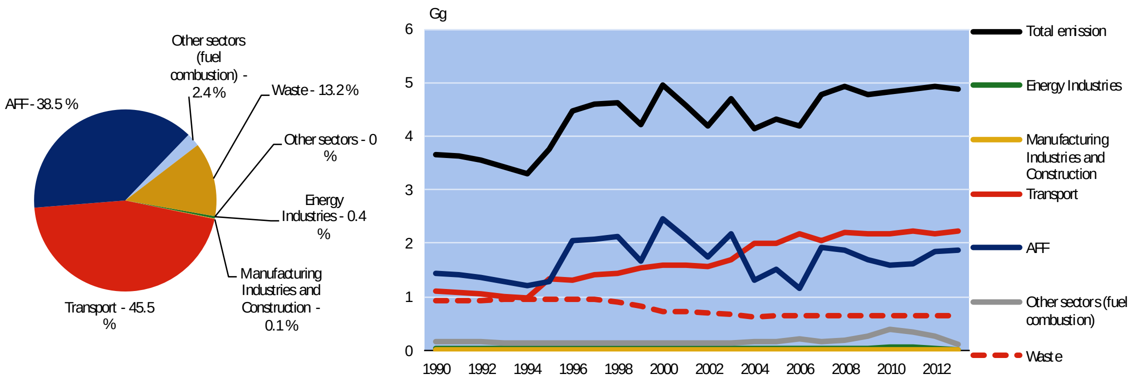

Figure 16.2.11 CO emissions. Distribution according to the main sectors (2013), and time series (1990-2013).

NMVOC

The emissions of NMVOC originate from many different sources and can be divided into two main groups: incomplete combustion and evaporation. Road vehicles and other mobile sources such as national navigation vessels fishing vessels and off-road machinery are the main sources of NMVOC emissions from incomplete combustion processes. Road transportation and fishing vessels are the main contributors to this pollutant. Road transportation is included under transportation, which obtain 45.2 % of the total NMVOC emission in 2013. Fishing vessels are included under AFF (agriculture, forestry and fisheries), which obtain 38.3 % of total NMVOC emission in 2013, see Figure 16.2.12.

The evaporative emissions mainly originate from the use of solvents and the extraction, handling and storage of oil. Emissions from solvent and other product use included under Industrial Processes and Product Use have decreased by 4.2 % from 1990 to 2013.

The total anthropogenic emissions have increased by 38.6 % from 1990 to 2013, largely due to the increase in road transportation and AFF activities.

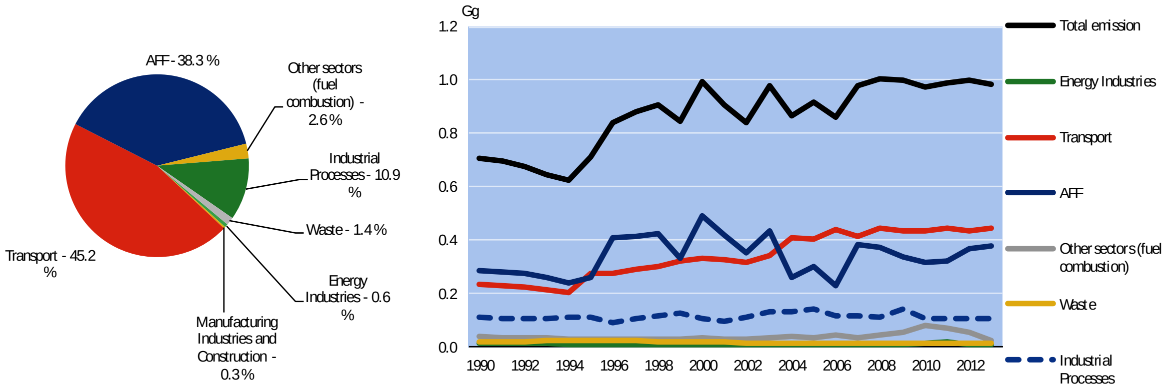

Figure 16.2.12 NMVOC emissions. Distribution according to the main sectors (2013), and time series (1990-2013).

SO_2

The main part of the SO_2 emission originates from the combustion of fossil fuels mainly gasoil in public power and district heating plants. From 1990 to 2013, total emission of SO_2 decreased by 8 %.

Emissions from AFF (Agriculture, Forestry and Fisheries) obtain 23.5 % of total SO_2 emission in 2013 followed by Energy Industries obtaining 19.5 % in 2013. Also emissions from other industrial combustion plants, non-industrial combustion plants and mobile sources are important. Transport contributed with 16.5 % of total SO_2 emission in 2013.

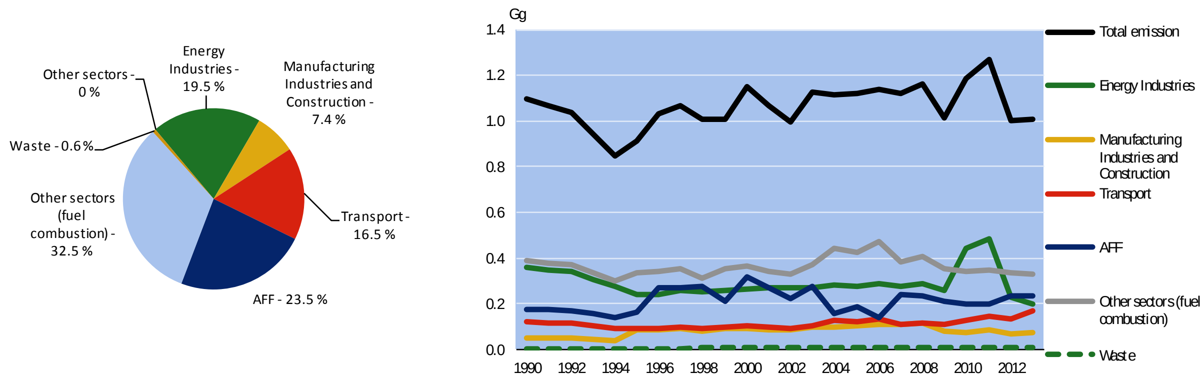

Figure 16.2.13 SO_2 emissions. Distribution according to the main sectors (2013), and time series (1990-2013).

16.3 Energy (CRF sector 1)

16.3.1 Overview of sector

The emission of greenhouse gases from energy activities includes CO_2, CH_4 and N_2O emission from fuel combustion. In 2010 fugitive emission of CO_2, CH_4 and N_2O occurred for the first time due to the initiation of well drilling and testing for oil and gas. However, since it has been impossible to obtain any information on the amount of oil and gas picked up during drillings in 2010 and 2011, fugitive emissions has been labelled with the notation key NA.

Emissions from the energy sector are reported in CRF Tables 1.A(a), 1.A(b), 1.A(c), 1.A(d) and 1.B. Furthermore, the emission of non-methane volatile organic compounds (NMVOC), NO_X, CO and SO_2 from fuel combustion is given in CRF Table 1.

Summary tables for the energy sector are shown in Table 16.3.1.

Table 16.3.1 CO_2 Emission from the Energy Sector.

Greenhouse gas source and sink categories	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
					Gg					
1. Energy	620.8	606.1	591.9	542.0	492.0	530.4	592.9	613.5	592.3	590.3
A. Fuel Combustion (Sectoral Approach)	620.8	606.1	591.9	542.0	492.0	530.4	592.9	613.5	592.3	590.3
1 . Energy Industries	182.2	177.0	172.8	156.4	139.9	120.8	121.6	128.6	126.5	128.6
2 . Manufacturing Industries and Construction	26.2	25.5	24.8	22.4	20.0	43.6	44.3	45.9	39.8	45.7
3 . Transport	96.1	95.6	93.6	87.2	80.8	88.8	92.7	96.7	101.2	104.5
4 . Other Sectors	308.1	300.1	292.9	269.0	245.0	270.6	327.6	335.6	318.2	304.8
5 . Other	8.2	8.0	7.8	7.0	6.3	6.6	6.6	6.6	6.6	6.6
B . Fugitive Emissions from Fuels	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
C . CO_2 Transport and Storage	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
continued	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
1. Energy	663.6	614.1	575.8	645.8	633.9	638.0	656.2	647.2	671.7	587.1
A. Fuel Combustion (Sectoral Approach)	663.6	614.1	575.8	645.8	633.9	638.0	656.2	647.2	671.7	587.1
1 . Energy Industries	132.1	133.2	133.9	134.4	137.8	136.5	141.7	134.5	143.3	125.5
2 . Manufacturing Industries and Construction	48.0	45.5	43.1	49.7	50.5	54.8	55.4	57.2	59.1	43.0
3 . Transport	105.9	96.1	92.4	101.4	113.3	111.7	120.9	110.2	116.9	105.7
4 . Other Sectors	370.9	332.6	299.8	353.7	324.8	327.7	328.6	337.7	342.4	297.0
5 . Other	6.6	6.6	6.6	6.6	7.4	7.3	9.6	7.6	10.0	15.9
B . Fugitive Emissions from Fuels	NO	NO	NO	NO	NO	NO	NO	NO	NO	0.02
C . CO_2 Transport and Storage	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
continued	2010	2011	2012	2013						
1. Energy	672.8	719.1	575.0	557.8						
A. Fuel Combustion (Sectoral Approach)	672.8	719.1	575.0	557.8						
1 . Energy Industries	225.5	250.6	110.7	94.4						
2 . Manufacturing Industries and Construction	38.6	47.1	36.5	39.3						
3 . Transport	108.3	115.4	110.7	110.1						
4 . Other Sectors	276.2	284.8	301.4	309.0						
5 . Other	24.3	21.2	15.6	4.9						
B . Fugitive Emissions from Fuels	NO	NA	NA	NO						
C . CO_2 Transport and Storage	NO	NO	NO	NO						

Table 16.3.2 CH_4 Emission from the Energy Sector.

Greenhouse gas source and sink categories	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
					Gg					
1. Energy	0.05	0.05	0.05	0.04	0.04	0.04	0.05	0.05	0.05	0.05
A. Fuel Combustion (Sectoral Approach)	0.05	0.05	0.05	0.04	0.04	0.04	0.05	0.05	0.05	0.05
1 . Energy Industries	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
2 . Manufacturing Industries and Construction	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3 . Transport	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.01	0.01	0.01
4 . Other Sectors	0.04	0.03	0.03	0.03	0.03	0.03	0.03	0.04	0.03	0.03
5 . Other	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
B . Fugitive Emissions from Fuels	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO

continued	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
1. Energy	0.06	0.05	0.05	0.06	0.06	0.06	0.06	0.06	0.06	0.05
A. Fuel Combustion (Sectoral Approach)	0.06	0.05	0.05	0.06	0.06	0.06	0.06	0.06	0.06	0.05
1 . Energy Industries	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
2 . Manufacturing Industries and Construction	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3 . Transport	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
4 . Other Sectors	0.04	0.04	0.03	0.04	0.04	0.04	0.04	0.04	0.04	0.03
5 . Other	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
B . Fugitive Emissions from Fuels	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO

continued	2010	2011	2012	2013
1. Energy	0.06	0.06	0.05	0.05
A. Fuel Combustion (Sectoral Approach)	0.06	0.06	0.05	0.05
1 . Energy Industries	0.01	0.02	0.01	0.01
2 . Manufacturing Industries and Construction	0.00	0.00	0.00	0.00
3 . Transport	0.01	0.01	0.01	0.01
4 . Other Sectors	0.03	0.03	0.03	0.03
5 . Other	0.00	0.00	0.00	0.00
B . Fugitive Emissions from Fuels	NA	NA	NO	NO

Table 16.3.3 N_2O Emission from the Energy Sector.

Greenhouse gas source and sink categories	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
					Gg					
1. Energy	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
A. Fuel Combustion (Sectoral Approach)	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
1 . Energy Industries	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2 . Manufacturing Industries and Construction	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3 . Transport	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4 . Other Sectors	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5 . Other	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
B . Fugitive Emissions from Fuels	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
continued	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
1. Energy	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
A. Fuel Combustion (Sectoral Approach)	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
1 . Energy Industries	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2 . Manufacturing Industries and Construction	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3 . Transport	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4 . Other Sectors	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5 . Other	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
B . Fugitive Emissions from Fuels	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
continued	2010	2011	2012	2013						
1. Energy	0.01	0.01	0.01	0.01						
A. Fuel Combustion (Sectoral Approach)	0.01	0.01	0.01	0.01						
1 . Energy Industries	0.00	0.00	0.00	0.00						
2 . Manufacturing Industries and Construction	0.00	0.00	0.00	0.00						
3 . Transport	0.00	0.00	0.00	0.00						
4 . Other Sectors	0.00	0.00	0.00	0.00						
5 . Other	0.00	0.00	0.00	0.00						
B . Fugitive Emissions from Fuels	NO	NA	NA	NO						

16.3.2 Source category description

In this section emission source categories, fuel consumption data and emission data are presented.

Activity data on fuel consumption is based on annual statistics on energy published by Statistics Greenland and information on waste incineration with energy recovery. The annual statistics on energy is divided into sectors according to the Greenlandic Business Register (GB2000). The register comprises 577 business categories. The official statistics on energy is published by aggregation into 34 categories.

In the Greenlandic emission database, all activity rates and emissions are based on the official statistics on energy. However, in order to fit the new CRF format fuel consumption from the official statistics on energy is further aggregated into 19 sectors.

Fuel combustion

In 2013, total fuel combustion was 7,773 TJ of which 7.583 TJ was liquid fossil fuels.

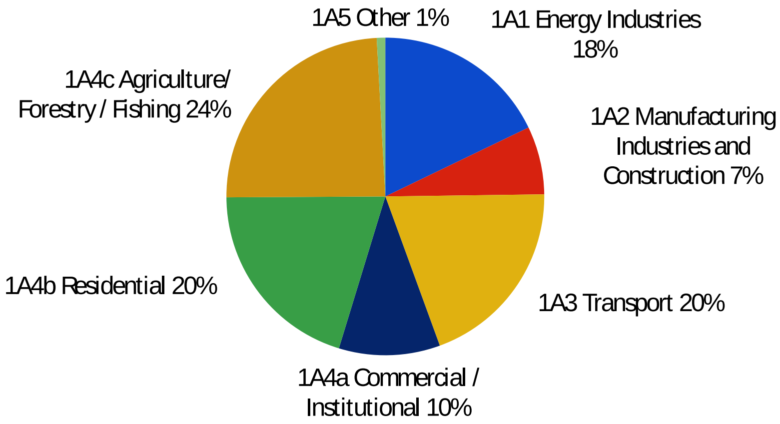

Figure 16.3.1 Fuel combustion rates, fossil fuels 2013 (Statistics Greenland).

In Greenland gasoil, kerosene and gasoline are used in fuel combustion. From 2010 fueloil is also being imported and combusted in ships. Gasoil and kerosene are the most utilised fuels. Gasoil is used in power plants to produce electricity and heat, as well as in district heating, private households, industries and for transportation. In 2010 and 2011 the combustion of gasoil increased significantly due to oil explorations. Due to a standstill in oil explorations total fuel combustion decreased significantly in 2012 and 2013.

Kerosene is primarily used in aviation, but also for heating in smaller settlements.

A time-series on the consumption of Liquid Petrol Gas (LPG) was introduced for the first time in the 2013 inventory submission. However, the consumption of LPG amount to less than 1 % of the total fuel combustion, see Figure 16.3.2. It has been possible to contruct a time-series on LPG consumption running from 2004 and onwards.

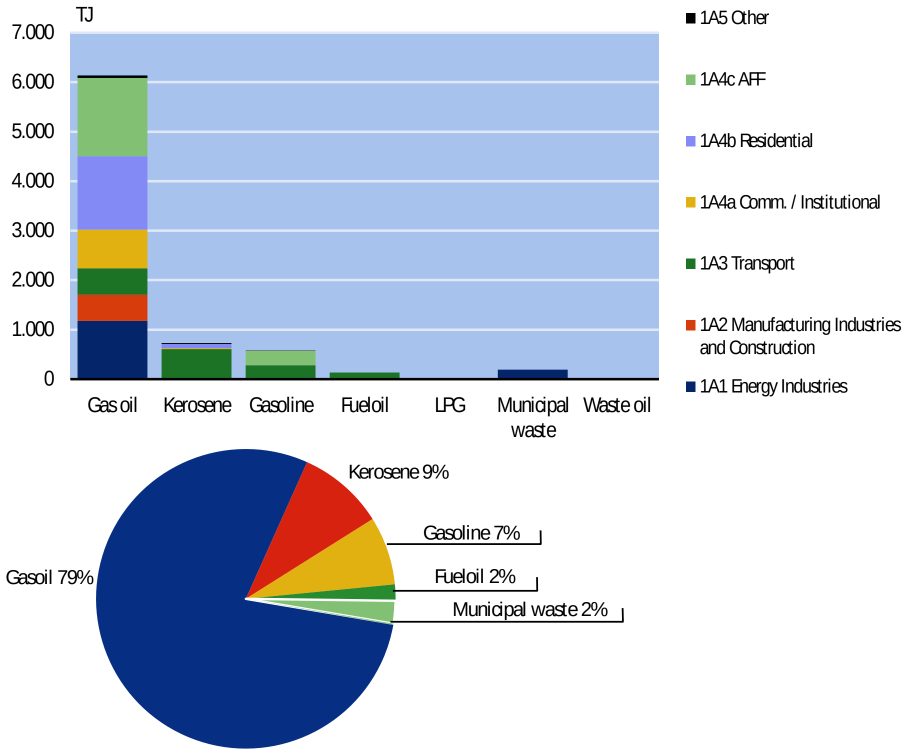

Figure 16.3.2 Fuel combustion, 2013 (Statistics Greenland).

Time-series on fuel consumption are presented in Figure 16.3.3. Total fuel consumption has decreased by 9.2 % from 1990 to 2013. This overall decrease in fuel consumption is caused by a drop in the consumption of liquid fossil by 10.9 %. Consumption of renewable waste-energy has increased continuously with a total increase of more than 300 % from 1990 to 2013.

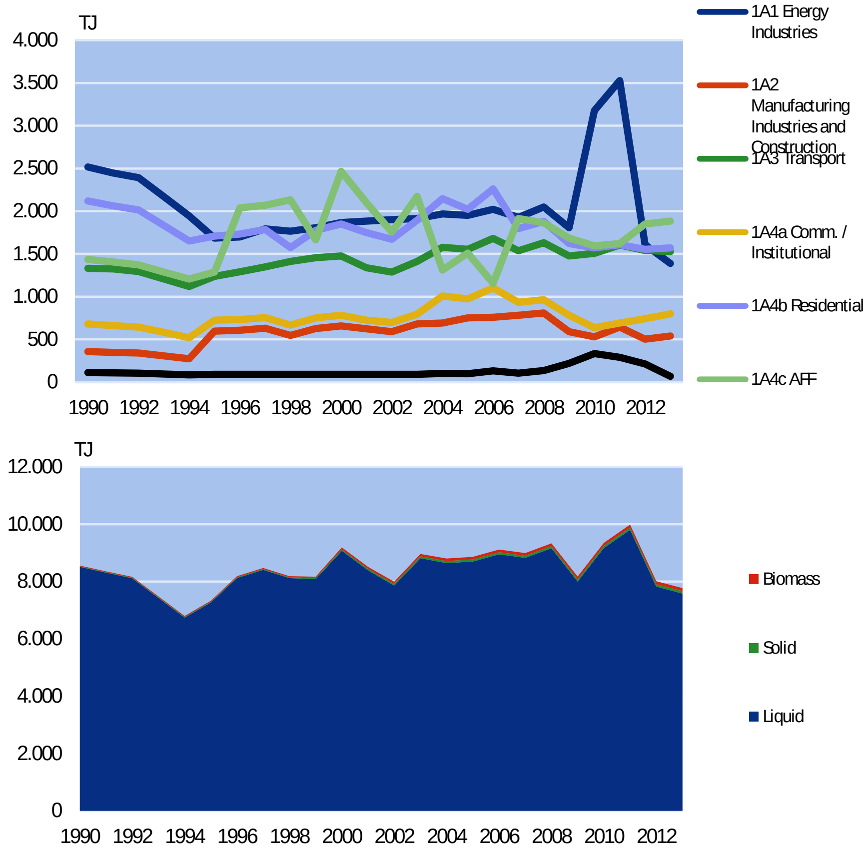

Figure 16.3.3 Fuel consumption time-series 1990-2013 (Statistics Greenland).

Fuel consumption is dominated by liquid fuels e.g. gasoil, kerosene and gasoline. In 2013 total fuel consumption consists of 98 % liquid fuels, 1 % solid fuels and 1 % biomass.

In 2013 Energy Industries accounted for 18 % of total fuel consumption. From 1990 to 1995 fuel consumption in Energy Industries decreased significantly due to the introduction of the first hydro power plant in 1993, and the introduction of burning waste to produce heat for district heating networks in 1989. Dependence on gasoil decreased immediately. Nevertheless, from 1995 an onwards consumption of gasoil once again increased due to the general economic development. In 2007 fuel consumption in Energy Industries decreased due to a relatively warm winter. Contrary to this, the winter in 2008 was relatively colder, which increased fuel consumption to produce heat. In 2009 hydro power productions increased further when a fourth plant was opened. Together with a relatively warm 2009 winter fuel consumption in Energy Industries decreased additionally. In 2010 and 2011 fuel consumption increased significantly due to oil explorations along the westcoast of Greenland. In 2012 and 2013, most recently fuel consumption decreased once again due to a standstill in the oil exploration and the opening of the fifth hydro power plant.

Fuel consumption in Agriculture, Forestry and Fisheries accounted for 24 % of total fuel consumption in 2013 making AFF the largest energy consuming sector. Fuel consumption in this sector has increased since 2010. Before 2004, annual fuel combustion in this sector varied a great deal due to fluctuations in fishing activities from year to year. However, some uncertainty is expected in the 1990-2003 time-series on fuel consumption in Agriculture, Forestry and Fisheries.

Residential fuel consumption accounted for 20 % of total fuel consumption in 2013. Fluctuations in fuel consumption are largely a result of variation in outdoor temperatures from year to year, which also causes fluctuations in fuel consumption in Energy Industries.

For 2004-2013 Statistics Greenland has conducted statistics on energy including detailed information on fuel consumption divided into 33 business categories and private households; see Section 16.3.3. Compared to the new statistics on energy the historic construction of time-series on fuel consumption in 1990-2003 was based on a much simpler method. Some uncertainty is therefore to be expected in the 1990-2003 time-series on sector-divided fuel consumption.

Fugitive Emissions from Fuels

Greenland has no coal mines, no off-shore activities, no oil refineries, no natural gas transmission or distribution. For that reason there have been no fugitive emissions from such activities in 1990-2009. However in 2010 a scotish company initiated a search for oil along the westcoast of Greenland. Three wells were drilled and tested in 2010. Five wells in 2011. There were no oil exploration activities in 2012 and 2013.

In the 2014 National Inventory Report calculation of fugitive emission was based on the annual number of drilled and tested wells and IPCC Guideline emission factors.

In this 2015 National Inventory report fugitive emission is to be based on the amount of drilled oil and gas and IPCC Guideline emission factors.

However, the scotish company has not been able to provide the Greenland Government with any information on the amount of oil and gas picked up during drillings in 2010 and 2011. To our knowledge the scotish company only discovered a few minor kicks with some minor inflow of water or gas during drillings.

With no data available, activity data in 2010 and 2011 has been marked with the notation key Not Applicable (NA). Since no amounts could be estimated, all fugitive emissions are assumed to be zeo, and also marked with the notation key Not Applicable (NA). This decision has been made in agreement with the DCE.

Besides from energy production, some fugitive emission occurs in the distribution of fuel e.g. when refuelling from ships to on-shore tanks, onshore loading of fuel to ships and offshore loading of ships. The emission would only be in the form of NMVOC. The fugitive emission from loading/unloading of ships is currently not estimated.

International bunker fuels

International Aviation Bunkers

Emissions from international aviation bunkers are considered to be of neglible importance. The Greenland Airport Authority has reported the annual amount of jet fuel loaded into foreign aircrafts including Danish aircrafts. However, it is not possible to distinguish between Danish aircrafts and other aircrafts. Since most foreign aircrafts by far are Danish the annual amount of jet fuel loaded into foreign aircrafts are therefore included as part of the IPCC category 1A3a Domestic aviation.

International Navigation Bunkers

Emission from international marine bunkers is included from 2004 and onwards. Before 2004 international marine bunkers are considered to be of neglible importance.

Feedstocks, reductants and other non-energy use of fuels

At the moment Greenland has no production or use of feedstocks. Emissions from non-energy use of fuels (e.g. bitumen and solvents) are included in the sector Industrial Processes and Product Use (CRF sector 2).

16.3.3 Methodological issues

Activity data

The Greenlandic emission inventory for fuel combustion has been performed according to the IPCC tier 1 methodology. The inventory is based on activity data from the Greenlandic energy statistics and on emission factors for different fuels, plants and sectors.

Total fuel combustion is based on data from Polaroil, Statoil and Malik Supply A/S. Polaroil imports and distributes fuel in all parts of Greenland. Statoil imports and distributes fuel in Kangerlussuaq. Malik Supply A/S, a Danish company, re-distributes fuel bought from Polaroil to Greenlandic trawlers, ships etc. By using detailed data from Polaroil, Statoil and Malik Supply A/S it is possible to determine total import, total export, total international bunkers and total domestic fuel combustion.

Total domestic fuel combustion is then divided into sectors and private households by using data from a survey on energy consumption, company specific sales data from Polaroil and local fuel distributors, company tax accountings, municipal accountings and Greenland Government accountings, and by estimation.

Since 2008 Statistics Greenland has conducted an annual survey among larger companies. By completing a questionnaire each company returns detailed information on annual consumption of specific types of fuel. The survey covered 52.2 % of total GHG emission from energy combustion in 2013, see Table 16.3.4. The decreased coverage by the survey is due to a drop in fuel combustion in companies that are covered by the survey primarily companies in Energy Industries.

By using detailed information on sales from Polaroil and local fuel distributors it is possible to determine fuel combustion in private companies and public offices with an automatic deal on supply. The sales data covered 11.5 % of total GHG emission from energy combustion in 2013, see Table 16.3.4.

Tax accountings in DKK are used to determine annual consumption of fuel in private companies, in municipalities, and within the Greenland Government. At the moment tax accountings are primarily used for determining fuel combustion in municipalities and public offices in settlements. Accountings cover 15.4 % of total GHG emission from energy combustion in 2013, see Table 16.3.4.

The remaining amount of total inland fuel combustion – approximately 21 % - is divided into sectors and private households by estimation. This work is carried out by involving statistical material on population, housing, public finances, fisheries and hunting, and national accountings. The Greenlandic Business Register (GER) is used to divide remaining companies into sectors. Information on employees, operating units, vehicles etc. is used to determine the activity in each company.

Fuel combustion in private households is estimated using detailed information from a number of local fuel distributors. Fuel deliveries are registered by buildings. In Greenland each building has a unique number registered in the Greenlandic Area Register (NIN). By combining the NIN-register and the GER-register (see above) with statistics on housing and population each building is labelled *private household* or located to a sector describing the main activity in the building. This new building-sector register, completed annually, is used extensively to determine the buyer of fuel delivered by Polaroil or local fuel distributors.

Fuel combustion in road traffic is based on a model designed by Statistics Greenland. The model contains data on the vehicle stock obtained from the Greenland Police Department's register on engine data. The vehicles are divided into broad categories of type i.e. personal car, lorry, taxi, truck, ambulance, motorbike etc. Each category is assigned with ratios on fuel type and mileage. Input data on mileage is derived from an annual survey among businesses and private road traffic in 2008-2014. Each vehicle is divided in business categories or labelled *private vehicle* according to the owner. For each group the emissions are estimated by combining vehicle and annual mileage numbers with standard emission factors according to the type of fuel. The model does not take cold start or hot engines into account.

For air traffic annual emissions are based on activity data from Air Greenland A/S and sales data from the Greenland Airport Authority. For navigation, ferries and freight, annual emissions are based on activity data from Royal Arctic Line A/S (freight), Royal Arctic Tankers A/S (freight), Royal Arctic Bygdeservice A/S (freight/passengers), and Arctic Umiaq Line A/S (passengers) and the liquidated Assartuivik A/S (passengers).

Table 16.3.4 shows the part of total CO_2 emission divided into sources - survey, specific sales data, tax accountings, and estimation.

Table 16.3.4 Allocation of CO_2 emission from fuel combustion into sources to sectoral division (2004-2013).

	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
					pct.					
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Survey	48.8	48.4	47.9	49.6	50.3	52.8	63.0	61.3	53.2	52.2
Sales data from Polaroil	2.7	3.4	3.7	3.6	3.4	3.0	4.2	5.0	5.7	6.3
Sales data from local fuel distributors	0.0	0.0	3.2	5.1	6.6	6.5	5.0	5.6	6.1	5.2
Accountings	12.7	12.1	12.9	12.8	12.2	12.7	10.8	11.0	13.1	15.4
Estimation	35.8	36.1	32.3	29.0	27.5	25.0	17.0	17.0	21.8	21.0

The procedure described above is used to divide total fuel combustion into sectors and private households during the period 2004-2013. Formerly, the period 1990-2003, activity data on sectors and private households were estimated using aggregated statistics on population, housing, companies, data on sales from Polaroil, and data on energy consumption in larger companies.

An increasing part of municipal waste incineration is utilised for heat and power production. Thus, incineration with energy-recovery is included in the Energy sector. Table 16.3.5 shows the activity data on fuel combustion for the period 1990-2013.

Table 16.3.5 Activity data on fuel combustion (SINK categories).

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
					TJ					
Total	8 559	8 358	8 166	7 484	6 801	7 331	8 190	8 475	8 189	8 172
Energy industries	2 519	2 447	2 393	2 169	1 944	1 685	1 698	1 794	1 766	1 805
Manufacturing industries and construction	360	349	340	307	274	598	607	630	546	626
Domestic aviation	541	556	547	524	500	581	636	660	775	748
Road transport	501	488	476	437	397	370	369	387	361	401
Domestic navigation	288	280	273	248	224	285	285	299	275	308
Commercial/Institutional	682	662	645	583	520	724	733	757	667	753
Residential	2 120	2 062	2 014	1 832	1 651	1 710	1 731	1 787	1 576	1 777
AFF	1 436	1 405	1 372	1 288	1 205	1 287	2 039	2 070	2 134	1 663
Other	113	110	107	97	86	91	91	91	91	91
continued	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Total	9 192	8 514	7 995	8 964	8 805	8 863	9 118	8 996	9 335	8 176
Energy industries	1 868	1 885	1 900	1 915	1 963	1 947	2 019	1 920	2 037	1 788
Manufacturing industries and construction	658	624	590	680	697	755	764	790	822	607
Domestic aviation	738	632	603	646	608	633	691	701	753	635
Road transport	417	399	388	433	506	503	573	503	533	492
Domestic navigation	321	308	297	334	462	419	420	333	346	349
Commercial/Institutional	783	725	699	796	1 009	974	1 102	935	964	781
Residential	1 851	1 748	1 670	1 895	2 146	2 023	2 261	1 796	1 880	1 621
AFF	2 465	2 101	1 755	2 174	1 312	1 510	1 157	1 913	1 863	1 684
Other	91	91	91	91	102	100	132	105	137	218
continued	2010	2011	2012	2013						
Total	9 351	9 988	8 014	7 773						
Energy industries	1 544	1 515	1 578	1 343						
Manufacturing and construction	2 163	2 657	532	583						
Domestic aviation	654	723	660	593						
Road transport	477	477	469	462						
National navigation	377	404	413	471						
Commercial/Institutional	638	690	742	800						
Residential	1 570	1 608	1 554	1 570						
AFF	1 594	1 621	1 851	1 883						
Other	333	291	215	67						

Emission factors

For each fuel and source category a set of general area source emission factors has been determined. The emission factors are either nationally referenced or based on the IPCC Reference Manual (IPCC, 2006).

CO_2

The CO_2 emission factors applied are presented in Table 16.3.6. For municipal waste and all other fuels the same emission factor is applied for 1990-2013.

In 2013 a technical analysis was conducted on the arctic gasoil that is by far the most dominant type of fuel in Greenland. The analysis was conducted by the Danish Technological Institute in order to gain a country specific emission factor on the Greenlandic gasoil, see Table 16.3.6 and Section 16.3.7 for further details.

In reporting to the Climate Convention, the CO_2 emission is aggregated to three fuel types: Liquid fuel, Biomass and Other fuel.

The CO_2 emission from incineration of municipal waste with energy-recovery (75.1 + 37.0 kg pr GJ) is divided into two parts: the emission from combustion of the plastic content of waste (which is included in the Greenlandic total) and the emission from combustion of the rest of the waste – the biomass part (which is reported as a memo item). In the IPCC reporting, the fossil part of the waste and the associated emissions from fuel combustion of the plastic content of the waste is reported in the fuel category, *Other fuels*. The emission factors on municipal waste were revised in the 2012 inventory submission. Greenland uses the Danish emission factors on municipal waste, which have been revised recently due to new information.

Table 16.3.6 CO_2 emission factors 1990-2013.

Fuel	Emission factor	Unit	Reference type	IPCC fuel category
Gasoil	72.967	kg pr GJ	Country specific	Liquid
Kerosene	71.867	kg pr GJ	IPCC reference manual	Liquid
Jet-Kerosene	71.500	kg pr GJ	IPCC reference manual	Liquid
Gasoline	69.300	kg pr GJ	IPCC reference manual	Liquid
Fueloil	77.367	kg pr GJ	IPCC reference manual	Liquid
LPG	63.100	kg pr GJ	IPCC reference manual	Liquid
Wasteoil	77.367	kg pr GJ	IPCC reference manual	Liquid
Municipal waste – biomass	75.100	kg pr GJ	Country specific	Biomass
Municipal waste – fossil fuel	37.000	kg pr GJ	Country specific	Other fuels

The CO_2 emission factor for gasoil, kerosene, jet-kerosene, gasoline, fueloil and wasteoil has been revised in this 2015 National Inventory Report due to a revision of the oxidation factor from the previously 0.99 to 1.

The CO_2 emission has been calculated by using the same methodology as described in the IPCC Guidelines (IPCC, 2006). This methodology implies use of C content per fuel type (default) and fraction of carbon oxidised (default); see the equation below.

$$E_{CO_2} = \sum Act_a \times EF_{C,a} \times Ox \times 44/12$$

where:

Act_a = activity; consumption of fuel a

$EF_{C,a}$ = C emission factor for fuel a

Ox = oxidation factor (by default equal to 1)

The emissions of CH_4, N_2O, NO_X, CO and NMVOC have been calculated at sector/fuel level by using IPCC default emission factors combined with measured/Danish EF waste incineration (with energy recovery), se Table 16.3.7 – Table 16.3.9 below.

The equation applied for each pollutant is:

$$E = \sum (EF_{ab} \times Act_{ab})$$

where:

EF = emission factor

Act = activity; fuel input

a = fuel type

b = sector activity

CH_4

The CH_4 emission factors applied for 1990-2013 are presented in Table 16.3.7. Emission factors for municipal waste refer to emission measurements carried out in Danish plants (Nielsen et al., 2010). Other emission factors refer to the IPCC Guidelines (IPCC, 2006).

Table 16.3.7 CH_4 emission factors 1990-2013.

Fuel group	Fuel	CRF sector		Emission factor, g pr GJ	Reference
Liquid	Gasoil	1A1	Energy Industries	3	IPCC, 2006
		1A2	Manufacturing Industries and Construction	2	IPCC, 2006
		1A3a	Transport – Domestic aviation	0.5	IPCC, 2006
		1A3b	Transport – Road transportation	3.9	IPCC, 2006
		1A3d	Transport – Domestic navigation	5	IPCC, 2006
		1A4a	Other sectors – Commercial / Institutional	10	IPCC, 2006
		1A4b	Other sectors – Residential	10	IPCC, 2006
		1A4c	Other sectors – AFF stationary	10	IPCC, 2006
		1A4c	Other sectors – AFF mobile	5	IPCC, 2006
		1A5b	Other – Military mobile	5	IPCC, 2006
	Kerosene	1A1	Energy Industries	3	IPCC, 2006
		1A2	Manufacturing Industries and Construction	2	IPCC, 2006
		1A3a	Transport – Domestic aviation	0.5	IPCC, 2006
		1A3b	Transport – Road transportation	20	IPCC, 2006
		1A3d	Transport – Domestic navigation	5	IPCC, 2006
		1A4a	Other sectors – Commercial / Institutional	10	IPCC, 2006
		1A4b	Other sectors – Residential	10	IPCC, 2006
		1A4c	Other sectors – AFF stationary	10	IPCC, 2006
		1A4c	Other sectors – AFF mobile	5	IPCC, 2006
		1A5b	Other – Military mobile	5	IPCC, 2006
	Gasoline	1A1	Energy Industries	3	IPCC, 2006
		1A2	Manufacturing Industries and Construction	2	IPCC, 2006
		1A3a	Transport – Domestic aviation	0.5	IPCC, 2006
		1A3b	Transport – Road transportation	25	IPCC, 2006
		1A3d	Transport – Domestic navigation	5	IPCC, 2006
		1A4a	Other sectors – Commercial / Institutional	10	IPCC, 2006
		1A4b	Other sectors – Residential	10	IPCC, 2006
		1A4c	Other sectors – AFF stationary	10	IPCC, 2006
		1A4c	Other sectors – AFF mobile	5	IPCC, 2006
		1A5b	Other – Military mobile	5	IPCC, 2006
	Fueloil	1A1	Energy Industries	3	IPCC, 2006
		1A2	Manufacturing Industries and Construction	2	IPCC, 2006
		1A3a	Transport – Domestic aviation	0.5	IPCC, 2006
		1A3b	Transport – Road transportation	5	IPCC, 2006
		1A3d	Transport – Domestic navigation	5	IPCC, 2006
		1A4a	Other sectors – Commercial / Institutional	10	IPCC, 2006
		1A4b	Other sectors – Residential	10	IPCC, 2006
		1A4c	Other sectors – AFF stationary	10	IPCC, 2006
		1A4c	Other sectors – AFF mobile	5	IPCC, 2006
		1A5b	Other – Military mobile	5	IPCC, 2006
	LPG	1A1	Energy Industries	1	IPCC, 2006
		1A2	Manufacturing Industries and Construction	5	IPCC, 2006
		1A3a	Transport – Domestic aviation	-	IPCC, 2006
		1A3b	Transport – Road transportation	50	IPCC, 2006
		1A3d	Transport – Domestic navigation	-	IPCC, 2006
		1A4a	Other sectors – Commercial / Institutional	5	IPCC, 2006
		1A4b	Other sectors – Residential	5	IPCC, 2006
		1A4c	Other sectors – AFF stationary	5	IPCC, 2006
		1A4c	Other sectors – AFF mobile	5	IPCC, 2006
		1A5b	Other – Military mobile	-	IPCC, 2006
	Wasteoil	1A1	Energy Industries	3	IPCC, 2006
Biomass	Municipal waste	1A1	Energy Industries	30	Nielsen et al., 2010
Other fuel	Municipal waste	1A1	Energy Industries	30	Nielsen et al., 2010

N_2O

The N_2O emission factors applied for 1990-2013 are presented in Table 16.3.8. Emission factors for municipal waste refer to emission measurements carried out in Danish plants (Nielsen et al., 2010). Other emission factors refer to the IPCC Guidelines (IPCC, 2006).

Table 16.3.8 N_2O emission factors 1990-2013.

Fuel group	Fuel	CRF sector		Emission factor g pr GJ	Reference
Liquid	Gasoil	1A1	Energy Industries	0.6	IPCC, 2006
		1A2	Manufacturing Industries and Construction	0.6	IPCC, 2006
		1A3a	Transport – Domestic aviation	2	IPCC, 2006
		1A3b	Transport – Road transportation	3.9	IPCC, 2006
		1A3d	Transport – Domestic navigation	0.6	IPCC, 2006
		1A4	Other sectors	0.6	IPCC, 2006
		1A5b	Other – Military mobile	0.6	IPCC, 2006
	Kerosene	1A1	Energy Industries	0.6	IPCC, 2006
		1A2	Manufacturing Industries and Construction	0.6	IPCC, 2006
		1A3a	Transport – Domestic aviation	2	IPCC, 2006
		1A3b	Transport – Road transportation	0.6	IPCC, 2006
		1A3d	Transport – Domestic navigation	0.6	IPCC, 2006
		1A4	Other sectors	0.6	IPCC, 2006
		1A5b	Other – Military mobile	0.6	IPCC, 2006
	Gasoline	1A1	Energy Industries	0.6	IPCC, 2006
		1A2	Manufacturing Industries and Construction	0.6	IPCC, 2006
		1A3a	Transport – Domestic aviation	2	IPCC, 2006
		1A3b	Transport – Road transportation	8	IPCC, 2006
		1A3d	Transport – Domestic navigation	0.6	IPCC, 2006
		1A4	Other sectors	0.6	IPCC, 2006
		1A5b	Other – Military mobile	0.6	IPCC, 2006
	Fueloil	1A1	Energy Industries	0.6	IPCC, 2006
		1A2	Manufacturing Industries and Construction	0.6	IPCC, 2006
		1A3a	Transport – Domestic aviation	2	IPCC, 2006
		1A3b	Transport – Road transportation	0.6	IPCC, 2006
		1A3d	Transport – Domestic navigation	0.6	IPCC, 2006
		1A4	Other sectors	0.6	IPCC, 2006
		1A5b	Other – Military mobile	0.6	IPCC, 2006
	LPG	1A1	Energy Industries	0.1	IPCC, 2006
		1A2	Manufacturing Industries and Construction	0.1	IPCC, 2006
		1A3a	Transport – Domestic aviation	-	IPCC, 2006
		1A3b	Transport – Road transportation	0.1	IPCC, 2006
		1A3d	Transport – Domestic navigation	-	IPCC, 2006
		1A4	Other sectors	0.1	IPCC, 2006
		1A5b	Other – Military mobile	0.1	IPCC, 2006
	Wasteoil	1A1	Energy Industries	0.6	IPCC, 2006
Biomass	Municipal waste	1A1	Energy Industries	4	Nielsen et al., 2010
Other fuel	Municipal waste	1A1	Energy Industries	4	Nielsen et al., 2010

SO_2, NO_X, NMVOC and CO

Emission factors for SO_2, NO_X, NMVOC and CO are listed in Table 16.3.9. The same emission factors have been applied in the period 1990-2013.

Table 16.3.9 SO_2, NO_X, NMVOC and CO emission factors 1990-2013 (g pr GJ).

Fuel group	Fuel	CRF sector		NO_X	CO	NMVOC	SO_2	Ref
Liquid	Gasoil	1A1	Energy Industries	200	15	5	141	1
		1A2	Manufacturing Industries and Construction	200	10	5	141	1
		1A3a	Transport – Domestic aviation	300	100	50	141	1
		1A3b	Transport – Road transportation	800	1 000	200	141	1
		1A3d	Transport – Domestic navigation	1 500	1 000	200	141	1
		1A4a,b	Other sectors	100	20	5	141	1
		1A4c	Other sectors – AFF stationary	100	20	5	141	1
		1A4c	Other sectors – AFF mobile	1 200	1 000	200	141	1
		1A5b	Other – Military mobile	1 500	1 000	200	141	1
	Kerosene	1A1	Energy Industries	200	15	5	23	1
		1A2	Manufacturing Industries and Construction	200	10	5	23	1
		1A3a	Transport – Domestic aviation	300	100	50	23	1
		1A3b	Transport – Road transportation	600	8 000	1 500	23	1
		1A3d	Transport – Domestic navigation	1 500	1 000	200	23	1
		1A4a,b	Other sectors	100	20	5	23	1
		1A4c	Other sectors – AFF stationary	100	20	5	23	1
		1A4c	Other sectors – AFF mobile	1 200	1 000	200	23	1
		1A5b	Other – Military mobile	1 500	1 000	200	23	1
	Gasoline	1A1	Energy Industries	200	15	5	46	1
		1A2	Manufacturing Industries and Construction	200	10	5	46	1
		1A3a	Transport – Domestic aviation	300	100	50	46	1
		1A3b	Transport – Road transportation	600	8 000	1 500	46	1
		1A3d	Transport – Domestic navigation	1 500	1 000	200	46	1
		1A4a,b	Other sectors	100	20	5	46	1
		1A4c	Other sectors – AFF stationary	100	20	5	46	1
		1A4c	Other sectors – AFF mobile	1 200	1 000	200	46	1
		1A5b	Other – Military mobile	1 500	1 000	200	46	1
	Fueloil	1A1	Energy Industries	200	15	5	492	1
		1A2	Manufacturing Industries and Construction	200	10	5	492	1
		1A3a	Transport – Domestic aviation	300	100	50	492	1
		1A3b	Transport – Road transportation	600	8 000	1 500	492	1
		1A3d	Transport – Domestic navigation	1 500	1 000	200	492	1
		1A4a,b	Other sectors	100	20	5	492	1
		1A4c	Other sectors – AFF stationary	100	20	5	492	1
		1A4c	Other sectors – AFF mobile	1 200	1 000	200	492	1
		1A5b	Other – Military mobile	1 500	1 000	200	492	1
	LPG	1A1	Energy Industries	150	20	5	0.13	1
		1A2	Manufacturing Industries and Construction	150	30	5	0.13	1
		1A3a	Transport – Domestic aviation	-	-	-	-	1
		1A3b	Transport – Road transportation	600	400	5	0.13	1
		1A3d	Transport – Domestic navigation	-	-	-	-	1
		1A4a,b	Other sectors	50	50	5	0.13	1
		1A4c	Other sectors – AFF stationary	50	50	5	0.13	1
		1A4c	Other sectors – AFF mobile	1 000	400	5	0.13	1
		1A5b	Other – Military mobile	-	-	-	-	1
	Wasteoil	1A1	Energy Industries	200	15	5	477	1
Biomass	Municipal waste	1A1	Energy Industries	134	7.4	0.98	138	2
Other fuel	Municipal waste	1A1	Energy Industries	134	7.4	0.98	138	2

Sources: 1) IPCC Guidelines (IPCC, 2006). 2) Nielsen et al., 2010.

16.3.4 Emissions

The greenhouse gas (GHG) emissions are listed in Table 16.3.10. The total emission of greenhouse gases from the energy sector accounts for 94.3 % of total Greenlandic GHG emission in 2013.

The CO_2 emission from energy accounts for 99.4 % of the Greenlandic CO_2 emission (excluding net CO_2 emission from Land Use, Land Use Change and Forestry (LULUCF). The CH_4 emission from fuel combustion (Sectoral Approach) accounts for 8.8 % of the Greenlandic emission and the N_2O emission from fuel combustion accounts for 24.8 % of the Greenlandic N_2O emission, see Table 16.3.10.

Table 16.3.10 Greenhouse gas emission for the year 2013.

		CO_2	CH_4	N_2O
		Gg CO_2 equivalent		
1A1	Fuel consumption, Energy Industries	94.4	0.2	0.4
1A2	Fuel consumption, Manufacturing Industries and Construction	39.3	0.0	0.1
1A3	Fuel consumption, Transport	110.1	0.2	1.2
1A4	Fuel consumption, Other sectors	313.9	0.8	0.8
1B	Fugitive emissions from fuel, Oil and natural gas	NO	NO	NO
Total emission from energy		557.8	1.3	2.5
Greenlandic emission (excluding net emission from LULUCF)		561.3	14.8	10.1
		%		
Emission share for energy		99.4	8.8	24.8

CO_2 is the most important GHG pollutant and accounts for 99.3 % of the GHG emission in CO_2 equivalents from energy, see Figure 16.3.4.

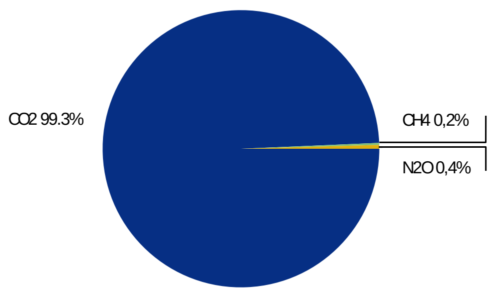

Figure 16.3.4 GHG emissions (CO_2 equivalent) from stationary combustion plants.

Figure 16.3.5 depicts the time-series of GHG emission in CO_2 equivalents from the energy sector. As shown by the blue curve the development in total GHG emission follows the CO_2 emission development very closely. Emission of CO_2 and total GHG emission are respectively 10.1 % and 10.0 % lower in 2013 compared to 1990.

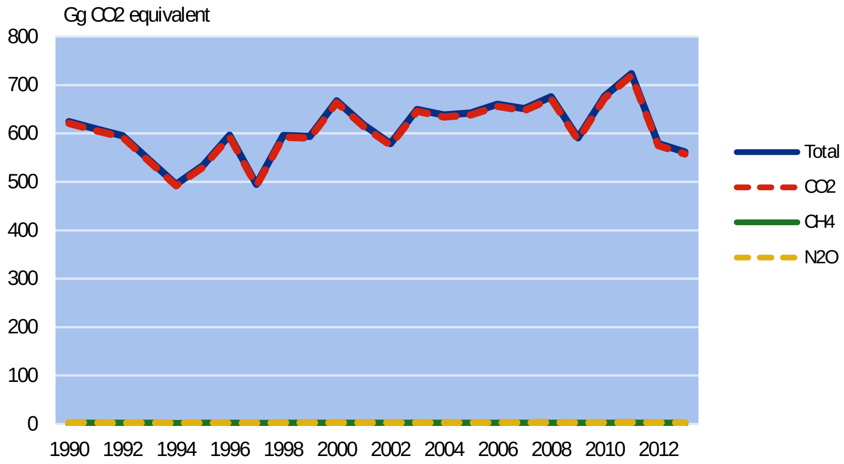

Figure 16.3.5 GHG emission time-series for the Energy Sector.

From 1990 to 1994 total GHG emission was reduced by 21 %. This was primarily due to the introduction of the first hydropower plant in 1993 but also to the introduction of burning waste to produce heat for district heating network in 1989. Dependence on gasoil conversion decreased immediately. Nevertheless, from 1995 an onwards consumption of gasoil once again increased due to the general economic development

In 2001-2002 total GHG emission decreased due to a minor recession in the economy. However since 1994 GHG emissions have increased in general with some fluctuations from year to year. The fluctuations are largely a result of outdoor temperature variations from year to year i.e. in 2008 the winter was relatively colder than in 2007. As a result fuel consumption increased in 2008 increasing GHG emission from fuel combustion. In 2009 GHG emission decreased by 12.6 % due to a significantly substitution in Energy Industries from fuel consumption to hydro power production together with a relatively warmer winter. However, in 2010 and 2011 GHG emission increased by 14.5 % and 6.9 % due to the initiation of oil exploration. In the most recent years, 2012 and 2013 GHG emission has decreased by 20.0 % and 3.0 % respectively due to the standstill in the oil exploration activities and a drop in fuel combustion in Energy Industries due to the opening of Greenlands fifth hydro power plant.

CO_2

CO_2 emission from energy accounts for 99.4 % of the total Greenlandic CO_2 emission. Table 16.3.11 lists the CO_2 emission inventory for the energy sector in 2013 as well as the relative percentage for each category under the sectoral approach.

The table reveals that Agriculture, Forestry and Fisheries (AFF) accounts for 24.4 % of the CO_2 emission. Other large CO_2 emission sources are Residental, Transportation and Energy Industries. These are sectors, which also account for a considerable share of fuel consumption.

Table 16.3.11 CO_2 emission from energy 2013.

		2013	
		Gg	%
1A1	Energy Industries	94.4	16.9
1A2	Manufacturing Industries	39.3	7.0
1A3	Transport	110.1	19.7
1A4a	Commercial / Institutional	58.3	10.5
1A4b	Residential	114.4	20.5
1A4c	Agriculture / Forestry / Fisheries	136.3	24.4
1A5	Other	4.9	0.9
1B	Fugitive emissions from fuel	NO	NO
1C	CO_2 Transport and Storage	NO	NO
Total		557.8	100.0

The CO_2 emission from combustion of biomass fuels is not included in the total CO_2 emission data, since biomass fuels are considered CO_2 neutral. The CO_2 emission from biomass combustion is reported as a memo item in the Climate Convention reporting. In 2013, the CO_2 emission from biomass combustion was 14.3 Gg.

Time-series for CO_2 emissions are provided in Figure 16.3.6. Fluctuations in CO_2 emission from AFF primarily regard fluctuations in fishing activities from year to year. Fluctuations in CO_2 emission from residential plants are largely a result of outdoor temperature variations from year to year. This also causes fluctuations in CO_2 emission from Energy Industries which cover electricity and heat production. However, the significant increase in emission from Energy Industries in 2010 continuing in 2011 is caused by the initiation of oil exploration in 2010, which is reported in the subsector “Manufacture of Solid Fuels and Other Energy Industries”. Due to a standstill in oil exploration fuel combustion in (and emissions from) Energy Industries dropped in 2012 and 2013.

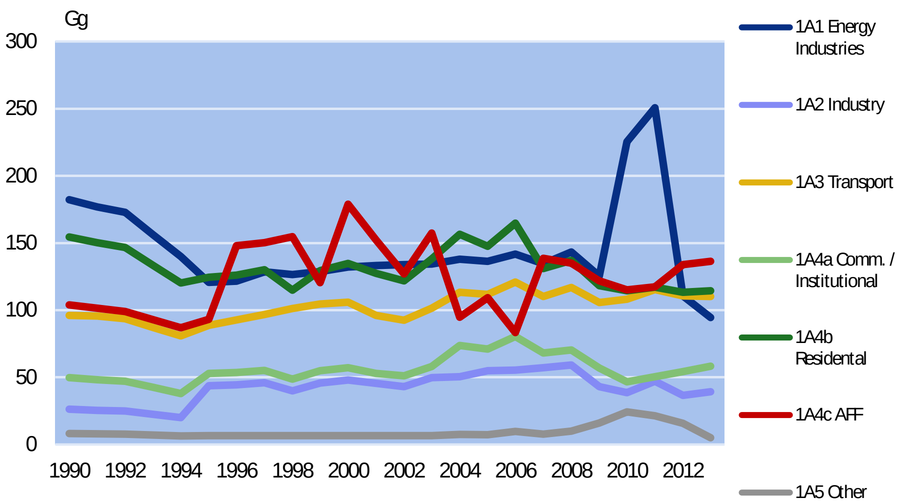

Figure 16.3.6 CO_2 Emission time-series for Fuel Combustion (Sectoral Approach).

Detailed trend discussion on CRF category level is available in Section 16.2.

CH_4

CH_4 emission from energy accounts for 8.8 % of the Greenlandic CH_4 emission. Table 16.3.12 lists the CH_4 emission inventory for energy in 2013. The table reveals that residental plants accounted for 30.2 % of the CH_4 emission from energy in 2013. Agriculture, Forestry and Fisheries accounted for 18.1 % of the emission in 2013, and Energy Industries for 17.9 %.

Table 16.3.12 CH_4 emission from fuel combustion 2013.

		2013	
		Mg	%
1A1	Energy Industries	9.3	17.9
1A2	Industry	1.1	2.1
1A3	Transport	8.2	15.7
1A4a	Commercial / Institutional	8.0	15.4
1A4b	Residential	15.7	30.2
1A4c	Agriculture / Forestry / Fisheries	9.4	18.1
1A5	Other	0.3	0.6
1B	Fugitive emissions from fuel	NO	NO
Total		52.0	100.0

The CH_4 emission from energy has increased by 4.6 % since 1990. You may notice that CH_4 emission has increased from 1990 to 2013 while CO_2 emission from energy has fallen in the same period. The reason for this is that the amount of recovered energy from waste has increased, while the consumption of liquid fossil fuel has decreased from 1990 to 2013. And in view of the fact that CH_4 emission from energy recovered waste by far exceeds the overall CH_4 emission from liquid fossil fuel, total CH_4 emission from energy increased from 1990 to 2013, while CO_2 emissions dropped.

Time-series for CH_4 emissions are provided in Figure 16.3.7. Fluctuations in CH_4 emission from AFF primarily regard fluctuations in fishing activities from year to year. Fluctuations in CH_4 emission from residential plants are largely a result of outdoor temperature variations from year to year. This also causes fluctuations in CH_4 emission from Energy Industries, which cover electricity and heat production and manufacture of solid fuels and other Energy Industries. The increase of CH_4 emission in 2010 and 2011 was caused by the initation of activities concerning oil exploration, while the decrease of CH_4 emission in 2012 and 2013 is due to a standstill in oil explorations in 2012 and 2013.

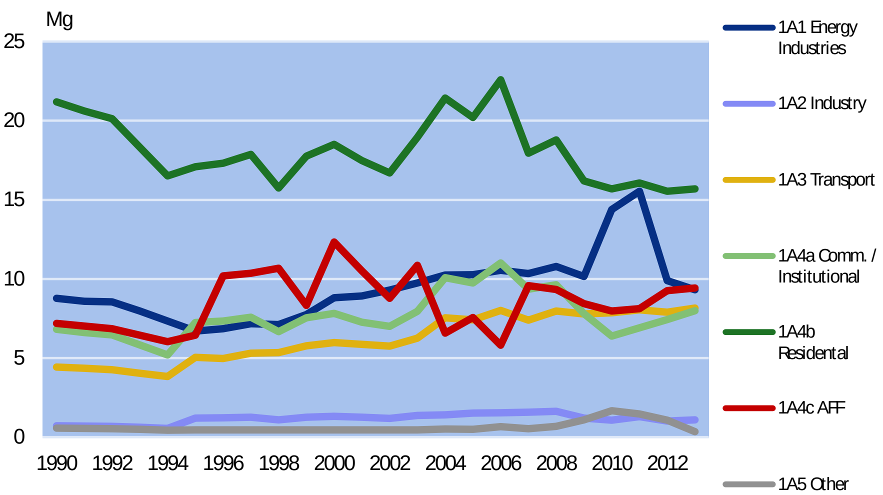

Figure 16.3.7 CH_4 emission time-series for energy.

Detailed trend discussion on CRF category level is available in Section 16.2.

N_2O

The N_2O emission from energy accounts for 24.8 % of the Greenlandic N_2O emission. Table 16.3.13 lists the N_2O emission inventory for energy in 2013. The table reveals that Transportations accounted fro 47.6 % of the N_2O emission from energy. Energy Industries accounted for 17.7 % of the emissions in 2013.

Table 16.3.13 N_2O emission from energy 2013.

		2013	
		Mg	%
1A1	Energy Industries	1.5	17.7
1A2	Industry	0.3	3.9
1A3	Transport	4.0	47.6
1A4a	Commercial / Institutional	0.5	5.7
1A4b	Residential	0.9	11.2
1A4c	Agriculture / Forestry / Fisheries	1.1	13.5
1A5	Other	0.0	0.5
1B	Fugitive emissions from fuel	NO	NO
Total		8.4	100.0

Figure 16.3.8 shows the time-series for the N_2O emission from energy. The N_2O emission has increased by 6.8 % from 1990 to 2013. Similar to the increase in CH_4 emissions, N_2O emissions have increased from 1990 to 2013 due to an increase in the use of recovered energy from waste simultaneously to a decrease in the consumption of liquid fuels.

Once again, the 2010 and 2011 increases in N_2O emission from Energy Industries are predominantly caused by the startup of oil explorative activities, while the decrease of N_2O emission in 2012 and 2013 is due to a standstill in oil explorations in 2012 and 2013.

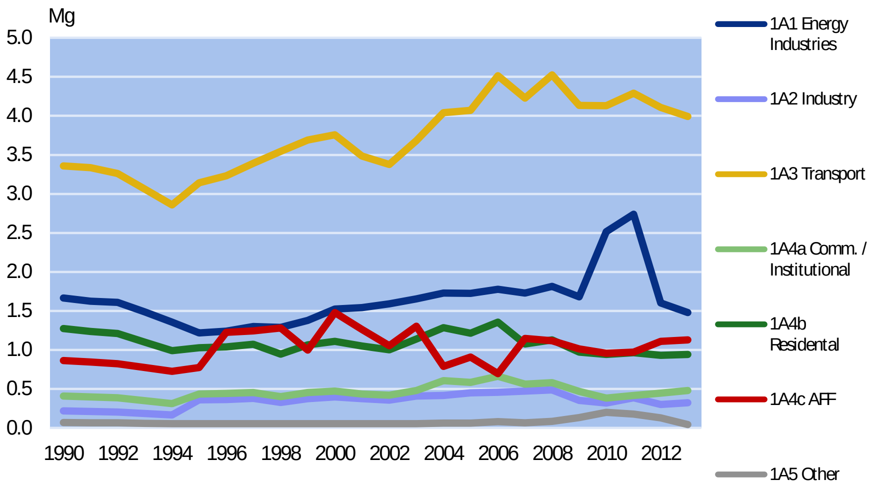

Figure 16.3.8 N_2O emission time-series for energy.

Detailed trend discussion on CRF category level is available in Section 16.2.

SO_2, NO_X, NMVOC and CO

The emissions of SO_2, NO_X, NMVOC and CO from energy in 2013 are presented in Table 16.3.14. SO_2 from energy accounts for 99.4 % of the Greenlandic SO_2 emission. NO_X, CO and NMVOC account for 99.0, 86.8 % and 87.0 % respectively, of the Greenlandic emissions for these substances.

Table 16.3.14 SO_2, NO_X, NMVOC and CO emission from energy 2013.

	NO_X	CO	NMVOC	SO_2
	Gg	Gg	Gg	Gg
1A1 Fuel consumption, Energy Industries	0.3	0.0	0.0	0.2
1A2 Fuel consumption, Manuf. Industries and Constr.	0.1	0.0	0.0	0.1
1A3 Fuel consumption, Transport	1.2	2.2	0.4	0.2
1A4 Fuel consumption, Other sectors	2.6	2.0	0.4	0.6
1B Fugitive emissions from fuel	NO	NO	NO	NO
Total emission from fuel consumption and fugitive emissions from fuel	4.2	4.2	0.9	1.0
Greenlandic emission	4.2	4.9	1.0	1.0
		%		
Emission share for fuel consumption	99.0	86.8	87.0	99.4

16.3.5 Uncertainties

A tier 1 uncertainty assessment has been carried out in accordance with the IPCC Guidelines (IPCC, 2006). The uncertainty has been estimated for all sources included in the reporting for the energy sector. The uncertainties for the activity data and emission factors are shown in Table 16.3.15.

Table 16.3.15 Uncertainties for activity data and emission factors for the energy sector.

Subsector	Pollutant	Activity data uncertainty	Emission factor uncertainty
1A Liquid fuels	CO_2	3	2
1A Municipal waste	CO_2	3	25
1B2 Oil exploration	CO_2	3	1 000
1A Liquid fuels	CH_4	3	100
1A Municipal waste	CH_4	3	100
1A Biomass	CH_4	3	100
1B2 Oil exploration	CH_4	3	1 000
1A Liquid fuels	N_2O	3	500
1A Municipal waste	N_2O	3	500
1A Biomass	N_2O	3	200
1B2 Oil exploration	N_2O	3	1 000

The activity data comes from the official Greenlandic energy statistics, which is considered to be of high quality. However the uncertainty of the activity data have been revised from 2 % to 3 % in order to fit the IPCC Guidelines (IPCC, 2006).

Regarding the emission factor uncertainty, the CO_2 emission factors are considered the most certain. Due to a technical analysis a country specific emission factor is now available on the Greenlandic gasoil; the dominating liquid fuel. Consequently, the CO_2 emission factor uncertainty has been revised from 5 % to 2 % for liquid fuels. This revision was done in the 2014 submission.

To account for the more inhomogeneous nature of municipal waste the emission factor uncertainty has been set to 25 %. For CH_4 the emission factor uncertainty has been set to 100 % in accordance with the IPCC Guidelines (IPCC, 2006). For N_2O the emission factor uncertainties have been estimated to lay between 200 % and 500 %. This is based on a first estimate and can be improved upon in the future.

Oil exploration has occurred in 2010 and 2011, but not in 2012. However, fugitive emissions have been set to NA due to the fact that it has been impossible to obtain any information on the amount of oil and gas picked up during drillings in 2010 and 2011.

The resulting uncertainties for the individual greenhouse gases and the total uncertainty on the greenhouse gas emission are shown in Table 16.3.16.

Table 16.3.16 Uncertainties for the emission estimates.

	Uncertainty %	Trend 1990-2013 %	Trend uncertainty %
GHG	± 4.1	-10.0	± 3.8
CO_2	± 3.6	-10.1	± 3.8
CH_4	± 89	4.6	± 11.2
N_2O	± 455	6.8	± 40

16.3.6 Source specific QA/QC

The elaboration of a formal QA/QC plan is to be completed.

However, the official Greenland energy statistics is continuously going through a great deal of quality work with regard to accuracy, comparability and completeness. Statistics Greenland is responsible for the official Greenlandic energy statistics, and as such responsible for the completeness of data. The uncertainties connected with estimating fuel consumption do not influence the coherence between the energy statistics and the datasets used in the emission inventory submission. For the remainder of the datasets, it is assumed that the level of uncertainty is relatively small. See chapter regarding uncertainties for further comments.

Statistics on fuel consumption is reported by Statistics Greenland in form of a spreadsheet. Annual consumption of gasoil, kerosene, gasoline and LPG are divided into business categories and private households. To ensure consistency data are compared with those from previous years and large discrepancies are checked.

All external data used for the emission inventory submission are archived in spreadsheets. Data are archived annually in order to ensure that the basic data for a given report are always available in their original form.

Safely stored and quality checked activity data are then processes by using a methodological approach consistent with international guidelines.

Calculated emission factors are compared with guideline emission factors to ensure that they are reasonable. The calculations follow the principle in international guidelines.

During data processing, it is checked that calculations are being carried out correctly. However, a documentation plan for this is to be elaborated.

Time-series for activity data, emission factors and calculated emissions are used to identify possible errors in the calculation procedure. In fact, during the calculation, numerous controls take place to ensure correctness. Sums are checked of the various stages in the calculation procedure. Implied emission factors are compared to emission factors.

Every single time-series imported to the CRF Reporter is checked for fuel rate, units for fuel rate, emission factor and plant-specific emissions. Additional checks are performed on the database. The database encloses every single activity data, emission factors, emission, notation key and comment imported to the CRF Reporter. In other words, no information is typed manually into the CRF Reporter. Instead, all information is imported to the CRF Reporter through an XML-file to ensure maximum accuracy and completeness.

Reference approach

In addition to the sector-specific CO_2 emission inventories (the Greenlandic approach), the CO_2 emission is also estimated using the reference approach described in the IPCC Reference manual (IPCC, 2006). The reference approach is based on data for fuel production, import, export and stock change. The CO_2 emission inventory based on the reference approach is reported to the Climate Convention and used for verification of the official data in the Greenlandic approach.

Data for import, export and stock change used in the reference approach originate from the annual "basic data" table prepared by Statistics Greenland. The fraction of carbon oxidised has been assumed to be 1.00. The carbon emission factors are default factors originating from the IPCC Reference Manual (IPCC, 2006). The country-specific emission factors are not used in the reference approach, the approach being for the purposes of verification.

The Climate Convention reporting tables include a comparison of the Greenlandic approach and the reference approach estimates. To make results comparable, the CO_2 emission from incineration of the plastic content of municipal waste is added in the reference approach while the fuel consumption is subtracted.

In 2013 the fuel consumption rates in the two approaches differ by 0.0 % and the CO_2 emission differs by -1.3 %. In the period 1990-2013 both the fuel consumption and the CO_2 emission differ by 1.3 % or less at all times. The differences in energy consumption are 0 % for all years. According to IPCC Good Practice Guidance (IPCC, 2000) the difference should be within 2 %. A comparison of the Greenlandic approach and the reference approach is illustrated in Figure 16.3.9.

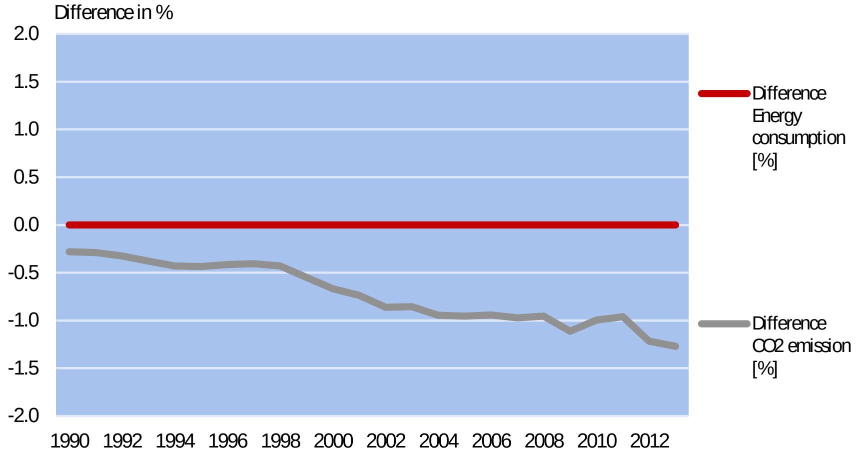

Figure 16.3.9 Comparison of the reference approach and the national approach.

16.3.7 Source specific recalculations and improvements

Improvements and recalculations since the 2014 emission inventory submission include:

- CO_2 emission factors from combustion of gasoil, kerosene, jet-kerosene, gasoline, fueloil and wasteoil have been revised due to a revision of the oxidation factor from the previously 0.99 to 1.
- Update of fuel rates according to the latest energy statistics. The update includes the years 2004-2012.
- Time-series for road transportation has been introduces according to new requirements in the CRF Reporter.
- Adjustment of municipal waste with energy recovery according to improvements in population statistics, which is used in the estimation of municipal waste.

Recalculations have not been performed in this 2015-submission.

16.3.8 Source specific planned improvements

Some planned improvements to the emission inventories are discussed below.

1) Improved documentation for emission factors

The reporting of, and references for, the applied emission factors have been improved in the current year and will be further developed in future inventories. This will happen on the advice from the Danish National Environmental Research Institute.

2) Improvements in plant specific fuel combustion

Plant specific fuel combustion will be further improved according to the developments made by Statistics Greenland in the energy statistics.

3) Uncertainty estimates

Uncertainty estimates are largely based on the default uncertainty levels for activity rates and emission factors. More country-specific uncertainty estimates will be incorporated in future inventories.

4) Country specific emission factors

Statistics Greenland has acquired a technical analysis on the gasoil that is imported to and used in Greenland. The technical analysis conducted by the Danish Techinal Institute has provided a country specific emission factor on the Greenlandic gasoil. The goal was to implement the new country specific emission factors in this 2015 submission, but with the technical results all ready in hand it was managed to implement the new country specific emission factor on gasoil in the 2014 submission. The arctic gasoil stands for 80 % of all liquid fuels in 2013.

The plan is to obtain additional country specific emission factors on other liquid fuels, but only if the UNFCCC recommend it as in the case of the Greenlandic gasoil.

16.3.9 References

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16.4 Industrial Processes and Product Use (CRF sector 2)

16.4.1 Overview of sector

In this chapter the emissions of greenhouse gases from industrial processes and product use, not related to generation of energy, are presented.

The emission of greenhouse gases from industrial processes and product use includes CO_2, HFCs and SF_6. The emissions are reported in CRF Tables 2(I), 2(I).A, 2(II) and 2(II).B. Furthermore, the emission of non-methane volatile organic compounds (NMVOC) and CO from industrial processes related to asphalt roofing, road paving with asphalt and production of food and drink are given in CRF Table 2(I). New to this section are the emissions of CO_2 and NMVOC from use of solvents in industrial processes and households that are related to the former source categories Paint application, Degreasing and dry cleaning, Chemical products, Manufacture and processing and Others. Emission of CO_2 and NMVOC from solvent use are reported in CRF Tables 2(I) and 2(I).A.

Solvents are chemical compounds that are used on a global scale in industrial processes and as constituents in final products to dissolve e.g. paint, cosmetics, adhesives, ink, rubber, plastic, pesticides, aerosols or are used for cleaning purposes, i.e. degreasing. NMVOCs are main components in solvents - and solvent use in industries and households is typically the dominant source of anthropogenic NMVOC emissions. In industrial processes where solvents are produced or used NMVOC emissions to air and as liquid can be recaptured and either used or destroyed. Solvent containing products are used indoor and outdoor and the majority of solvent sooner or later evaporate. A small fraction of the solvent ends up in waste or as emissions to water and may finally also contribute to air pollution by evaporation from these compartments.

In this section the methodology for the Greenland NMVOC emission inventory for solvent use is presented and the results for the period 1990-2013 are summarised. The method is based on the detailed approach described in EMEP/CORINAIR (2004) and emissions are calculated for the CRF sectors mentioned above.

An overview of sources identified is presented in Table 16.4.1 with an indication of the contribution to the industrial part of the emission of greenhouse gases in 2013. Emissions are extracted from the CRF tables.

Table 16.4.1 Overview of greenhouse gas sources 2013.

Process	IPCC Code	Substance	Emission tonnes CO_2 eqv.	%
Mineral Industry				
Limestone and Dolomite Use	2A4	CO_2	0.00	0.0
Non-Energy Products of Fuels and Solvent use				
Paraffin Wax Use	2D2	CO_2	91.26	1.1
Solvent Use	2D3	CO_2	223.53	2.6
Road Paving with Asphalt	2D3	CO_2	0.20	0.0
Asphalt Roofing	2D3	CO_2	0.04	0.0
Product uses as substitutes for ODS				
Refrigeration and Air Conditioning Equipment	2F1	HFCs	8 303	96.3
Other product manufacture and use				
Electrical Equipment	2G	SF_6	2.74	0.0
Total emission			8 621	100

The subsector *Product uses as substitutes for ODS* (2F) constitutes 96.3 % of the industrial emission of greenhouse gases. This reflects the emission of HFCs from refrigeration and air conditioning equipment. The subsector *Non-Energy Products of Fuels and Solvent use* (2D) constitutes 3.7 % of the industrial emission of greenhouse gases. In this subsector we find emissions from paraffin wax use and solvents, both new to this sector, as well as road paving with asphalt and asphalt roofing.

The total emission of greenhouse gases (excl. LULUCF) in Greenland is estimated to 594.5 Gg CO_2 equivalents, of which industrial processes contribute with 8.621 Gg CO_2 equivalents (1.5 %). The emission of greenhouse gases from industrial processes from 1990-2013 are presented in Figure 16.4.1.

Greenland has no chemical industry, metal production or production of halocarbons or SF_6. Greenland has no consumption of PFCs.

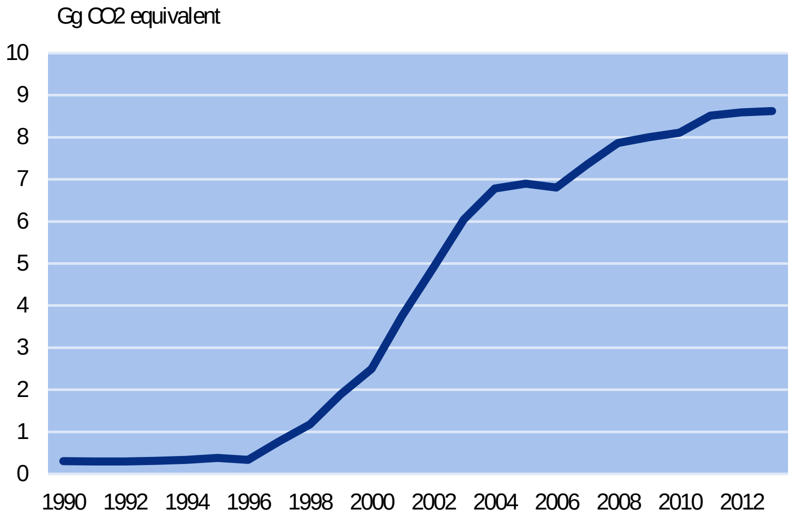

Figure 16.4.1 Emission of greenhouse gases from industrial processes 1990-2013.

The key category in the industrial sector *Consumption of Halocarbons* constitutes 1.4 % of the total emission of greenhouse gases. The trends in greenhouse gases from the industrial sector/subsectors are presented in Table 16.4.2. The emissions are extracted from the CRF tables.

Table 16.4.2 Emission of greenhouse gases from industrial processes and product use in different subsectors from 1990-2013.

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
CO_2 (tonnes CO_2)										
A. Mineral Industry	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
D. Non-energy products from fuels and solvent use	306	301	300	310	315	320	241	314	343	391
CH_4	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
N_2O	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
HFCs (tonnes CO_2 eqv.)										
F. Product uses as ODS substitutes	NE	NE	NE	NE	18	27	88	455	833	1 497
PFCs (tonnes CO_2 eqv.)										
F. Product uses as ODS substitutes	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
SF_6 (tonnes CO_2 eqv.)										
G. Other product manufacture and use	NE	NE	NE	NE	NE	34.2	3.2	3.2	3.2	3.2
continued	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
CO_2 (tonnes CO_2)										
A. Mineral Industry	3.96	2.77	1.32	2.64	1.80	0.11	0.03	1.51	2.96	0.03
D. Non-energy products from fuels and solvent use	301	282	320	474	421	489	354	354	355	450
CH_4	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
N_2O	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
HFCs (tonnes CO_2 eqv.)										
F. Product uses as ODS substitutes	2 190	3 473	4 569	5 566	6 352	6 407	6 448	6 999	7 499	7 546
PFCs (tonnes CO_2 eqv.)										
F. Product uses as ODS substitutes	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
SF_6 (tonnes CO_2 eqv.)										
G. Other product manufacture and use	3.1	3.1	3.1	3.0	3.0	3.0	2.9	2.9	2.9	2.9
continued	2010	2011	2012	2013						
CO_2 (tonnes CO_2)										
A. Mineral Industry	4.94	0.00	19.57	0.00						
D. Non-energy products from fuels and solvent use	329	334	352	315						
CH_4	NO	NO	NO	NO						
N_2O	NO	NO	NO	NO						
HFCs (tonnes CO_2 eqv.)										
F. Product uses as ODS substitutes	7 770	8 180	8 215	8 303						
PFCs (tonnes CO_2 eqv.)										
F. Product uses as ODS substitutes	NO	NO	NO	NO						
SF_6 (tonnes CO_2 eqv.)										
G. Other product manufacture and use	2.8	2.8	2.8	2.7						

Greenland has no production of halocarbons or SF_6. Data on consumption of F-gases (HFCs and SF_6) are obtained from the Statistics Greenland (imports) and by an annual survey on consumption halocarbons and SF_6. Information on consumption of F-gases is available from 1995 onwards. Greenland has no consumption of PFCs.

One single plant in Greenland has reported use of SF_6 in 1995. The emission of SF_6 was 35.9 tonnes CO_2 equivalents in 1995. The annual emission from 1996 and onwards is assumed to be 0.5 % of the amount filled into the plant in 1995. This causes a relative high emission of SF_6 in 1995 and a much lower emission in the period 1996-2013.

Energy consumption associated with industrial processes and emissions thereof are included in the Energy sector of the inventory.

16.4.2 Source category description

Mineral Industry

The subsector *Mineral Industry* (2A) covers the following processes:

- 2A4d Limestone and dolomite use.

Emissions from limestone and dolomite use are presented in the CRF sector 2A.4d under 2A.4 Other Process Uses of Carbonates. The time-series for the emission of CO_2 from Mineral industry (2A) is presented in Table 16.4.3. The emissions are extracted from the CRF tables and the values are rounded.

Table 16.4.3 Time-series for emission of CO_2 (tonnes) from Mineral Industry (2A).

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
4d Limestone and dolomite use	-	-	-	-	-	-	-	-	-	-
continued	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
4d Limestone and dolomite use	3.96	2.77	1.32	2.64	1.80	0.11	0.03	1.51	2.96	0.03
continued	2010	2011	2012	2013						
4d Limestone and dolomite use	4.94	0.00	19.57	0.00						

The use of limestone and dolomite started in 2000. Hence there is no emission from limestone and dolomite use before 2000. The use of limestone and dolomite has been estimated from the annual import of these products to Greenland. Imports seem to vary a great deal from year to year, which causes the estimated use to vary as well.

The CO_2 emission from subsectors under Mineral Industry fluctuates a great deal from year to year, as seen in Figure 16.4.2. This is caused by fluctuations in activities from year to year. However fluctuations in CO_2 are primarily caused by the fact that activity data for Mineral Industry are based on import data, which do not allow distinction of imported amount into consumption and stockpiling.

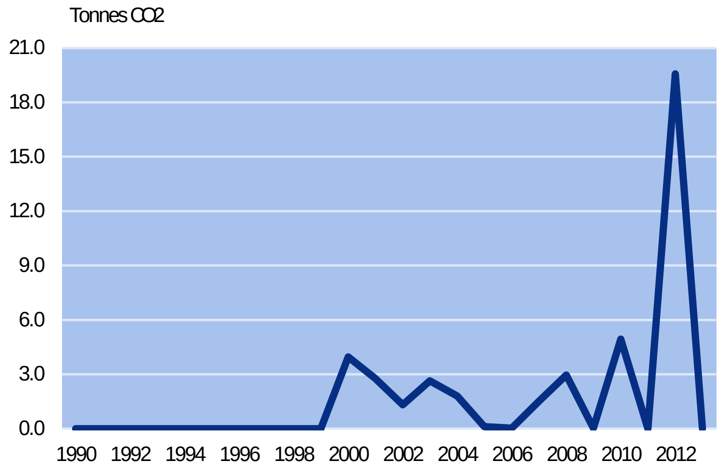

Figure 16.4.2 Emission of CO_2 from Mineral Industry.

Non-energy Products from Fuels and Solvent Use

The subsector *Non-energy Products from Fuels and Solvent Use* (2D) covers the following processes:

- 2D2 Paraffin Wax Use.
- 2D3a Solvent Use.
- 2D3b Road paving with asphalt.
- 2D3c Roof covering with asphalt materials.

Emissions from paraffin wax use are presented in the CRF 2D.2 subsector Paraffin Wax Use, while emissions from solvent use, road paving with asphalt and roof covering with asphalt materials are specified separately in the CRF 2D.3 subsector Other.The time-series for the emission of CO_2 from Non-energy Products from Fuels and Solvent Use (2D) are presented in Table 16.4.4. The emissions are extracted from the CRF tables and the values are rounded.

Table 16.4.4 Time-series for emission of CO_2 (tonnes) from Non-energy Products from Fuels and Solvent Use (2D).

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
2. Paraffin Wax Use	42.6	40.8	42.4	47.4	39.3	43.1	32.1	50.0	72.3	81.2
3a. Solvent Use	263.4	259.7	257.4	262.5	275.6	276.7	209.3	263.4	271.0	310.1
3b. Asphalt roofing	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
3c. Road paving	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	306.0	300.7	299.8	310.0	315.0	319.9	241.5	313.6	343.4	391.5
continued	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
2. Paraffin Wax Use	53.1	58.7	86.0	160.1	143.3	162.0	121.1	129.4	135.0	112.7
3a. Solvent Use	247.9	223.6	233.5	314.0	277.5	326.1	232.5	224.0	219.9	337.5
3b. Asphalt roofing	0.1	0.2	0.1	0.4	0.2	0.4	0.1	0.2	0.2	0.1
3c. Road paving	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.1	0.1	0.1
Total	301.1	282.5	319.7	474.5	421.0	488.5	353.7	353.6	355.2	450.4
continued	2010	2011	2012	2013						
2. Paraffin Wax Use	115.8	110.8	120.3	91.3						
3a. Solvent Use	213.0	223.1	231.2	223.5						
3b. Asphalt roofing	0.1	0.3	0.1	0.2						
3c. Road paving	0.1	0.0	0.0	0.0						
Total	328.9	334.3	351.6	315.0						

In 2013 the most significant CO_2 emission came from the use of solvents which constituted 71.0 % of total CO_2 emission from *Non-energy Products from Fuels and Solvent Use* in 2013. Emission of CO_2 from paraffin wax use accounted for 29.0 % of total CO_2 emission from this subsector in 2013, while CO_2 emission from asphalt roofing and road paving constituted 0.1 and less in 2013.

The CO_2 emission from subsectors under Non-energy Products from Fuels and Solvent Use fluctuates a great deal from year to year, as seen in Figure 16.4.3. This is among others caused by fluctuations in building activities and road paving. However fluctuations in CO_2 are also caused by the fact that activity data for non-energy products and solvent use are based on import data, which do not allow distinction of imported amount into consumption and stockpiling.

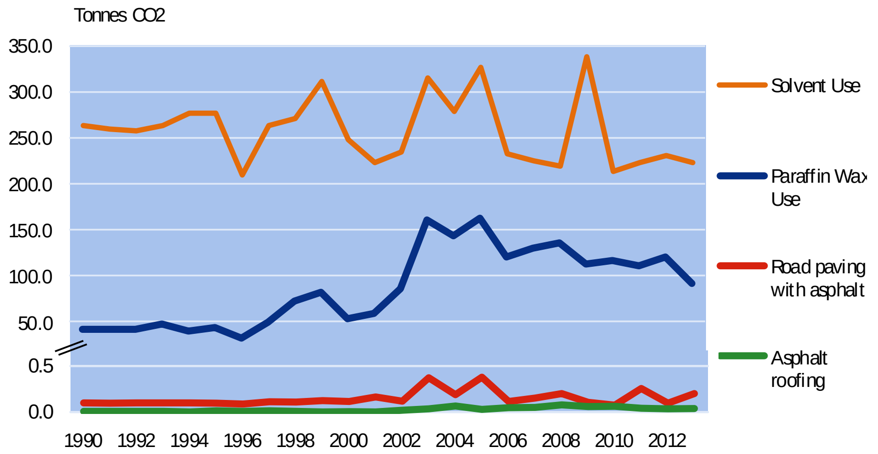

Figure 16.4.3 Emission of CO_2 from Non-energy Products from Fuels and Solvent Use.

Product Uses as Substitutes for ODS – Consumption of Halocarbons

The subsector *Product Uses as Substitutes for ODS* (2F) includes the following source categories and the following halocarbons of relevance for Greenlandic emissions:

- 2F1 Refrigeration: HFC32, 125, 134a, 143a, unspecified HFCs.

A quantitative overview is given below for each of these source categories and each halocarbon, showing their emissions in tonnes through the time-series. The data is extracted from the CRF tables that form part of this submission and the data presented is rounded values. It must be noticed that the inventories for the years 1990-1993 (1994) might not cover emissions of these gases in full. The chosen base-year for these gases is 1995 for Greenland.

Table 16.4.5 Emission of HFCs from refrigeration (t).

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
HFC32	NE	NE	NE	NE	NE	NA	0.00	0.00	0.00	0.00
HFC125	NE	NE	NE	NE	NE	NA	0.01	0.04	0.08	0.15
HFC134a	NE	NE	NE	NE	0.01	0.02	0.03	0.06	0.10	0.17
HFC143a	NE	NE	NE	NE	NE	NA	0.01	0.05	0.09	0.16
Unspecified HFCs	NE	NE	NE	NE	NE	NA	0.00	0.00	0.00	0.00
continued	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
HFC32	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
HFC125	0.22	0.35	0.46	0.56	0.64	0.64	0.65	0.71	0.76	0.77
HFC134a	0.24	0.35	0.45	0.55	0.63	0.65	0.65	0.68	0.67	0.64
HFC143a	0.24	0.39	0.51	0.63	0.71	0.72	0.72	0.79	0.86	0.88
Unspecified HFCs	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
continued	2010	2011	2012	2013						
HFC32	0.01	0.01	0.01	0.01						
HFC125	0.80	0.84	0.85	0.87						
HFC134a	0.62	0.63	0.59	0.55						
HFC143a	0.91	0.97	0.98	1.00						
Unspecified HFCs	0.00	0.00	0.00	0.00						

HFCs are used in various types of refrigeration in industry, retail, buildings and onboard ships. In 1994 and 1995 consumption of HFC134a was the only reported HFC used for refrigeration. Since 1996 consumption of HFC32, 125, 134A, 143A has been reported continuously. The emission of

HFCs has increased rapidly since 1995. Emission of HFCs from refrigeration is shown in Figur 16.4.4.

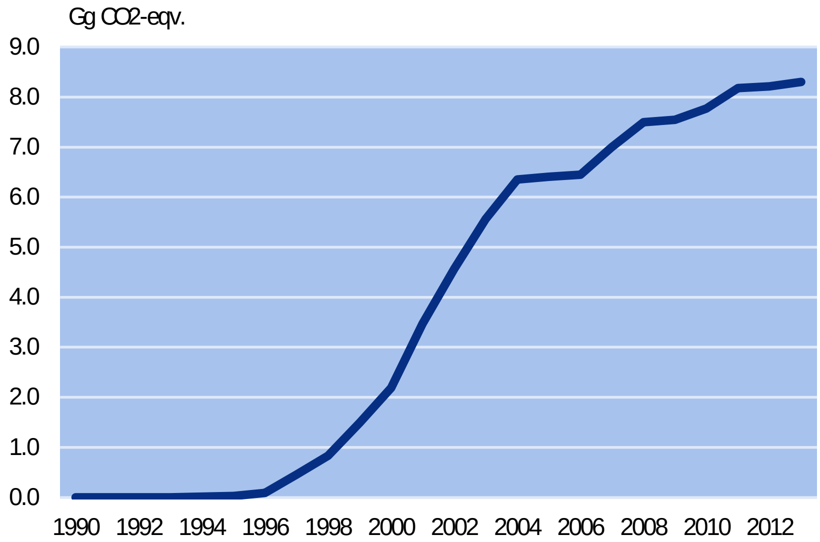

Figure 16.4.4 Emission of HFCs (from refrigeration).

Other Product Manufacture and Use – Consumption of SF_6

The subsector *Other Product Manufacture and Use* (2G) includes the following source categories and the following F-gases of relevance for Greenlandic emissions:

- 2G1 Electrical Equipment: SF_6.

Emissions of SF_6 are shown in Table 16.4.6 below. The data is extracted from the CRF tables that form part of this submission and the data presented is rounded values. It must be noticed that the inventories for the years 1990-1993 (1994) might not cover emissions of these gases in full. The chosen base-year for these gases is 1995 for Greenland.

Table 16.4.6 Emission of SF_6 from Electrical Equipment (kg).

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
SF_6	NE	NE	NE	NE	NE	1.50	0.14	0.14	0.14	0.14
continued	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
SF_6	0.14	0.14	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
continued	2010	2011	2012	2013						
SF_6	0.12	0.12	0.12	0.12						

The emission of SF_6 was highest in 1995, when one single plant in Greenland reported use of SF_6. The emission of SF_6 was 1.5 kg in 1995. Since 1995 the annual emission is assumed to be 0.5 % of the amount filled into the plant in 1995. This causes a relative high emission of SF_6 in 1995 and a much lower emission in the following years. In 2013 the emission of SF_6 was 0.12 kg. Emission of SF_6 from electrical equipment is shown in Figur 16.4.5.

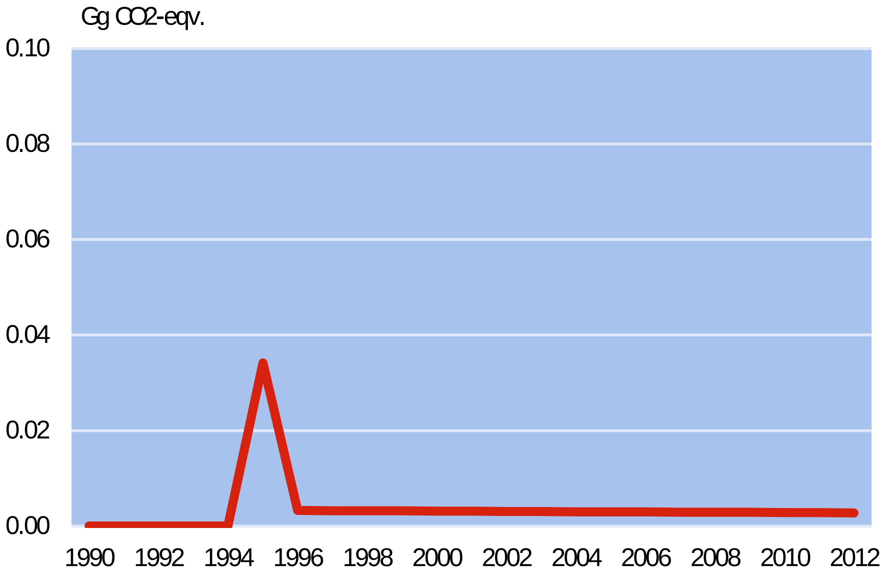

Figure 16.4.5 Emission of SF_6 (from electrical equipment).

Table 16.4.7 quantifies an overview of the emissions of the all F-gases in CO_2-eqv. from the two subsectors Product Uses as Substitutes for ODS (2F) and Other Product Manufacture and Use (2G). The emissions are extracted from the CRF tables and the values are rounded.

Table 16.4.7 Time-series for emission of HFCs and SF_6 (tonnes CO_2-eqv.).

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
HFCs	NE	NE	NE	NE	18	27	88	455	833	1 497
SF_6	NE	NE	NE	NE	NE	34.2	3.2	3.2	3.2	3.2
continued	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
HFCs	2 190	3 473	4 569	5 566	6 352	6 407	6 448	6 999	7 499	7 546
SF_6	3.1	3.1	3.1	3.0	3.0	3.0	2.9	2.9	2.9	2.9
continued	2010	2011	2012	2013						
HFCs	7 770	8 180	8 215	8 303						
SF_6	2.8	2.8	2.8	2.7						

HFCs is by far the most dominant group among the F-gases. HFCs constitute a key category both with regard to the key category level and the trend analysis.

Other

The subsector *Other* (2H) covers the following processes:

- 2H2 Food and Beverages Industry.

Emission of NMVOC from food and beverages industry is presented in the CRF sector 2H.2 Other. There is no emission of CO_2 from this source.

16.4.3 Methodological issues

General

The CO_2 emission from the use of limestone and dolomite, paraffin wax, asphalt materials used for roof covering and road paving has been estimated from the annual import of these products to Greenland.

The emissions of HFCs and SF_6 have been estimated from data on consumption of F-gases. Activity data includes annual imports and data on consumption of halocarbons and SF_6 obtained from an annual survey among importers and consumers of F-gases.

The emission modelling of solvents is done by estimating the amount of (pure) solvents consumed (EMEP/CORINAIR, 2004). All relevant solvents are estimated, or at least those representing more than 90 % of the total NMVOC emission. The estimation and modelling is based on a detailed set of data on imports of chemicals and products to Greenland. Each chemical (NMVOC) and chemical containing product (group) is estimated separately. The sum of emissions of all estimated NMVOCs used as solvents equals the NMVOC emission from solvent use.

The following sections contain a description of activity data and emission factors used for the subsectors under industrial processes. The section is concluded by a description of the emissions of greenhouse gases from industrial processes and product use.

Activity data

Activity data for subsectors *Mineral Industry* (2A), *Non-Energy Products of Fuel and Solvent Use* (2D) and *Other* (2H) are presented in Table 16.4.8. Activity data under subsector *Other* (2H) are used for calculation of emission of non-methane volatile organic compounds (NMVOC). Emission of non-methane volatile organic compounds (NMVOC) is also calculated from the use of solvents under subsector 2D.

The activity data are rounded. Notice that production of beer is given in hectolitre (hl). All other activity data are given in tonnes (t).

Statistics on imports are used to estimate annual consumption in mineral industry and the use of non-energy products of fuel and solvents.

The definitions of solvents and VOC that are used are as defined in the solvent directive (Directive 1999/13/EC) of the EU legislation: “Organic solvent shall mean any VOC which is used alone or in combination with other agents, and without undergoing a chemical change, to dissolve raw materials, products or waste materials, or is used as a cleaning agent to dissolve contaminants, or as a dissolver, or as a dispersion medium, or as a viscosity adjuster, or as a surface tension adjuster, or a plasticiser, or as a preservative”. VOCs are defined as follows: “Volatile organic compound shall mean any organic compound having at 293.15 K a vapour pressure of 0.01 kPa or more, or having a corresponding volatility under the particular condition of use”.

Import figures of chemicals and chemical containing products are obtained from Statistics Greenland. There is no production or export of chemicals and chemical containing products, therefore the import amount is assumed to be equivalent to the used amount.

Statistics on imports of whole coffee beans and yeast for baking are used to estimate annual production of coffee and bread. Statistics on landings of fish and seafood to domestic plants are used to determine domestic processing of fish and seafood. Statistics on imports are produced by Statistics Greenland (2014b).

Production of beer including a fermentation process has taken place at the brewery “Godthåb Bryghus” since 2005 (Godthåb Bryghus, 2014). The brewery has reported annual production in rounded hectolitre. The much larger company "Nuuk Imeq" has no production of beer including a fermentation process. As a bottling company the activity at "Nuuk Imeq" only includes diluting of the concentrated quantities imported to Greenland and afterwards bottling of the beer.

Table 16.4.8 Time-series for activity data for Mineral Industry, Non-energy Products of Fuel and Solvent Use, and Other.

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Mineral Industry										
2A4d Limestone and dolomite use (t)	-	-	-	-	-	-	-	-	-	-
Non-energy Products from Fuels and Solvent Use										
2D2 Paraffin wax use (t)	86	83	86	96	79	87	65	101	146	164
2D3a Solvent use (t)	190	187	188	195	198	174	141	198	206	254
2D3b Road paving with asphalt (t)	591	581	595	604	597	577	532	664	649	752
2D3c Asphalt roofing (t)	37	35	39	39	13	56	29	59	39	7
Other Production, Food and Beverage Industry										
2H2 Beans roasted to produce coffee (t)	0	0	0	0	-	0	-	-	0	0
2H2 Production of bread (t)	356	346	339	358	501	244	415	500	847	689
2H2 Landings of fish and seafood (t)	81 768	72 395	65 553	59 423	64 479	67 786	60 662	62 244	67 247	63 750
2H2 Production of beer (hl)	-	-	-	-	-	-	-	-	-	-

continued	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Mineral Industry										
2A4d Limestone and dolomite use (t)	9	6	3	6	4	0	0	3	7	0
Non-energy Products from Fuels and Solvent Use										
2D2 Paraffin wax use (t)	107	119	174	324	290	328	245	262	273	228
2D3a Solvent use (t)	159	155	196	264	271	351	291	258	209	325
2D3b Road paving with asphalt (t)	694	988	705	2 218	1 127	2 258	698	912	1 206	629
2D3c Asphalt roofing (t)	26	11	81	149	263	114	193	209	321	241
Other Production, Food and Beverage Industry										
2H2 Beans roasted to produce coffee (t)	0	1	-	0	0	0	0	1	0	0
2H2 Production of bread (t)	687	566	1 020	1 048	1 338	1 014	1 134	859	931	587
2H2 Landings of fish and seafood (t)	74 105	66 929	85 970	80 667	102 570	103 642	111 351	118 260	109 420	102 393
2H2 Production of beer (hl)	-	-	-	-	-	1 000	2 000	2 000	1 850	1 650

continued	2010	2011	2012	2013	Source
Mineral Industry					
2A4d Limestone and dolomite use (t)	11	0	45	0	1
Non-energy Products from Fuels and Solvent Use					
2D2 Paraffin wax use (t)	234	224	243	185	1
2D3a Solvent use (t)	224	233	293	271	1
2D3b Road paving with asphalt (t)	443	1 529	583	1 200	1
2D3c Asphalt roofing (t)	256	173	142	160	1
Other Production, Food and Beverage Industry					
2H2 Beans roasted to produce coffee (t)	0	0	1	3	2
2H2 Production of bread (t)	790	584	563	567	2
2H2 Landings of fish and seafood (t)	97 955	104 020	97 532	102 677	3
2H2 Production of beer (hl)	2 010	2 115	2 080	1 985	4

Sources:

1) Statistics on imports are used to estimate annual consumption.

2) Statistics on imports of whole coffee beans and yeast for baking are used to estimate annual production of coffee and bread.

3) Statistics on landings of fish and seafood to domestic plants are used to determine domestic processing of fish and seafood.

4) Data from the brewery "Godthåb Bryghus" are used to determine annual production of beer.

The data for emission of HFCs and SF_6 has been obtained in continuation on the work on inventories for previous years. The determination includes the quantification and determination of any import and export of HFCs and SF_6 contained products and substances in stock form. This is in accordance with IPCC guidelines (IPCC, 2006), as well as the relevant decision trees from the IPCC Good Practice Guidance (IPCC, 2006).

The following sources of information have been used (Statistics Greenland, 2014a):

- Importers, wholesaler and suppliers.
- Statistics Greenland.
- Consuming enterprises.

Importers and suppliers provide consumption data of F-gases. Emission factors are defaults from the GPG. Import/export data for sub-source categories where import/export is relevant are quantified on estimates from import/export statistics of products + default values of the amount of gas in the product.

The determination of emissions of F-gases is based on a calculation of the actual emission. The actual emission is the emission in the evaluation year, accounting for the time lapse between consumption and emission. The actual emission includes Greenlandic emissions from production and from products during their lifetimes. Consumption and emissions of F-gases are, whenever possible for individual substances, even though the consumption of certain HFCs has been limited. This has been varied out to ensure transparency of evaluation in the determination of GWP values. However, the continued use for Other HFCs has been necessary since not all importers and suppliers have specified records of sales for individual substances.

Only the actual emission has been calculated. Thus, the potential emission is assumed to be the same as the actual emission in the CRF tables.

Table 16.4.9 Content (w/w%) of "pure" HFC in HFC-mixtures, used as trade names.

HFC mixtures	HFC32	HFC125	HFC134a	HFC143a	Unspecified HFCs
	%	%	%	%	%
HFC-134, total			100		
HFC-404, total		44	4	52	
HFC-407c, total	23	25	52		
HFC-507a, total		50		50	
Unspecified HFCs					100

The substances have been accounted for in the survey according to their trade names, which are mixtures of HFCs used in the CRF. In the transfer to the "pure" substances used in the CRF reporting schemes, the ratios shown in Table 16.4.9 have been used.

Activity data for the consumption of F-gases is shown in Table 16.4.10. The activity data are rounded and given in kg.

Table 16.4.10 Time-series for activity data for the consumption of F-gases by trade-names.

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
					Kg					
HFC-134										
Domestic	NE	NE	NE	264	139	91	187	134	453	319
Commercial and Industry	NE	NE	NE	-	-	-	123	123	247	247
Transport	NE	NE	NE	-	-	-	64	64	128	128
HFC-404a										
Commercial and Industry	NE	NE	NE	-	-	-	488	488	976	976
Transport	NE	NE	NE	-	-	-	82	82	164	164
HFC-407c										
Commercial and Industry	NE	NE	NE	-	-	-	34	34	68	68
HFC-507a										
Transport	NE	NE	NE	-	-	-	113	113	225	225
Unspecified HFCs										
Commercial and Industry	NE	NE	NE	-	-	-	45	45	90	90
SF_6										
Electrical Equipment	NE	NE	NE	-	-	30	-	-	-	-
continued	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
HFC-134										
Domestic	289	492	774	635	635	-	-	-	-	-
Commercial and Industry	493	493	493	493	260	208	680	329	312	195
Transport	256	256	256	256	120	120	30	30	-	-
HFC-404a										
Commercial and Industry	1 952	1 952	1 952	1 952	1 324	1 041	2 033	2 069	1 950	2 089
Transport	328	328	328	328	154	222	369	413	384	241
HFC-407c										
Commercial and Industry	135	135	135	135	68	83	31	4	112	90
HFC-507a										
Transport	450	450	450	450	-	-	120	180	-	120
Unspecified HFCs										
Commercial and Industry	180	180	180	180	326	314	556	698	309	400
SF_6										
Electrical Equipment	-	-	-	-	-	-	-	-	-	-
continued	2010	2011	2012	2013						
HFC-134										
Domestic	-	-	-	-						
Commercial and Industry	484	340	225	120						
Transport	-	-	-	-						
HFC-404a										
Commercial and Industry	2 993	2 687	2 760	2 691						
Transport	205	205	205	205						
HFC-407c										
Commercial and Industry	-	90	45	-						
HFC-507a										
Transport	-	180	180	180						
Unspecified HFCs										
Commercial and Industry	576	600	35	10						
SF_6										
Electrical Equipment	-	-	-	-						

Source: Statistics Greenland (2014a)

Emission factors

The CO_2 emission factors applied for products in 2013 are presented in Table 16.4.11. The same emission factor has been applied for 1990-2013.

Table 16.4.11 CO_2 emission factors 2013.

Product	Emission factor	Unit	Reference	IPCC Category
Limestone and dolomite use	440	kg pr tonne	IPCC, 2006	2A4d
Paraffin wax use	494	kg pr tonne	IPCC, 2006	2D2
Asphalt used for road paving	0.168	kg pr tonne	Nielsen et al., 2011	2D3b
Asphalt materials used for roofing	0.25	kg pr tonne	Nielsen et al., 2011	2D3c

The CO emission factors applied for the consumption of asphalt products in 2013 are presented in Table 16.4.12. The same emission factor has been applied for 1990-2013.

Table 16.4.12 CO emission factors 2013.

Product	Emission factor	Unit	Reference	IPCC Category
Asphalt used for road paving	0.075	kg pr tonnes	Nielsen et al., 2011	2D3b
Asphalt materials used for roofing	0.01	kg pr tonnes	Nielsen et al., 2011	2D3c

The NMVOC emission factors applied for the consumption of asphalt products and products used in the production of food and beverages in 2013 are presented in Table 16.4.13. The same emission factor has been applied for 1990-2013.

Table 16.4.13 NMVOC emission factors 2013.

Product	Emission factor	Unit	Reference	IPCC Category
Asphalt used for road paving	0.015	kg pr tonnes	Nielsen et al., 2011	2D3b
Asphalt materials used for roofing	0.08	kg pr tonnes	Nielsen et al., 2011	2D3c
Food and Beverages Industry - Beans roasted to produce coffee	0.55	kg pr tonnes	IPCC, 1997	2H2
Food and Beverages Industry - Production of bread	8	kg pr tonnes	IPCC, 1997	2H2
Food and Beverages Industry - Landings of fish and seafood	0.3	kg pr tonnes	IPCC, 1997	2H2
Food and Beverages Industry - Production of beer	0.0625	kg pr hl	Nielsen et al., 2011	2H2

For some chemicals, in the calculation of emissions from solvent use, the emission factors are precise. For others they are rough estimates. In the Danish inventory emission factors are divided into four categories: 1) chemical industry (lowest EF), 2) other industry, 3) non-industrial activities, 4) domestic and other diffuse use (highest EF). This implies that high emission factors are applicable for use of solvent containing products and lower emission factors are applicable for use in industrial processes.

The default NMVOC-CO_2 conversion factor of 0.85 * 3.667 = 3.11 is used for solvents.

The emission factors used in the Greenlandic inventory are the same as developed for the Danish inventory (please refer to Chapter 5).

16.4.4 Emissions

The greenhouse gas (GHG) emissions are listed in Table 16.4.14. The emission from industrial processes and product use accounts for 1.5 % of the Greenlandic GHG emission.

The CO_2 emission from industrial processes and product use accounts for just 0.06 % of the Greenlandic CO_2 emission (excluding net CO_2 emission from Land Use, Land Use Change and Forestry (LULUCF). The HFC emission from industrial processes and product use accounts for 100 % of the Greenlandic emission and the SF_6 emission accounts for 100 % of the Greenlandic SF_6 emission.

Table 16.4.14 Greenhouse gas emission for the year 2013.

		CO_2	HFC	SF_6
		Tonne CO_2 equivalent		
2A4	Limestone and Dolomite Use	0.00	NA	NA
2D2	Paraffin Wax Use	91.26	NA	NA
2D3	Solvent use	223.53	NA	NA
2D3	Road paving with asphalt	0.20	NA	NA
2D3	Asphalt roofing	0.04	NA	NA
2F1	Refrigeration and air conditioning	NA	8 303	NA
2G1	Electrical Equipment	NA	NA	2.7
Total emission from industrial processes and product use		315.04	8 303	2.7
Greenlandic emission (excluding net emission from LULUCF)		561 284	8 303	2.7
			%	
Emission share for industrial processes and product use		0.06	100	100

HFC is the most important GHG pollutant and accounts for 96.3 % of the GHG emission in CO_2 equivalents from industrial processes and product use. Illustration of the percentage of share in a figure is omitted due to the large share of HFC, which completely dominates as the most significant GHG pollutant from industrial processes.

CO_2

Figure 16.4.6 depicts the time-series of CO_2 emission from industrial processes. As shown by the blue curve total CO_2 emission follows the CO_2 emission from solvent use closely. The reason is that solvent use is such a dominat source to CO_2 emission with in the sector *Industrial processes and product use*.

Data on imports are used to estimate the annual use of paraffin wax use, solvent use, limestone and dolomite as well as asphalt for road paving and roofing. This causes a great deal of fluctuations from year to year. Hence, in years with none or low import of solvent, i.e. 2008 and 2010, CO_2 emission from the solvent use are also low.

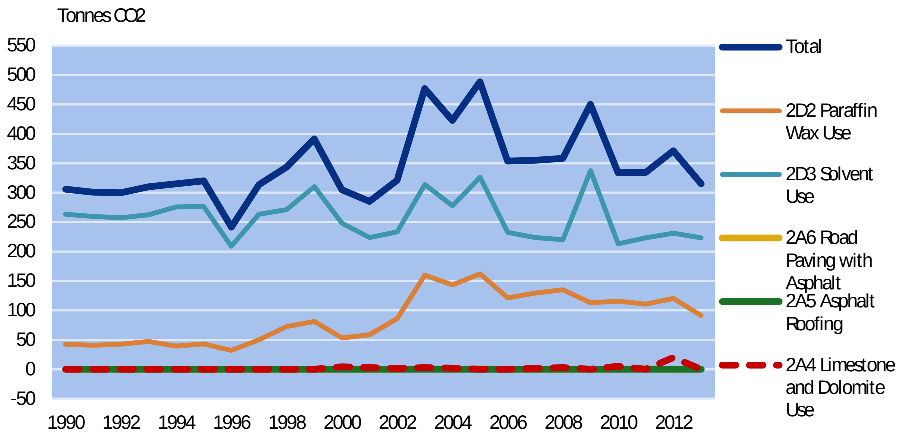

Figure 16.4.6 Emission of CO_2 from industrial processes and product use.

Emission of HFCs and SF_6 are illustrated in Figure 16.4.4 and Figure 16.4.5.

NMVOC and CO

The emissions of NMVOC and CO from industrial processes and product use in 2013 are presented in Table 16.4.15. NMVOC and CO account for 10.9 % and 0.002 % respectively, of the Greenlandic emissions for these substances.

Table 16.4.15 NMVOC and CO emission from industrial processes 2013.

		NMVOC	CO
		Tonnes	
2D3	Solvent Use	71.66	NA
2D3	Asphalt Roofing	0.01	0.00
2D3	Road Paving with Asphalt	0.02	0.09
2H2	Food and beverages industry	35.46	NA
Total emission from industrial processes and product use		107.15	0.09
Greenlandic emission		982.7	4 883.6
		%	
Emission share for industrial processes and product use		10.90	0.002

16.4.5 Uncertainties

A tier 1 uncertainty assessment has been carried out in accordance with the IPCC GPG (IPCC, 2006). The uncertainty has been estimated for all sources included in the reporting for industrial processes. The uncertainties for the activity data and emission factors are shown in Table 16.4.16.

Table 16.4.16 Uncertainties for activity data and emission factors for industrial processes.

Subsector	Pollutant	Activity data uncertainty	Emission factor uncertainty
2A4 Limestone and dolomite use	CO_2	5	5
2D2 Paraffin wax use	CO_2	5	25
2D3 Solvent use	CO_2	5	25
2D3 Road paving with asphalt	CO_2	5	25
2D3 Asphalt roofing	CO_2	5	25
2F Consumption of HFC	HFC	10	50
2G Consumption of SF_6	SF_6	10	50

The activity data comes from the import statistics, which is considered to be of high quality. Therefore the uncertainty value of the activity data has been set to 5 % for limestone and dolomite use, paraffin wax use, solvent use and asphalt used for road paving and roofing. For consumption of HFCs and SF_6 the uncertainty value of the activity data has been set to 10 %.

Regarding the emission factor uncertainty, the CO_2 emission factor for limestone and dolomite use is considered very certain. It is derived from stoichiometric calculations. Thus an emission factor of 5 % has been assumed. The uncertainty levels for paraffin wax use, solvent use, asphalt roofing and road paving are expert judgements set to 25 % for the emission factor. The emission of F-gases is dominated by emissions from refrigeration equipment and, therefore, the uncertainties assumed for this sector will be used for all the F-gases. The IPCC Guidelines (IPCC, 2000) proposed an uncertainty at 30-40 % for regional estimates. However, Greenlandic statistics have been developed over a number of years and, therefore the uncertainty on activity data is assumed to be 10 %. The uncertainty on the emission factor is, on the other hand, assumed to be 50 %. The base year for F-gases for Greenland is 1995.

The resulting uncertainties for the individual greenhouse gases and the total uncertainty on the greenhouse gas emission are shown in Table 16.4.17.

Table 16.4.17 Uncertainties for the emission estimates.

	Uncertainty %	Trend 1990-2013[1] %	Trend uncertainty %
GHG	± 49	2 248	± 1 170
CO_2	± 20	2.9	± 7.8
HFC	± 51	30 692	± 4 355
SF_6	± 51	-92	± 1.1

[1] For f-gases the base year of 1995 is used.

16.4.6 Source specific QA/QC

The elaboration of a formal QA/QC plan is to be completed.

However, the official Greenland import statistics has gone through a great deal of quality work with regard to accuracy, comparability and completeness. Statistics Greenland is responsible for the official Greenlandic import statistics, and as such responsible for the completeness of data.

Statistics on imports is reported by Statistics Greenland in form of a spreadsheet. Annual import of limestone and dolomite, paraffin wax use, asphalt materials used for roof covering and road paving, chemicals and chemical containing products, whole coffee beans and yeast for baking are compared with imports in previous years and large discrepancies are checked. The same procedure is used to ensure accuracy in annual use of F-gases and statistics on landings of fish and seafood to domestic plants.

All external data used for the emission inventory submission are archived in spreadsheets. Data are archived annually in order to ensure that the basic data for a given report are always available in their original form.

Safely stored and quality checked activity data are then processes by using a methodological approach consistent with international guidelines.

Calculated emission factors are compared with guideline emission factors to ensure that they are reasonable. The calculations follow the principle in international guidelines.

During data processing, it is checked that calculations are being carried out correctly. However, a documentation plan for this needs to be elaborated.

Time-series for activity data, emission factors and calculated emissions are used to identify possible errors in the calculation procedure. In fact, during the calculation, numerous controls take place to ensure correctness. Sums are checked in the various stages in the calculation procedure. Implied emission factors are compared to emission factors.

Every single time-series imported to the CRF Reporter is checked for annual activity, units for activity, emission factor and emissions. Additional checks are performed on the database. The database encloses every single activity data, emission factors, emission, notation key and comment imported to the CRF Reporter. In other words, no information is typed manually into the CRF Reporter. Instead, all information is imported to the CRF Reporter through the XML-file to ensure maximum accuracy and completeness.

16.4.7 Source specific recalculations and improvements

As from this 2015 emission inventory submission the CRF sector 2 *Industrial Processes and Product Use* now consists of the two formerly CRF sectors 2 and 3; the previous sectors *Industrial Processes* and *Solvent and other Product Use*.

Activity data from the previous sectors *Industrial Processes* and *Solvent and other Product Use* has been combined in the new CRF sector *Industrial Processes and Product Use*. Apart from this, data on the use of paraffin wax has been implemented to meet new requirements in the IPCC Guidelines.

In the Greenlandic emission inventory submission the following subsectors are used: *Mineral Industry* (2A), *Non-energy Products from Fuels and Solvent Use* (2D), *Product Uses as Substitutes for ODS* (2F), *Other Product Manufacture and Use* (2G) and *Other* (2H).

Priorily the notation key NE has been used regarding N_2O from fire extinguishers. However, a Danish research on the matter has showed that N_2O is not used in fire extinguishers. Since Greenland imports all fireextinguishers from Denmark, the notation key on N_2O in fire extinguishers has been changed from NE to NO concerning every year in the time-series 1990-2013. With regard to aerosol cans, we are aware that N_2O is found in the products. Since we can not find any activity data on aerosol cans, we continue to report the notation key NE for N_2O in aerosol cans.

Recalculations have not been performed in this 2015-submission.

16.4.8 Source specific planned improvements

Some planned improvements to the emission inventories are discussed below.

1) Distribution of unspecified mix of HFCs into single HFCs

An unspecified mix of HFCs is used in commercials and industries. In future inventories attempts will be made in order to distribute the unspecified mix of HFCs into single substances.

It will be investigated whether use of N_2O from solvents is occurring in Greenland.

16.4.9 References

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Statistics Greenland, 2014b: Foreign Trade, Import and Export. Available at: http://www.stat.gl/publ/da/IE/201401/pdf/Udenrigshandel%202013.pdf as "Grønlands udenrigshandel 2014" (27-03-2014). Data more detailed than the published version of the foreign trade statistics are used in order to access imports at the most detailed level.

16.5 Agriculture (CRF sector 3)

The emission of greenhouse gases from agricultural activities includes CH_4 emission from enteric fermentation, CH_4 and N_2O emission from manure management and N_2O emission from agricultural soils. The emissions are reported in CRF Tables 3.A, 3.B, 3.D and 3.G.

Emission from rice production, burning of agricultural crop residue and burning of savannas does not occur in Greenland and the CRF Tables 3.C, 3.E and 3.F have, consequently, not been completed.

Emission of non-methane volatile organic compounds (NMVOC) from agricultural activities has not been estimated.

16.5.1 Overview of sector

In CO_2 equivalents, the agricultural sector (without LULUCF) contributes with 1.6 % of the overall greenhouse gas emission (GHG) in 2013. From 1990 to 2013 emissions decreased from 9.55 Gg CO_2 equivalents to 9.45 Gg CO_2 equivalents, which correspond to a decrease of 1.0 %, see Table 16.5.1. This emission increase is primarily caused by a decrease in the number of reindeers.

Table 16.5.1 Emission of GHG in the agricultural sector 1990-2013 in Gg CO_2 equivalents.

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
CH_4	7.79	7.86	7.06	6.20	6.76	7.27	7.48	8.18	7.79	7.06
N_2O	1.76	1.78	1.60	1.44	1.57	1.67	2.29	2.04	2.51	2.60
Total	9.55	9.63	8.66	7.64	8.33	8.94	9.77	10.22	10.31	9.66
continued	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
CH_4	6.86	6.97	6.70	6.79	7.14	7.43	7.21	7.37	7.19	7.04
N_2O	2.32	2.38	2.24	2.28	2.43	2.55	2.57	2.27	3.32	2.46
Total	9.18	9.36	8.94	9.07	9.57	9.98	9.78	9.64	10.52	9.50
continued	2010	2011	2012	2013						
CH_4	7.22	7.07	7.03	6.99						
N_2O	2.42	2.64	2.50	2.46						
Total	9.64	9.71	9.53	9.45						

As showed in Figure 16.5.1, CH_4 emission contributed with 73.9 % of the total GHG emission from the agricultural sector in 2013. N_2O contributed with 26.0 % given in CO_2 equivalents, and CO_2 from liming with 0.04 %. The major part of the emission is related to livestock production, which in Greenland particularly means the production of sheep. A smaller part is related to the reindeer production. Concerning the emission from agricultural soils, the main sources are use of inorganic fertilizer, nitrogen leaching from leaching and run-off and emission from grassing animals.

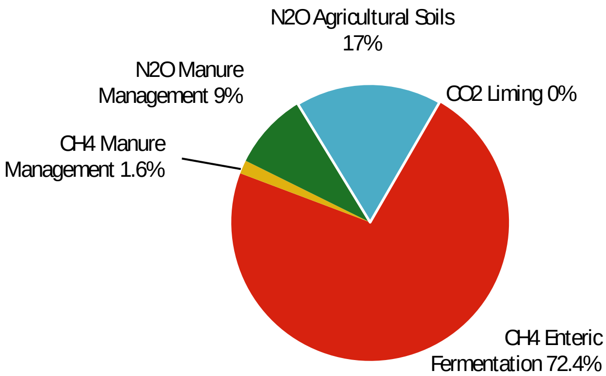

Figure 16.5.1 Emission of greenhouse gases from agriculture in 2013.

16.5.2 Source category description

The calculations of the emissions are based on methods described in the IPCC Reference Manual (IPCC, 2006) and the Good Practice Guidance (IPCC, 2000).

Statistics Greenland is responsible for collecting of data, preparation of emission inventory and reporting. Inputs of data are basically obtained from Statistics Greenland and the Greenland Agricultural Consulting Services (ACS). Data on climate are supplied by the Danish Meteorological Institute (DMI) and Greenland Survey (ASIAQ), and published by Statistics Greenland.

Table 16.5.2 List of institutes involved in the emission inventory for the agricultural sector.

References	Link	Abbrevia-tion	Data/information
Statistics Greenland	*www.stat.gl*	GST	- reporting - data collecting - no. of animal - feed import - use of inorganic fertilizer - spring temperature
The Agricultural Consulting Services	*http://nunalerineq.org/*	ACS	- N-excretion - milk yield - feed consumption and composition - stable- and grassing situation - animal growth and weight - land use - crop production
The Danish Plant Directorate	*www.pdir.dk*	PD	- N content in different fertilizer types
The Danish Agricultural Advisory Centre, Aarhus University	*www.lr.dk*	DAAC	- N content in crop residue - CO_2 from liming

16.5.3 CH_4 emission from Enteric Fermentation (CRF sector 3A)

Description

The major part of the agricultural CH_4 emission originates from digestive processes. In 2013, this source accounts for 72.47 % of the total GHG emission from agricultural activities. The emission is primarily related to ruminants, which in Greenland is sheep. In 2013 sheep contributed with 88 % and the remaining 12 % from reindeer.

Methodological issues

The implied emission factors for all animal categories are based on the Tier 2/Country Specific (CS) approach. Feed consumption and composition for sheep and reindeer is based on data from Statistics Greenland and the Agricultural Consulting Services (ACS), which has information concerning the agricultural conditions in practice. Default values for the methane conversion rate (Y_m) for sheep given by the IPCC are used, as an average of mature sheep and lambs, which mean an Y_m value of 6.5 % for sheep (changed from 6.0 % in the 2014 submission) and 6.0 % for reindeer.

Gross energy intake (GE)

The gross energy intake for sheep and reindeer is based on feeding plans for sheep from the Greenland Agricultural Consulting Services supplemented by data on imported feed. For reindeer information on gross energy intake is based on an article on reindeer management in Greenland.

Table 16.5.3 Parameters for calculation of emission from enteric fermentation.

Animal Category	Gross Energy (GE)	Methane conversion factor (Y_m)	Emission factor
	MJ pr head pr day		Kg CH_4 pr head pr yr
Sheep	28.4	0.065	12.1
Reindeer	27.5	0.060	10.7

The default CH_4 emission factor for sheep Tier 1 methodology is estimated to 8 kg CH_4 per animal per year for developed countries. The default GE is given as 20 MJ/head/yr, which is lower than the calculated GE for Greenland, and can explain the lower emission factor. Another reason could be the fact that the national value for feed intake includes lambs. After lambing, ewes and lambs are put out to pasture. Thus lambs only feed through their mother and grass. Lambs are not fed separately before slaughter.

There is no default GE for reindeer. However, Norway, Sweden and Finland have estimated gross energy intake for reindeer to 29.6 – 31.6 MJ/head/day. Based on an article on reindeer management in southern Greenland by H.E. Rasmussen in 1992, the Greenlandic gross energy intake for reindeer has been estimated to 27.5 MJ pr head pr day, which is lower than Norway, Sweden and Finland. However, holding in mind that food conditions for reindeer is more scarcely in Greenland compared to conditions in Norway, Sweden and Finland, which have more forest, and that reindeer in Greenland are not fed separately, the estimated of gross energy intake for reindeer in Greenland seems acceptable.

Activity data

Table 16.5.4 shows the development in livestock. The number of sheep is varying slightly. The number of reindeer has decreased considerably since 1990. The reindeer livestock decreased significantly in 1999, when one of two reindeer stations closed. Since 1999 there has been only one reindeer station in Greenland.

Table 16.5.4 Number of animals from 1990-2013 (CRF Table 3.A. 3.B (a) and 3.B (b).

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Sheep	19 929	20 134	17 900	16 256	17 818	19 464	20 163	23 134	19 929	21 007
Reindeer	6 000	6 000	5 600	4 300	4 600	4 600	4 600	3 800	6 000	2 106
continued	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Sheep	20 444	20 394	18 967	19 259	20 383	21 317	21 289	21 704	21 080	20 139
Reindeer	2 000	2 480	3 100	3 100	3 100	3 100	2 318	2 441	2 500	3 000
continued	2010	2011	2012	2013						
Sheep	20 729	20 232	20 107	19 994						
Reindeer	3 000	3 000	3 000	3 000						

Implied emission factor

The implied emission factor (IEF) could vary across years for sheep and reindeer due to changes in feed consumption. However, no existing data can document a change in feed intake. Therefore the same IEF is used for all years.

Time-series consistency

The emission from enteric fermentation is given in Table 16.5.5. From 1990 to 2013, the emission has decreased by 10.3 % due to a fall in number of reindeer.

Table 16.5.5 Emission of CH_4 from Enteric Fermentation 1990-2013, tonnes CH_4.

CRF 3.A	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Sheep	241	243	216	197	215	235	244	280	241	254
Reindeer	64	64	60	46	49	49	49	41	64	23
Total, tonnes CH_4	305	308	276	243	265	284	293	320	305	276
Total, tonnes CO_2 eqv.	7 627	7 689	6 907	6 063	6 615	7 112	7 324	8 008	7 627	6 912
continued	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Sheep	247	247	229	233	246	258	257	262	255	243
Reindeer	21	27	33	33	33	33	25	26	27	32
Total, tonnes CH_4	269	273	262	266	280	291	282	288	282	276
Total, tonnes CO_2 eqv.	6 714	6 827	6 561	6 650	6 989	7 272	7 054	7 212	7 040	6 889
continued	2010	2011	2012	2013						
Sheep	251	245	243	242						
Reindeer	32	32	32	32						
Total, tonnes CH_4	283	277	275	274						
Total, tonnes CO_2 eqv.	7 067	6 917	6 879	6 845						

16.5.4 CH_4 and N_2O emission from Manure Management (CRF sector 3B)

Description

The emissions of CH_4 and N_2O from manure management are given in CRF Table 3.B (a) and 3.B (b). This source contributes with 10.5 % of the total emission from the agricultural sector in 2013. The major part of the emission originates from the production of sheep.

Methodological issues

CH_4 emission

The IPCC Tier 2/CS methodology has been used for the estimation of the CH_4 emission from manure management. Calculation of volatile solids, VS is based on national value of gross energy intake (GE). Default values is used for the maximum methane producing capacity (B_0), digestibility (DE), the ash content and the methane conversion factor (MCF).

For reindeer no default values exists. Thus DE, ASH and B_o estimates for sheep are used. Sheep and reindeer are similar creatures, both ruminants. Greenlandic reindeer weigh an average of 70 kg. Greenlandic sheep weight approximately 50 kg. However, while sheep are fed relative more intensively, reindeer only feed on what they find in nature all year around. On these arguments the best estimate is to use DE, ASH and B_0 estimates for sheep on reindeer as well.

Table 16.5.6 CH_4 – Manure management – use of national parameters and IPCC default values.

Parameter	Unit	Sheep	Reindeer	Default or national value
Gross energy intake (GE)	MJ pr head pr day	28.4	27.2	National
Digestibility (DE)	Percent	60	60	IPCC default
Ash content (ASH)	Percent	8	8	IPCC default
Volatile solids (VS)	Kg VS pr head pr day	0.57	0.54	National
Max. methane producing capacity (B_0)	M^3 pr kg VS	0.19	0.19	IPCC default
CH_4 conversion factor (MCF), dry lot	Percent	1	1	IPCC default
CH_4 conversion factor (MCF), pasture, range and paddock	Percent	1	1	IPCC default
Emission factor	Kg CH_4 pr head pr yr	0.26	0.25	Tier 2

There are no changes in stable conditions or feed intake during the years 1990 to 2013. The implied emission factor is therefore the same for all years.

The default emission factor for sheep is 0.19 kg CH_4 per head per year. The higher national value is due to a higher estimate for gross energy intake.

Table 16.5.7 shows a decrease in the CH_4 emission from manure management from 1990 to 2013 by 11.0 %, which primarily is related to the fall in the production of reindeer.

Table 16.5.7 Emission of CH_4 from Manure Management 1990-2013, tonnes CH_4.

CRF 3.A	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Sheep	5.2	5.2	4.7	4.2	4.6	5.1	5.2	6.0	5.2	5.5
Reindeer	1.5	1.5	1.4	1.1	1.2	1.2	1.2	1.0	1.5	0.5
Total, tonnes CH_4	6.7	6.7	6.1	5.3	5.8	6.2	6.4	7.0	6.7	6.0
continued	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Sheep	5.3	5.3	4.9	5.0	5.3	5.5	5.5	5.6	5.5	5.2
Reindeer	0.5	0.6	0.8	0.8	0.8	0.8	0.6	0.6	0.6	0.8
Total, tonnes CH_4	5.8	5.9	5.7	5.8	6.1	6.3	6.1	6.3	6.1	6.0
continued	2010	2011	2012	2013						
Sheep	5.4	5.3	5.2	5.2						
Reindeer	0.8	0.8	0.8	0.8						
Total, tonnes CH_4	6.1	6.0	6.0	5.9						

N_2O emission

Based on information from the Greenland Agricultural Consulting Services it is estimated that for sheep 55 % of the N-excretion is taken place in stable (dry lot) and all manure is handled as solid manure. The IPCC default emission value is applied, which means 2.0 % of the N-excretion for solid manure. Sheep is grassing 45 % of the year. The emission from manure deposits on grass is included in "Pasture, Range and Paddock".

Reindeer is grassing all year. The emission from manure deposits on grass is included in "Pasture, Range and Paddock".

The total nitrogen excretion for sheep has increased by 0.3 % from 1990 to 2013 (Table 16.5.8) due to an increase in the number of sheep.

Table 16.5.8 Total nitrogen excretion for sheep, 1990-2013, tonnes N.

CRF table 3.B(b)	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
N-excreted, tonnes in total	154	155	140	122	133	143	147	161	154	138
N-excretion, tonnes in stable	66	66	59	54	59	64	67	76	66	69
continued	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
N-excreted, tonnes in total	134	137	132	133	140	146	141	144	141	138
N-excretion, tonnes in stable	67	67	63	64	67	70	70	72	70	66
continued	2010	2011	2012	2013						
N-excreted, tonnes in total	142	139	138	137						
N-excretion, tonnes in stable	68	67	66	66						

Time-series consistency

As shown in Table 16.5.9 total emission from manure management from 1990 to 2013 in CO_2 equivalents has decreased by 3.8 % due to a decrease in the number of reindeer.

Table 16.5.9 Emissions of N_2O and CH_4 from Manure Management 1990-2013.

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
N_2O emission, tonnes CO_2 eqv.	869	877	782	704	771	839	867	983	869	882
CH_4 emission, tonnes CO_2 eqv.	167	168	151	133	145	155	160	174	167	150
Total, tonnes CO_2 eqv.	1 036	1 046	933	837	915	994	1 027	1 158	1 036	1 032
continued	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
N_2O emission, tonnes CO_2 eqv.	858	860	806	818	864	903	896	914	888	854
CH_4 emission, tonnes CO_2 eqv.	145	148	143	145	152	158	153	156	153	150
Total, tonnes CO_2 eqv.	1 004	1 008	949	963	1 016	1 061	1 048	1 070	1 041	1 003
continued	2010	2011	2012	2013						
N_2O emission, tonnes CO_2 eqv.	878	857	852	848						
CH_4 emission, tonnes CO_2 eqv.	153	150	149	149						
Total, tonnes CO_2 eqv.	1 031	1 008	1 002	996						

16.5.5 N_2O emission from Agricultural Soils (CRF sector 3D)

Description

The N_2O emissions from agricultural soils CRF Table 3.D contributed in 2013 with 17.0 % of the total emission from the agricultural sector. Figure 16.5.2 shows the overall development from 1990 to 2013 and the distribution on different sources. Since 1990 N_2O emissions increased suddenly in 1996, when farmers increased their use of inorganic fertilizer significantly. From 1997 to 2007 the emission of N_2O varied with an increasing trend. In 2008 the emission of N_2O increased considerably due to a considerable increase in the use of inorganic fertilizer caused by a periodical drought in the agricultural part of Greenland. In 2009 the use of inorganic fertilizer returned back to a more normal level, thus the emission of N_2O dropped as well. In 2013 the use of inorganic fertilizer decreased by of 3.8 % compared to 2012.

Emission from inorganic fertilizer and nitrogen leaching is an essential part of the total emission from agricultural soils and contributes totally with 49.8 %. Of the remaining sources the greatest part of the emission, by 19.2

%, origins from urine and dung deposited by grazing animals. Emissions from all sources have increased from 1990 to 2013 except from grassing animal where a fall in number of reindeer has taken place.

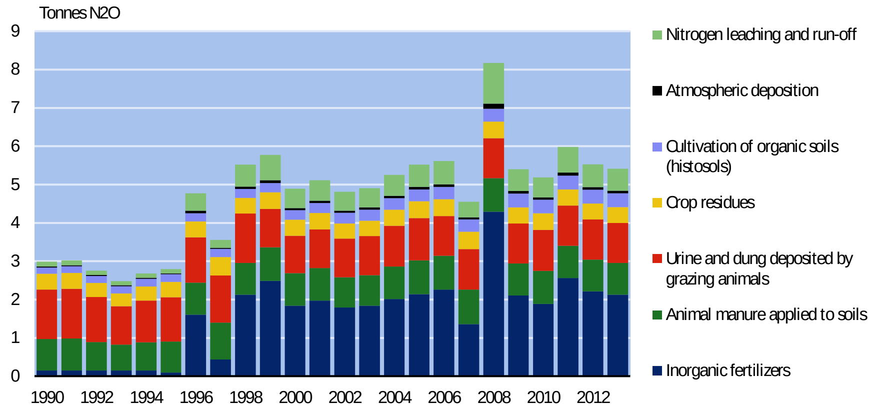

Figure 16.5.2 N_2O emissions from agricultural soils 1990-2013.

Methodological issues

To calculate the N_2O emission a combination of IPCC Tier 1a and Tier 1b is used. Tier 1b is used in calculation of emission from crop residues. Emissions of N_2O are closely related to the nitrogen balance. Data concerning the N-excretion, evaporation of ammonia from inorganic fertilizer and grassing animal are based on national values.

The NH_3 and N_2O emission factor survey is presented in Table 16.5.10 and shows that except from histosols all N_2O emission factor is based on IPCC default values. The estimated emissions from the different sub-sources are described in the text which follows.

Table 16.5.10 Emissions factor - N_2O emission from Agricultural Soils 1990-2013.

Agricultural soils – emission sources CRF Table 3.D	Ammonia emission factor	N_2O emission factor (country specific value)	N_2O emission factor (IPCC default value)
	Kg NH_3-N pr kg N	kg N_2O-N pr ha	kg N_2O -N pr kg N
a. Direct N_2O emissions from managed soils			
1. Inorganic N fertilizers	0.03 (CS)		0.01
2. Organic N fertilizers			
Animal manure applied to soils	0.20 (IPCC default)		0.01
3. Urine and dung deposited by grazin animals			0.01
4. Crop residues			0.01
Cultivation of organic soils (i.e. histosols)		1.35*	
b. Indirect N_2O emissions from managed soils			
Atmospheric deposition			0.01
Nitrogen leaching and run-off			0.0075

CS = country specific value. FracGASF, depending upon the annual mix of inorganic fertilizers.
* Include both emission from cropland and improved grassland. For further details see Section 16.6.

Direct emissions

Inorganic fertilizer

The calculation of nitrogen (N) applied to soil from use of inorganic fertilizer is based on data on imports from the Statistics Greenland. No data is available before 1994. The consumption for 1990 to 1993 is assumed to be on the same level as 1994. The nitrogen content for each fertilizer type is estimated based on expert judgement from the Danish Plant Directorate (Troels Knudsen, pers. comm.).

Table 16.5.11 shows the consumption of each type of fertilizer. Furthermore, the ammonia emission factor for each fertilizer is given, based on the values given in EMEP/EEA emission inventory guide book 2013 (Table 3-2). The emission factors are depending on the mean spring temperature estimated to seven degrees in Greenland. The spring temperature has to reflect the time where the fertilizers are applied, which in Greenland normally is June.

Table 16.5.11 Inorganic fertilizer consumption 2013 and the NH_3 emission factors.

Inorganic fertilizer	Calculation of ammonia emission factor[1]	NH_3 emission factor[1] kg NH_3-N pr kg N	Consumption[2] t N
Fertilizer type			
Ammonium sulphate	0.0130	1.30	NO
Ammonium nitrate	0.0370	3.70	NO
Calcium ammonium nitrate	0.0370	3.70	NO
Anhydrous ammonia	0.0110	1.10	NO
Urea	0.2430	24.30	NO
Nitrogen solutions	0.0481	4.81	NO
Ammonium phosphates	0.1130	11.30	NO
Other NK and NPK	0.0370	3.70	135
Total use of N in inorganic fertilizer			135
National emission of NH_3-N, tonnes	4.1		
Average NH_3-N emission (FracGASF)	0.03		

*ts= means spring temperature=7 degree

[1]) EMEP/EEA (2013).

[2]) Statistics Greenland and the Danish Plant Directorate

The Greenlandic value for the FracGASF is estimated to 0.03 in 2013, which is considerably lower than the recommended default value 0.10 (IPCC 2006. Table 11-3). The major part of the fertilizer types used in Greenland is related to NPK fertilizer where the emission factor is quite low, i.e. 0.0370 kg NH_3-N pr kg N. Before 1995 urea accounted for a higher fraction. The value of FracGASF for these years is estimated to 0.03-0.20.

Table 16.5.12 FracGASF, 1990-2013.

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
FracGASF	0.20	0.20	0.20	0.20	0.20	0.16	0.04	0.06	0.03	0.03
continued	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
FracGASF	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.04	0.03	0.03
continued	2010	2011	2012	2013						
FracGASF	0.03	0.03	0.03	0.03						

Table 16.5.13 shows an increase in use of fertilizer and a particularly high increase in 2008. Due to a relatively small number of farms the individual handling of one farmer has a high effect on the total consumptions. With consumption of fertilizers being based on imports of fertilizers it is not possible to account for fertilizers bought for stockpiling. Thus it is possible that the relative high increase in use of fertilizers in 2008 is due to stockpiling. Another explanation could be that both 2007 and 2008 were relative dry years leading to a considerable decrease in amount of hey harvested. Hence, it is possible that farmers have tended to increase the use of fertiliz-

ers in 2008 to produce more feed. In 2013 the use of inorganic fertilizers decreased 3.8 %.

Table 16.5.13 Nitrogen applied as fertilizer to agricultural soils 1990-2013.

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
N content in inorganic fertilizer, tonnes N	9	9	9	9	9	6	102	28	135	158
NH_3-N emission, tonnes	2	2	2	2	2	1	4	2	4	5
N in fertilizer applied on soil, tonnes N	7	7	7	7	7	5	98	26	131	154
N_2O emission, tonnes	0.15	0.15	0.15	0.15	0.15	0.10	1.60	0.43	2.13	2.49
continued	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
N content in inorganic fertilizer, tonnes N	117	126	114	117	128	136	144	86	273	134
NH_3-N emission, tonnes	4	4	3	4	4	4	4	3	8	4
N in fertilizer applied on soil, tonnes N	113	122	111	113	124	132	139	83	265	130
N_2O emission, tonnes	1.84	1.97	1.79	1.84	2.01	2.14	2.26	1.36	4.29	2.10
continued	2010	2011	2012	2013						
N content in inorganic fertilizer, tonnes N	120	163	141	135						
NH_3-N emission, tonnes	4	5	4	4						
N in fertilizer applied on soil, tonnes N	116	158	136	131						
N_2O emission, tonnes	1.89	2.56	2.21	2.13						

Manure applied to soil

The amount of nitrogen applied to soil from sheep on stables is estimated as the N-excretion in stables minus the ammonia emission, which occur in stables, under storage and in relation to the application of manure. There are no measurements of ammonia emission from stables in Greenland. Thus IPCC default is used. However, the FracGASM default at 0.20 (IPCC 2006. Table 11-3) match the Danish emission ammonia from sheep, which are estimated to 24 % in 1990 reduced to 19 % in 2008. A lower ammonia emission in Greenland is expected due to the cold climate, but on the other hand no ammonia reducing measures are implemented as in Denmark. The FracGASM at 0.20 are therefore considered as reliable.

Table 16.5.14 shows the development in nitrogen excretion in stables, the estimated amount of N applied on soil and the N_2O emission.

Table 16.5.14 Nitrogen applied as manure to agricultural soils 1990-2013.

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
N-excretion in stable, tonnes N	66	66	59	54	59	64	67	76	66	69
NH_3-N emission, tonnes N	13	13	12	11	12	13	13	15	13	14
N in manure applied on soil, tonnes N	53	53	47	43	47	51	53	61	53	55
N_2O emission, tonnes N_2O	0.83	0.84	0.74	0.67	0.74	0.81	0.84	0.96	0.83	0.87
continued	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
N-excretion in stable, tonnes N	67	67	63	64	67	70	70	72	70	66
NH_3-N emission, tonnes N	13	13	13	13	13	14	14	14	14	13
N in manure applied on soil, tonnes N	54	54	50	51	54	56	56	57	56	53
N_2O emission, tonnes N_2O	0.85	0.85	0.79	0.80	0.85	0.88	0.88	0.90	0.87	0.84
continued	2010	2011	2012	2013						
N-excretion in stable, tonnes N	68	67	66	66						
NH_3-N emission, tonnes N	14	13	13	13						
N in manure applied on soil, tonnes N	55	53	53	53						
N_2O emission, tonnes N_2O	0.86	0.84	0.83	0.83						

Crop residue

The cultivated area is approximately 1,079 ha with the main part as grass fields, only 10.5 ha are used for potato production. The cultivated area decreased from 2009 to 2012 due to the shutdown of four farms. To estimate the emission from crop residue, IPCC Tier 1b has been applied. N_2O emissions from crop residues are calculated based on the total above- and belowground N-content in crop residue returned to soil, which in Greenland includes residue of leafs and roots from grass fields and the top and root from potatoes. Harvest of potatoes and grass-clover are calculated based on relatively few observations related to Danish conditions, but are at present the best available data.

Nitrogen content in grass-clover and potatoes is calculated by using IPCC default factors (IPCC 2006, Table 11.2). However, the dry matter fraction (DRY) of harvested grass-clover is taken from the Danish Emission Inventory where a dry matter fraction of 0.27 is used instead of the IPCC default DRY that is 0.9. In future inventories the dry matter fraction for grass-clover will be changed to the IPCC default factor.

Table 16.5.15 N-content in crop residues 2013.

	Husks	Stubble	Top	Leafs	Frequency of ploughing	Nitrogen content in crop residue	
Crop type	kg N pr ha				No. of years between ploughing	kg N pr ha	kg N
Potatoes	7.1	-	4.8	-	1	12.0	125
Grass-Clover mixtures in rotation	-	15.5	-	9.1	1 (*)	24.6	26 301
Total N from crop residue, kg							26 426

Reference: National data and IPCC 2006 (Table 11.2).
(*) The number of years between ploughing will in future inventories be changed from 1 to 5 for grass-clover.

To calculate the N_2O emission the IPCC standard emission factor 1.0 % is used. The national emission from crop residues has been relatively stable from 1990 to 2013 (Table 16.5.16).

Table 16.5.16 Emission from crop residues 1990-2013.

Crop residue	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Potatoes, kg N	-	-	-	-	-	-	-	-	-	-
Grass-Clover, kg N	26 215	26 485	23 546	21 384	23 439	25 604	26 523	30 431	26 215	27 633
Crop residue total, kg N	26 215	26 485	23 546	21 384	23 439	25 604	26 523	30 431	26 215	27 633
N_2O emission, kg	412	416	370	336	368	402	417	478	412	434
continued	2000	2001	2004	2005	2006	2007	2008	2009	2010	2011
Potatoes, kg N	-	60	60	60	60	60	60	60	60	78
Grass-Clover, kg N	26 893	26 827	24 950	25 334	26 813	28 041	28 004	28 550	27 729	26 492
Crop residue total, kg N	26 893	26 887	25 010	25 394	26 872	28 101	28 064	28 610	27 789	26 569
N_2O emission, kg	423	423	393	399	422	442	441	450	437	418
continued	2010	2011	2012	2013						
Potatoes, kg N	78	125	125	125						
Grass-Clover, kg N	27 268	26 614	26 450	26 301						
Crop residue total, kg N	27 345	26 739	26 575	26 426						
N_2O emission, kg	430	420	418	415						

Cultivation of histosols

N_2O emissions from histosols are based on the area with organic soils multiplied by the emission factor of 1.35 kg N_2O-N pr. kg N in 2013. See Section 16.6 on LULUCF for further description on cultivation of histosols.

Table 16.5.17 shows an increase in the N_2O emission from 1990 to 2013 due to extend of the agricultural area.

Table 16.5.17 Activity data and emission from cultivation of histosols 1990-2013.

CRF – Table 3.D	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Cultivated histosols, ha	123	129	136	142	149	155	161	168	174	181
N_2O emission, kg	160	169	177	186	194	203	211	220	228	237
continued	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Cultivated histosols, ha	187	195	214	220	223	232	242	245	250	274
N_2O emission, kg	245	260	285	293	297	308	321	325	332	365
continued	2010	2011	2012	2013						
Cultivated histosols, ha	268	270	268	270						
N_2O emission, kg	357	364	361	364						

Pasture, Range and Paddock

The amount of nitrogen deposited on grass includes grassing from reindeer 365 days a year and from sheep 164 days a year. An ammonia emission factor of 7 % is used for all animal categories based on investigations from the Netherlands and the United Kingdom (Jarvis et al., 1989a. Jarvis et al., 1989b and Bussink, 1994). EMEP/EEA Emission Inventory Guidebook 2013 use a similar emission factor at 6 % for grassing dairy cattle (calculated from 3B, Appendix B).

Table 16.5.18 shows the estimated values of N-excretion from grassing animals, ammonia emission and N_2O emission. As a consequence of an overall drop in number of reindeer N_2O emission has decreased from 1990 to 2013.

Table 16.5.18 Emission from grassing animals 1990-2013.

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
N-excretion on grass, tonnes N	88	89	81	69	75	79	81	84	88	69
NH_3-N emission, tonnes	6	6	6	5	5	6	6	6	6	5
N deposited on grass, tonnes N	82	83	75	64	69	73	75	78	82	64
N_2O emission, tonnes	1.29	1.30	1.18	1.00	1.09	1.15	1.18	1.23	1.29	1.01
continued	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
N-excretion on grass, tonnes N	67	69	69	70	73	75	71	73	71	72
NH_3-N emission, tonnes	5	5	5	5	5	5	5	5	5	5
N deposited on grass, tonnes N	62	64	64	65	68	70	66	68	66	67
N_2O emission, tonnes	0.97	1.01	1.01	1.02	1.06	1.10	1.03	1.06	1.04	1.05
continued	2010	2011	2012	2013						
N-excretion on grass, tonnes N	73	72	72	71						
NH_3-N emission, tonnes	5	5	5	5						
N deposited on grass, tonnes N	68	67	67	66						
N_2O emission, tonnes	1.07	1.05	1.05	1.04						

Indirect emissions

Atmospheric deposition

Atmospheric deposition includes ammonia emission from manure management, use of inorganic fertilizer and from grassing animals.

The N_2O emission from atmospheric deposition has more than doubled from 1990 to 2013. While a fall in number of reindeer is compensated by an increase in the number of sheep, the increasing use of inorganic fertilizer has increased NH_3-N emission from inorganic fertilizer by 123.7 % from 1990 to 2013.

Table 16.5.19 Emission from atmospheric deposition 1990-2013.

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
NH_3-N manure management, tonnes	13	13	12	11	12	13	13	15	13	14
NH_3-N inorganic fertlizer, tonnes	2	2	2	2	2	1	4	2	4	5
NH_3-N pasture, tonnes	6	6	6	5	5	6	6	6	6	5
NH_3-N total, tonnes	21	21	19	17	19	19	23	23	23	24
N_2O emission, tonnes	0.03	0.03	0.03	0.03	0.03	0.02	0.07	0.03	0.06	0.08
continued	2001	2002	2002	2003	2004	2005	2006	2007	2008	2009
NH_3-N manure management, tonnes	13	13	13	13	13	14	14	14	14	13
NH_3-N inorganic fertlizer, tonnes	4	4	3	4	4	4	4	3	8	4
NH_3-N pasture, tonnes	5	5	5	5	5	5	5	5	5	5
NH_3-N total, tonnes	22	22	21	21	22	23	23	23	27	22
N_2O emission, tonnes	0.06	0.06	0.05	0.06	0.06	0.07	0.07	0.05	0.13	0.06
continued	2010	2011	2012	2013						
NH_3-N manure management, tonnes	14	13	13	13						
NH_3-N inorganic fertlizer, tonnes	4	5	4	4						
NH_3-N pasture, tonnes	5	5	5	5						
NH_3-N total, tonnes	22	23	23	22						
N_2O emission, tonnes	0.06	0.08	0.07	0.06						

Nitrogen leaching and Run-off

The amount of nitrogen lost by leaching and run-off is calculated by using the IPCC default FracLEACH-(H) at 0.3 (IPCC 2006, Table 11-3).

The N_2O emission from N-leaching and runoff more than doubled from 1990 to 2008. However, lately in 2009-2010 and 2011-2013 total N_2O emission has decreased each year. In 2013 the N_2O emission from N-leaching and runoff amounted to 0.57 tonnes, which is 356 % more than in 1990.

From 1990 ton 2013 total nitrogen content in manure has decreased due to a fall in the reindeer production. However, in the same period the use of inorganic fertilizers has increased significantly causing the overall N_2O emission from N-leaching and runoff to increase.

Table 16.5.20 Emission from N-leaching and runoff 1990-2013.

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
N-excretion total, tonnes N	154	155	140	122	133	143	147	161	154	138
N in inorganic fertilizer, tonnes	9	9	9	9	9	6	102	28	135	158
N_2O emission, tonnes	0.13	0.13	0.12	0.11	0.12	0.11	0.45	0.21	0.57	0.66
continued	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
N-excretion total, tonnes N	134	137	132	133	140	146	141	144	141	138
N in inorganic fertilizer, tonnes	117	126	114	117	128	136	144	86	273	134
N_2O emission, tonnes	0.51	0.54	0.49	0.50	0.55	0.58	0.61	0.41	1.06	0.57
continued	2010	2011	2012	2013						
N-excretion total, tonnes N	142	139	138	137						
N in inorganic fertilizer, tonnes	120	163	141	135						
N_2O emission, tonnes	0.52	0.67	0.59	0.57						

Activity data

Table 16.5.21 provides an overview on activity data from 1990 to 2013 used to the estimation of N_2O emission from agricultural soils. For all emission sources the unit tonnes of nitrogen are used except from cultivation of histosols, where the unit is given as hectare.

Table 16.5.21 Activity data - agricultural soils 1990-2013, tonnes N (cultivation of histosols = ha).

CRF – Table 3.D	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
A. Direct N_2O emissions from managed soils										
Inorganic fertilizer	9	9	9	9	9	6	102	28	135	158
Animal manure applied to soils	53	53	47	43	47	51	53	61	53	55
Urine and dung deposited by grazing animals	82	83	75	64	69	73	75	78	82	64
Crop residue	26	26	24	21	23	26	27	30	26	28
Cultivation of histosols	123	129	136	142	149	155	161	168	174	181
b. Indirect N_2O emissions from managed soils										
Atmospheric deposition	2	2	2	2	2	1	4	2	4	5
Nitrogen leaching and run-off	11	11	10	9	10	10	39	17	48	56
continued	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
A. Direct N_2O emissions from managed soils										
Inorganic fertilizer	117	126	114	117	128	136	144	86	273	134
Animal manure applied to soils	54	54	50	51	54	56	56	57	56	53
Urine and dung deposited by grazing animals	62	64	64	65	68	70	66	68	66	67
Crop residue	27	27	25	25	27	28	28	29	28	27
Cultivation of histosols	187	195	214	220	223	232	242	245	250	274
b. Indirect N_2O emissions from managed soils										
Atmospheric deposition	4	4	3	4	4	4	4	3	8	4
Nitrogen leaching and run-off	43	46	42	43	46	49	52	34	90	48
continued	2010	2011	2012	2013						
A. Direct N_2O emissions from managed soils										
Inorganic fertilizer	120	163	141	135						
Animal manure applied to soils	55	53	53	53						
Urine and dung deposited by grazing animals	68	67	67	66						
Crop residue	27	27	27	26						
Cultivation of histosols	268	270	268	270						
b. Indirect N_2O emissions from managed soils										
Atmospheric deposition	4	5	4	4						
Nitrogen leaching and run-off	44	57	50	49						

Time-series consistency

The N_2O emissions from agricultural soils have increased from 6.0 tonnes N_2O in 1990 to 16.3 tonnes N_2O in 2008. The more than doubled emission is a consequence of a significant increase in use of nitrogen in inorganic fertilizer. In 2013 N_2O emissions from agricultural soils decreased primarily due to a fall in the use of inorganic fertilizer.

Table 16.5.22 Emissions of N_2O from Agricultural Soils 1990–2013, tonnes N_2O.

CRF – Table 3.D	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Total N_2O emission	3.0	3.0	2.8	2.5	2.7	2.8	4.8	3.6	5.5	5.8
A. Direct N_2O emissions from managed soils										
Inorganic fertilizer	0.1	0.1	0.1	0.1	0.1	0.1	1.6	0.4	2.1	2.5
Animal manure applied on soil	0.8	0.8	0.7	0.7	0.7	0.8	0.8	1.0	0.8	0.9
Urine and dung deposited by grazing animals	1.3	1.3	1.2	1.0	1.1	1.2	1.2	1.2	1.3	1.0
Crop residue	0.4	0.4	0.4	0.3	0.4	0.4	0.4	0.5	0.4	0.4
Cultivation of histosols	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
b. Indirect N_2O emissions from managed soils										
Atmospheric deposition	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.1	0.1
Nitrogen leaching and run-off	0.1	0.1	0.1	0.1	0.1	0.1	0.5	0.2	0.6	0.7
continued	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Total N_2O emission	4.9	5.1	4.8	4.9	5.3	5.5	5.6	4.6	8.2	5.4
A. Direct N_2O emissions from managed soils										
Inorganic fertilizer	1.8	2.0	1.8	1.8	2.0	2.1	2.3	1.4	4.3	2.1
Animal manure applied on soil	0.8	0.8	0.8	0.8	0.8	0.9	0.9	0.9	0.9	0.8
Urine and dung deposited by grazing animals	1.0	1.0	1.0	1.0	1.1	1.1	1.0	1.1	1.0	1.0
Crop residue	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Cultivation of histosols	0.2	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.4
b. Indirect N_2O emissions from managed soils										
Atmospheric deposition	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Nitrogen leaching and run-off	0.5	0.5	0.5	0.5	0.5	0.6	0.6	0.4	1.1	0.6
continued	2010	2011	2012	2013						
Total N_2O emission	5.2	6.0	5.5	5.4						
A. Direct N_2O emissions from managed soils										
Inorganic fertilizer	1.9	2.6	2.2	2.1						
Animal manure applied on soil	0.9	0.8	0.8	0.8						
Urine and dung deposited by grazing animals	1.1	1.1	1.0	1.0						
Crop residue	0.4	0.4	0.4	0.4						
Cultivation of histosols	0.4	0.4	0.4	0.4						
b. Indirect N_2O emissions from managed soils										
Atmospheric deposition	0.1	0.1	0.1	0.1						
Nitrogen leaching and run-off	0.5	0.7	0.6	0.6						

16.5.6 Uncertainties

A tier 1 uncertainty assessment has been carried out in accordance with the IPCC Guidelines (IPCC, 2006). The uncertainty has been estimated for all sources included in the reporting for agricultural sector. The uncertainties for the activity data and emission factors are shown in Table 16.5.23.

Table 16.5.23 Uncertainties for activity data and emission factors for agriculture.

Subsector	Pollutant	Activity data uncertainty	Emission factor uncertainty
3A Enteric Fermentation	CH_4	10	100
3B Manure Management	CH_4	10	100
3B Manure Management	N_2O	10	100
3D Agricultural soils	N_2O	20	50
3G Liming	CO_2	5	50

The resulting uncertainties for the individual greenhouse gases and the total uncertainty on the greenhouse gas emission are shown in Table 16.5.24.

Table 16.5.24 Uncertainties for the emission estimates.

	Uncertainty %	Trend 1990-2013 %	Trend uncertainty %
GHG	± 74	-1.1	± 13.9
CO_2	± 50	-50.0	± 3.5
CH_4	± 98	-10.3	± 12.4
N_2O	± 49	39.8	± 35.5

16.5.7 Source specific QA/QC

The elaboration of a formal QA/QC plan is to be completed.

However, data on livestock, land-use categories, inorganic fertilizers and cultivation of histosols has gone through a great deal of quality work with regard to accuracy, comparability and completeness.

All external data used for the emission inventory submission are archived in spreadsheets. Data are archived annually in order to ensure that the basic data for a given report are always available in their original form.

Annual data on livestock, land-use categories, inorganic fertilizers and cultivation of histosols are compared with previous years and large discrepancies are checked.

Safely stored and quality checked activity data are then processes by using a methodological approach consistent with international guidelines.

Calculated emission factors are compared with guideline emission factors to ensure that they are reasonable. The calculations follow the principle in international guidelines.

During data processing, it is checked that calculations are being carried out correctly. However, a documentation plan for this needs to be elaborated.

Time-series for activity data, emission factors and calculated emissions are used to identify possible errors in the calculation procedure. In fact, during the calculation, numerous controls take place to ensure correctness. Sums are checked of the various stages in the calculation procedure. Implied emission factors are compared to emission factors.

Every single time-series imported to the CRF Reporter is checked for annual activity, units for activity, emission factor and emissions. Additional checks are performed on the database. The database encloses every single activity data, emission factors, emission, notation key and comment imported to the CRF Reporter. In other words, no information is typed manually into the CRF Reporter. Instead, all information is imported to the CRF Reporter through the XML-file to ensure maximum accuracy and completeness.

16.5.8 Source specific recalculations and improvements

A large range of emission factors have been revised in this 2015 submission according to new IPCC Guidelines (IPCC, 2006). Besides from that new calculations have been made to account for both above and below ground material in crop residues.

Recalculations have not been performed in this 2015-submission.

16.5.9 Source specific planned improvements

The Greenlandic emission inventory for the agricultural sector largely meets the request as set down in the IPCC Good Practice Guidance. Thus for the moment improvements especially concern the QA/QC practice.

16.5.10 References

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http://bank.stat.gl/database/Greenland/Energy/Climate/Climate.asp

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16.6 LULUCF (CRF sector 4)

16.6.1 Overview of LULUCF

This LULUCF chapter covers only the territory of Greenland. Greenland is part of the Danish Kingdom.

Figure 16.6.1 Municipalities and major cities in Greenland.

Greenland is the world's largest non-continental island located on the northern American continent between the Arctic Ocean and the North Atlantic Ocean, northeast of Canada. The northernmost point of Greenland, Cape Morris Jesup, is only 740 km from the North Pole. The southernmost point is Cape Farewell, which lies at about the same latitude as Oslo in Norway. Geographical coordinates are 72 00 N, 40 00 W.

Greenland is covering approximately 2,166,086 km^2. It has been estimated that 81 % is covered permanently with ice leaving only 410,449 km^2 ice free. The distance from the South to the North is 2,670 km, and from East to West 1,050 km.

The terrain is flat to gradually sloping ice cap, which covers all but a narrow, mountainous, barren, rocky coast. The ice cap is up to 3 km thick, and contains 10 per cent of the world's resources of freshwater.

The climate is arctic to sub-arctic with cool winters and cold summers in which the mean temperature does not exceed 10° C.

The mean temperature in January is for Nuuk, -8.6°, Kangerlussuaq, -17.0° and Ilulissat -9.6° (2007) and for July: Nuuk 7.7°, Kangerlussuaq 11.5° and Ilulissat 9.6° (2007).

Greenland is normally defined as having three different climatic zones. For the purpose of reporting is used the definition "Polar and Moist" according to IPCC 2006 Guidelines although some areas may qualify as arctic deserts.

The sparse population is confined to small settlements along the coast, but close to one-quarter of the population lives in the capital, Nuuk. The total population in January 2013 was 56 370 inhabitants.

Due to the cold climate and the small constant population there is almost no land use change occurring. The total area with Forests has been estimated to 232.5 hectares and 10.5 hectares with Cropland. Grassland is divided into improved Grassland covering 1069 hectares and unimproved Grassland covering 241 000 hectares. Wetlands consist of man made water reservoirs – in total 1076 hectares. Settlements cover 5650 hectares. Land classified as "Other Land" is then 99.9 % of the total area.

In the following text the abbreviations are used in accordance with definitions in the IPCC guidelines:

A:	Afforestation, areas with forest established after 1990 under Article 3.3.
R:	Reforestation, areas which have temporarily been unstocked for less than 10 years - included under Article 3.4.
D:	Deforestation, areas where forests are permanently removed to allow for other land use, included under Article 3.3.
FF:	Forest remaining Forest, areas remaining forest after 1990.
FL:	Forest Land meeting the definition of forests.
CL:	Cropland.
GL:	Grassland.
SE:	Settlements.
OL:	Other land, unclassified land.
HWP:	Harvested Wood Products.

The LULUCF sector differs from the other sectors in that it contains both sources and sinks of carbon dioxide. LULUCF are reported in the CRF format. Removals are given as negative figures and emissions are reported as positive figures in accordance with the guidelines.

In total the LULUCF sector has been estimated as a net source of 1.12 Gg CO_2 equivalents in 2013 equivalent to 0.2 % of the total Greenlandic emission.

The overall land use change from 1990 to 2013 is very small. Afforestation has been made on 14 hectares. No deforestation has occurred and the Cropland area has increased from none to 10.5 hectares.

The emission data are reported in the new CRF format under IPCC categories 4A (Forestry), 4B (Cropland), 4C (Grassland), 4D (Wetlands), 4E (Settlements) and 4F (Other Land).

Fertilisation of forests and other land is not occurring and all fertilizer consumption is therefore reported in the agricultural sector. No drainage of forest soils is made. All liming is reported under Grassland because liming is not occurring in the forests and the very small area with Cropland. Field burning of wooden biomass is not occurring. Wildfires may occur sporadic in the mountains and these are reported as "Other land". Hence wildfires are reported as NO.

Table 16.6.1 gives an overview of the emission from the LULUCF sector in Greenland. The Forests are a net sink. Cropland is ranging from being zero in 1990 (no Cropland was occurring in 1990) to being a net source in 2013. GL has been estimated to be a small net source in 2013 due a decrease in the improved area with grassland.

Table 16.6.1 Overall emission (´kt CO_2) from the LULUCF sector in Greenland, 1990-2013.

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	1990	1995	2000	2005	2010	2011	2012	2013
4. Land use, land-use change and forestry(2)	0.21	0.38	0.52	0.63	1.42	1.21	1.32	1.12
A. Forest land	IE,NO	-0.02	-0.03	-0.05	-0.04	-0.04	-0.04	-0.05
B. Cropland	NO	NO	NO	0.02	0.03	0.05	0.05	0.05
C. Grassland	0.21	0.41	0.55	0.66	1.42	1.20	1.31	1.12
D. Wetlands	NO	NO	NO	NO	NO	NO	NO	NO
E. Settlements	NO	NO	NO	NO	NO	NO	NO	NO
F. Other land	NO	NO	NO	NO	NO	NO	NO	NO
G. Harvested wood products	NO	NO	NO	NO	NO	NO	NO	NO

16.6.2 Forest remaining forest (4A1)

Forests and forest management

Greenland has virtually no forests and therefore there exist no official forest statistics. All forests are situated in the most southern part of Greenland. In an attempt to introduce trees to Greenland research were carried out to find species adaptable to the Greenlandic climate. This resulted in establishment of the Greenlandic Arboretum, which covers 150 hectares out of the total area of 218.5 hectares, Figure 16.6.2 and Table 16.6.2. Information about the Greenlandic Arboret can be found at:

http://ign.ku.dk/om/arboreter/arboret-groenland/skovplantninger/

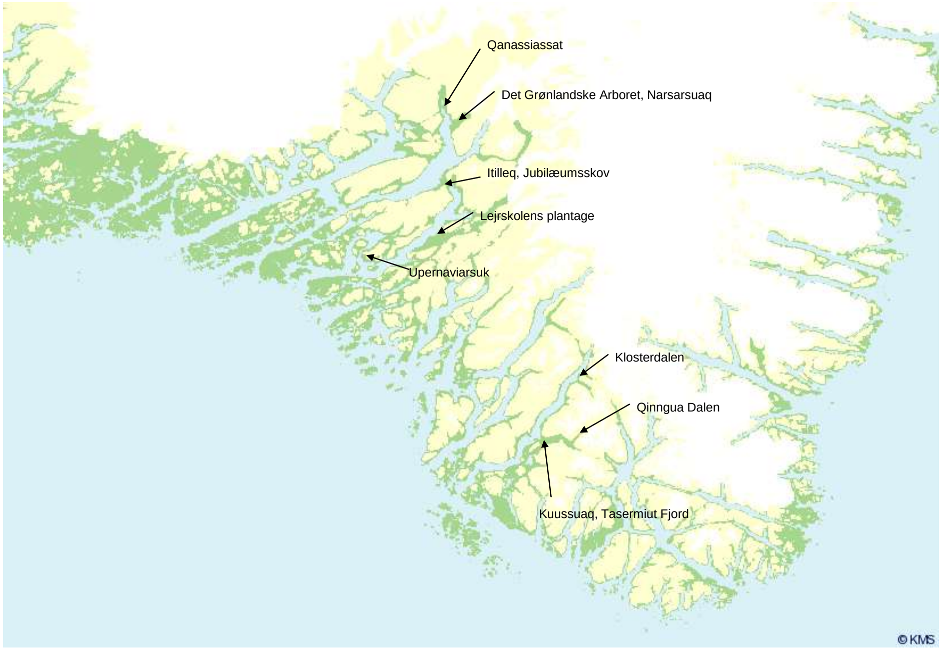

Figure 16.6.2 The position of the Greenlandic forests (Courtesy to Rasmus Enoksen Christensen).

Table 16.6.2 Forests in Greenland 1990 and 2010.

Location	Established	Dominant tree	Area,ha	1990 average tree height (m)	2013 average tree height	Density 1990 (trees pr ha)	Density 2009
Qinngua Valley	Natural	Birch and mountain ash	45	n.a	6	100	100
Qanassiassat Forest	1953-63	Conifer	1	5	11.76	1500	1000
Kuussuaq Forest	1962-64 -1982	Conifer	5	3	11.1	1300	900
Kuussuaq Forest	2008	Conifer	3	***	< 1	***	3500
Greenland Arboretum	(1976-1980)	Conifer	3	4	7	300	300
Greenland Arboretum	1980 -	Conifer	150	2	3	1500	1700
Itilleq	2004-2005	Conifer	6	***	< 1	***	3500
Upernaviarsuk	1954	Conifer	0,5	1,5	3	200	200
Lejrskolen	1999-2005	Conifer	4	***	1	***	2500
Klosterdalen	2000	Conifer	1	***	1	***	2000
Total			232.5				

Forest definition

The forest definition adopted in Greenland is almost identical to the FAO definition (TBFRA, 2000). It includes "wooded areas larger than 0.5 ha, that are able to form a forest with a height of at least 5 m and crown cover of at least 10 %. The minimum width is 20 m." Temporarily non wooded areas, fire breaks, and other small open areas, that are an integrated part of the forest, are also included. However, due to extreme slow growing rates many of the forests are currently below 5 meters height.

Figure 16.6.3 shows a picture of the best developed forest in Greenland.

Figure 16.6.3 The forest in Kuusuaq. Photo: Rasmus E. Christensen, 2005.

Of special interest is the forest in Qinngua Valley. The Qinngua Valley is situated in a remote area. It consists of natural birch (*Betula pubescens spp. czerepanovii* and *B. glandulosa.)* which develops to forest like trees probably due to an introgressiv hybridisation (Rasmus Enoksen Christensen). This forest will probably not follow the FAO forest definition but are included in the inventory as a sub-division under forests. The Qinngua-valley is not included in the FAO forest statistics.

Figure 16.6.4 Kuussuaq, Tasermiut fjor. Photo: Rasmus Christensen, Juni 2004.

Methodological issues for forests

Estimation of volume, biomass and carbon pools

Due to lack of precise data and slow growth rates, simple functions are used that only include the height of the trees and the number per hectare.

The height of the trees has been estimated by Rasmus Enoksen Christensen based on data from the Aboretum. It is assumed that the trees are conical and the stem diameter at ground level is based on the general formula for even-aged forests (Vanclay, 2009).

$$D = \beta(H - 1.3) / \ln(N) \qquad \text{(eq.1)}$$

Where:
D = diameter at breast height, cm
ß = slope, species dependent
H = Height of the trees (meters)
N = Number of trees per hectare

Eq. 1 has been simplified by omitting the breast height (1.3 meters) to

$$D = \beta(H)/\ln(N) \qquad \text{(eq.2)}$$

so that D is representing the diameter at ground level. The ß-value used is given in Table 16.6.3.

Table 16.6.3 ß-values for estimating the diameter of trees (from Vanclay, 2009).

	Betula, spp	Conifers
ß-values	6.54	7.51

In order to estimate the C stock and C stock change is used the average default values from the IPCC 2006 guidelines for BCEF, density, C-content and Root-Shoot ratio for Boreal stands with a growing stock level of 21-50 m^3, IPCC table 4.5, pp 4.50. The values are given in Table 16.6.4.

Table 16.6.4 Biomass expansion factors used for Greenland.

		Qinngua Walley (Betula, spp.) Birch	Conifers	Orpiuteqarfia (Larix sibirica) Sibirian Larch)
BCEF	Dimensionless	0.7	0.66	0.78
Density	kg dry matter per litre	0.51	0.4	0.46
C-content	kg C per kg dry matter	0.48	0.51	0.51
Root-shoot-ratio	Dimensionless	0.39	0.39	0.39
Dead Organic Matter	kg per kg aboveground biomass	0.1	0.2	0.1

Source: IPCC 2006 guidelines.

Dead wood volume, biomass and carbon

The volume of dead organic matter (DOM) is estimated as a fraction of the aboveground biomass (Table 16.6.4). It is assumed that litter is included in DOM.

Forest soils: forest floors and mineral soil

Following the cold climate and the slow growing rate it is assumed that no changes takes place in C-stock in the soil and hereby following the IPCC 2006 guidelines at Tier 1 level.

Uncertainties and time series consistency

The uncertainty in estimation of the C stock changes in the Greenlandic forests is very high. As there are very limited resources to visit and monitor in the remote areas there are very few data available. The current inventory is therefore based on the best knowledge available. It should also be taken into consideration that the importance of the forest sector in Greenland is marginal as only very little thinning is taking place as well as no deforestation and that the effect on the inventory is almost not measurable.

In the overall uncertainty section for the LULUCF is made a Tier 1 uncertainty analysis.

QA/QC and verification

Focus on the measurements of carbon pools in forest in Greenland will contribute to QA/QC and verification, but at the moment there are no plans to a further monitoring of the Greenlandic forests.

Recalculations and changes made in response to the review process

No recalculations have been made.

Planned improvements

No improvements are planned.

16.6.3 Land converted to forests (4A2)

Forest area

See Section 16.2.1 Information on approaches used for representing land areas and on land-use databases used for the inventory preparation.

Forest definition

See Section 16.2.1 Land-use definitions and the classification systems used and their correspondence to the LULUCF categories (e.g. land use and land-use change matrix).

Methodological issues for land converted to forest

See also Section 16.2.1.

Since 1990 there has been a slight increase in the forest area of 14 hectares. This has taken place on land converted from “OL”.

Uncertainties and time series consistency

For time series consistency see Section 16.2.1. For uncertainties, please see Chapter 16.6.15.

QA/QC and verification

No QA/QC plan has been made yet. The afforestated area is known.

Recalculations, including changes made in response to the review process

None

Planned improvements

No improvements are planned.

16.6.4 Cropland (4B)

Cropland and cropland management (4B1)

In 1990 there were no cropland occurring in Greenland. Due to the global warming it is now possible to have a few crops which may mature. In 2001 the first five hectares with annual crops were established. These are reported under 5.B.2. A more intensive description of the agriculture in Greenland can be found at
http://nunalerineq.gl/english/landbrug/jord/index-jord.htm

Land converted to cropland (4B2)

In 2001 the first annual crops were grown in Greenland. Approximately five hectares with garden crops were grown. Of this is it assumed that 25 %

of the area is on organic soils (pers. comm. with Kenneth Høeg, former chief agricultural advisor in Greenland). The area converted to cropland was improved grassland.

Figure 16.6.5 Cropland and Grassland in Greenland.
(Photos from: http://nunalerineq.gl/english/landbrug/landbrug/index-landbrug.htm).

The region is generally characterized by a slightly podsol type of soil with a low pH value and small amounts of accessible plant nutrients. Larger concentrations of clay rarely occur, but considerable quantities of silt are often observable on the surface. Also, a certain amount of brown earth occurs in inland areas.

Methodological issues

Change in carbon stock in living biomass

For land converted to cropland is used a standard default value of 5,000 kg DM (dry matter) per hectare in above- and below-ground (IPCC 2006).

Change in carbon stock in dead organic matter

No organic matter is reported under CL.

Change in carbon stock in soils

No C stock changes in mineral soils are assumed. The emission in the 25 % organic soils is estimated by using the IPCC 2006 default value for cropland, Table 5.6 pp 5.19 of 5,000 kg C per ha per year. The emission factors for organic soils in the 2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands (IPCC 2014a) are based on expert judgement assumed to be too high for the cold conditions in Greenland.

Uncertainties and time series consistency

The time series are complete. For uncertainties, please see Chapter 16.6.15.

Category-specific QA/QC and verification

The number of hectares is provided by the Greenlandic Agricultural Consulting Services. As agricultural activities are economically subsidised in Greenland the figures are very accurate.

Category-specific recalculation

No recalculations have been made.

Category-specific planned improvements

No improvements are planned.

16.6.5 Grassland (4C)

Grassland remaining grassland (4C1)

Grassland in Greenland is dominated by unimproved grassland where the sheep is grazing. The total area with GL has been estimated to 242,000 hectares. Of these only approximately 1,000 hectare is improved where stones have been removed combined with sowing of more high yielding species, see Figure 16.6.5.

Since 1990 the area with improved grassland has been extended from 460 hectares to 1069 hectares.

Methodological issues for grassland

Grassland is divided into improved and unmanaged Grassland.

Change in carbon stock in living biomass

As more GL becomes improved the amount of living biomass at peak is increased. To estimate the amount of living biomass in improved GL is using the same default value as for Cropland, e.g. 5000 kg DM per hectare, IPCC 2006 default value for cropland, Table 5.9 pp 5.28. For unmanaged Grassland is used a default value of 1700 kg DM per hectare according to IPCC 2006 default, Table 6.4 pp 6.27. No estimates for below-ground biomass are given. For conversion from DM to C is used a default value of 0.5 kg C per kg DM.

Change in carbon stock in dead organic matter

No changes in dead organic matter are estimated as this is not occurring for this category.

Change in carbon stock in soils

No changes in the carbon stock in mineral soils are assumed. For organic soils on improved grassland is used a default EF of 1,250 kg C per ha per year (IPCC, 2006) default value for grassland, Table 6.3 pp 6.17. For unmanaged grassland no carbon stock change is expected. The emission factors for organic soils in the 2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands (IPCC 2014a) are based on expert judgement assumed to be too high for the cold conditions in Greenland.

Uncertainties and time series consistency

The time series is complete. For uncertainties, please se Chapter 16.6.15.

Category-specific QA/QC and verification
The number of hectares is provided by the Greenlandic Agricultural Consulting Services. As the agriculture is subsidised in Greenland the figures are very accurate.

Recalculations
No recalculation has been made.

Planned improvements
No improvements are planned.

16.6.6 Wetlands (4D)

Wetland in Greenland includes only human made water reservoirs and not naturally occurring wetlands. In total 1,076 hectares with ponds and water reservoirs distributed on 48 locations are reported.

No emission estimates from these reservoirs has been made yet.

Uncertainties and time series consistency
Not estimated.

QA/QC and verification
QA and QC have been made by DCE and Statistics Greenland.

Recalculations
No recalculations have been made.

Category-specific planned improvements
No improvements are planned.

16.6.7 Settlements (4E)

In total there are approximately 56,000 inhabitants in Greenland with about one quarter of the population in the capital, Nuuk.

Table 16.6.5 Inhabitants and the area occupied with houses, hectares.

	1990	2000	2013
Cities, inhabitants	44,427	45,734	48,151
Small villages, inhabitants	11,131	10,373	8,219
City area, ha	2,964	3,051	38.3
Villages, ha	1,825	1,825	3,830
Settlements, total, ha	4,789	4,876	5,655

The cities are build on the rocky coastline where almost none vegetation occurs. As a consequence estimates for C stock in living biomass and in soil have been made.

The small increase in the area with Settlements since 1990 has taken place on "Other land".

Currently, no official data or measurements of the area of villages and settlements are available. Alternatively, land utilized for villages and settlements have been measured by the use of NunaGIS, which is a digital internet atlas displaying maps over villages and settlements in Greenland. NunaGIS is available at www.nunagis.gl.

16.6.8 Other land (4F)

The far major part of Greenland is covered with snow or rocks. Thus Other Land consists of 99.9 % of the total area.

No emission estimates have been made for this area.

The global warming can be seen in Greenland with longer and warmer summers, which again increase the amount of living biomass. Especially since the early 1990's there has been changes observed in the environment, e.g. as given in the area with Cropland and Grassland has increased. However, no methodology exists currently to estimate a proper estimate of the amount of living biomass in the large area classified as "Other land".

16.6.9 Harwested Wood Products (4G)

Due to the very low area with slowgrowing forests and the constant Grenlandic population is it assumed that no national changes in the carbon stock in Harwested Wood Products (HWP) are taking place.

16.6.10 Direct nitrous oxide (N2O) emissions from nitrogen (N) inputs to managed soils– 4(I)

Reported under 3.D.

16.6.11 Emissions and removals from drainage and rewetting and other management of organic and mineral soils – 4(II)

Not estimated

16.6.12 Direct nitrous oxide (N2O) emissions from nitrogen (N) mineralization/immobilization associated with loss/gain of soil organic matter - 4(III)

Not occurring.

16.6.13 Indirect nitrous oxide (N2O) emissions from managed soils– 4(IV)

Reported under 3.D.

16.6.14 Biomass burning – 4(V)

No biomass burning takes place in Greenland, and wildfires rarely occur due to the moist climate.

16.6.15 Uncertainties

A tier 1 uncertainty assessment has been carried out in accordance with the IPCC GPG (IPCC, 2000). The uncertainty has been estimated for all sources included in the reporting for LULUCF. The uncertainties for the activity data and emission factors are shown in Table 16.6.6.

Table 16.6.6 Uncertainties for activity data and emission factors for LULUCF.

Subsector	Pollutant	Activity data uncertainty	Emission factor uncertainty
5A Forest	CO_2	5	50
5B Cropland	CO_2	5	50
5C Grassland	CO_2	5	50

The assumed uncertainties represent expert judgement.

The resulting uncertainties for the individual greenhouse gases and the total uncertainty on the greenhouse gas emission are shown in Table 16.6.7.

Table 16.6.7 Uncertainties for the emission estimates.

	1990	2013				
	Emission/sink, kt CO_2 eqv.	Emission/sink, kt CO_2 eqv.	Activity data, %	Emission factor, %	Combined uncertainty	Total
						kt CO_2 eqv.
5. LULUCF	0.206	1.120	5	50	50.2	± 56.27
5.A Forests	0	-0.045	5	50	50.2	± -2.26
5.B Cropland	0	0.048	5	50	50.2	± 2.42
5.C.Grassland	0.206	1.117	5	50	50.2	± 56.11

16.6.16 References

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16.7 Waste (CRF sector 5)

16.7.1 Overview of sector

The waste sector consists of the CRF source category 5.A. Solid Waste Disposal, 5.C. Incineration and Open Burning of Waste and 5.D. Wastewater Treatment and Discharge.

In CO_2 equivalents, the waste sector (without LULUCF) contributes with 2.5 % of the overall greenhouse gas emission (GHG) in 2013. This corresponds to an emission of 14.7 Gg CO_2 equivalents.

The Greenlandic inventory includes CH_4 emissions from managed and unmanaged waste disposal sites on land, N_2O from wastewater and CO_2, CH_4, N_2O, NO_x, CO, NMVOC and SO_2 from open burning and waste incineration and open burning. Only emissions from waste incineration without energy recovery are included in the waste sector. Emissions from waste incineration with energy recovery are included in the energy sector.

Table 16.7.1 shows the greenhouse gas emissions from the waste sector. The emissions are taken from the CRF tables and are presented as rounded figures.

Table 16.7.1 Emissions from the waste sector, Gg CO_2 equivalents.

		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
5A Solid waste disposal	CH_4	4.3	4.4	4.5	4.5	4.6	4.7	4.8	4.8	4.9	4.9
5B Incineration and open burning	CO_2	2.6	2.6	2.6	2.6	2.7	2.7	2.9	3.1	3.5	3.4
5B Incineration and open burning	CH_4	2.7	2.7	2.7	2.8	2.8	2.8	2.8	2.8	2.6	2.4
5B Incineration and open burning	N_2O	0.7	0.7	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.7
5C Wastewater treatment and discharge	N_2O	7.2	7.2	7.1	7.1	7.2	7.2	7.2	7.2	7.2	7.2
5. Waste total		17.5	17.6	17.7	17.8	18.0	18.2	18.4	18.6	19.0	18.7
continued		2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
5A Solid waste disposal	CH_4	5.0	4.9	4.9	4.9	4.9	4.8	4.8	4.8	4.7	4.7
5B Incineration and open burning	CO_2	3.2	3.3	3.2	3.1	3.1	3.1	3.1	3.1	3.1	3.1
5B Incineration and open burning	CH_4	2.1	2.1	2.1	1.9	1.9	1.9	1.9	1.9	1.9	1.9
5B Incineration and open burning	N_2O	0.6	0.6	0.6	0.6	0.5	0.5	0.6	0.6	0.5	0.6
5C Wastewater treatment and discharge	N_2O	7.2	7.2	7.2	7.2	7.2	7.2	7.2	7.3	7.6	6.3
5. Waste total		18.1	18.1	18.0	17.7	17.5	17.5	17.5	17.6	17.8	16.5
continued		2010	2011	2012	2013						
5A Solid waste disposal	CH_4	4.7	4.6	4.6	4.6						
5B Incineration and open burning	CO_2	3.1	3.1	3.1	3.1						
5B Incineration and open burning	CH_4	1.9	1.9	1.9	1.9						
5B Incineration and open burning	N_2O	0.6	0.6	0.6	0.6						
5C Wastewater treatment and discharge	N_2O	6.0	6.1	5.7	4.6						
5. Waste total		16.2	16.3	15.9	14.7						

The largest sources of greenhouse gas emission from the waste sector in 2013 are CH_4 emission from solid waste disposal (31.2 %) and N_2O emission from waste water treatment and discharge (30.9 %) followed by CO_2 from waste incineration and open burning (21.3 %).

The total greenhouse gas emission from the waste sector has decreased by 15.6 % from 1990 to 2013. In 2013 emissions from all sources except wastewater treatment and discharge were more or less unchanged. However, N_2O from wastewater treatment and discharge decreased by 19.7 % due to a decrease in the amount of industrial used water.

16.7.2 Solid waste management

Activity data for waste amounts for solid waste management are shown in Table 16.7.2.

Table 16.7.2 Waste amounts for solid waste management, tonnes.

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
5A1 Managed waste disposal sites	6 056	6 124	6 168	6 232	6 334	6 428	6 410	6 416	6 145	5 697
5A2 Unmanaged waste disposal sites	1 362	1 359	1 358	1 360	1 341	1 289	1 217	1 160	1 060	988
5C1 Incineration, with energy recovery	5 519	5 578	5 618	5 733	5 918	6 072	6 178	6 275	6 398	8 200
5C1 Incineration, without energy rec.	0	0	0	0	56	225	795	1 240	2 663	2 896
5C2 Open burning of waste	16 566	16 713	16 808	16 955	17 140	17 235	17 033	16 922	16 093	14 930
5. Waste total	29 503	29 775	29 952	30 280	30 788	31 249	31 633	32 014	32 360	32 712
continued	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
5A1 Managed waste disposal sites	4 876	4 943	4 746	4 451	4 215	4 246	4 264	4 293	4 312	4 346
5A2 Unmanaged waste disposal sites	910	868	843	835	828	826	818	791	763	746
5C1 Incineration, with energy recovery	11 279	11 526	12 658	14 084	15 312	15 572	15 788	16 056	16 366	16 686
5C1 Incineration, without energy rec.	3 148	3 306	3 391	3 415	3 437	3 461	3 485	3 468	3 444	3 466
5C2 Open burning of waste	12 920	12 979	12 483	11 804	11 263	11 329	11 350	11 355	11 335	11 371
5. Waste total	33 132	33 623	34 121	34 589	35 055	35 435	35 705	35 964	36 220	36 614
continued	2010	2011	2012	2013						
5A1 Managed waste disposal sites	4 413	4 476	4 503	4 518						
5A2 Unmanaged waste disposal sites	722	692	658	631						
5C1 Incineration, with energy recovery	17 077	17 500	17 854	18 131						
5C1 Incineration, without energy rec.	3 486	3 488	3 501	3 523						
5C2 Open burning of waste	11 470	11 540	11 526	11 500						
5. Waste total	37 168	37 695	38 043	38 303						

The waste amounts are based on municipal data on waste and waste incineration with energy recovery on local incinerator plants in 2004, and a survey by Consulting Company Carl Bro in 1996 and 2001, where waste amounts per person per year was identified as 650 kg and 455 kg for Greenlandic towns and villages, respectively. For the time-series these amounts were regulated by 1 % per year upwards for years after 2004 and by 1 % per year downwards for years before 2004. Further, to construct the time-series statistical data from Statistics Greenland on population in towns and villages were used. Other results of the survey used for the time-series are that it was estimated that (1) 70 % of waste amounts is incinerated and 30 % deposited and (2) 80 % of combustible waste amounts deposited is burned in open burning.

Solid waste disposal

Source Category Description

The category consists of managed and unmanaged disposal sites of waste on land.

Methodological issues, activity data, emission factors and emissions

In Table 16.7.3 the composition of the waste according to the survey mentioned is shown.

Table 16.7.3 Composition of household and commercial waste before and after open burning.

Fraction	Household waste[2]	Commercial waste[2]	Household / Commercial Weighted	After open burning	Weighted (after open burning)
			%		
Paper/cardboard, dry	8.00[1]	20.00	11.84	2.37	7.66
Paper/cardboard, wet	10.00[1]	7.00	9.04	1.81	5.85
Plastics	7.00[1]	9.00	7.64	1.53	4.94
Organic waste	44.00[1]	34.00	40.80	8.16	26.40
Other combustible	17.50[1]	16.00	17.02	3.40	11.00
Glass	7.50[1]	3.00[1]	6.06	6.06	19.60
Metal	3.50[1]	3.00[1]	3.34	3.34	10.80
Other, non combustible	1.00[1]	5.00	2.28	2.28	7.37
Hazardous waste	1.50[1]	3.00[1]	1.98	1.98	6.40
Total	100.00	100.00	100.00	30.93	100.00
Pct (%)	68[3]	32[3]		80[4]	

Notes:

1 Measured values.

2 Source: Former Environmental and Nature Agency, Ministry of Infrastructure and Environment. Survey from 2004.

3 Distribution of household and commercial waste.

4 Share of combustible waste burned at waste disposal sites.

A Tier 2 approach with a first order decay model is used for estimation of emissions of CH_4 from the solid waste disposals. For this purpose the activity data in Table 16.7.2 are estimated back to 1960 (not shown) based on the methodology described in connection to Table 16.7.2. Combining these activity data and the composition data in Table 16.7.3 time-series for 1960-2013 with amounts of waste in waste fractions is calculated.

For these time-series the waste fractions are associated to (1) Dissolved Organic Carbon (DOC) values according to Section 16.7.2 of this NIR and (2) emission factors based on DOC values and values of methane correction factors, fraction of DOC dissimilated and fraction of CH_4 in gas emitted according to the IPCC Gudelines and GPG for managed disposals, Table 16.7.4 and unmanaged disposals, Table 16.7.5.

Table 16.7.4 DOC values and emission factors for CH_4 for managed disposals.

	Paper / cardboard, dry	Paper / cardboard, wet	Plastics	Organic waste	Other combustible	Glass	Metal	Other, non combus-tible	Hazardous waste
DOC weighted (after open burn-ing) fraction	0.40	0.20	0.00	0.20	0.20	0.00	0.00	0.00	0.00
Emission factor kg CH_4/tonnes[1]	133.3	66.7	0.0	66.7	66.7	0.0	0.0	0.0	0.0
[1]) based on:									
Methane correction factor				1					
Fraction of DOC dissimilated and emitted				0.5					
Fraction of CH_4 in gas emitted				0.5					

Table 16.7.5 DOC values and emission factors for CH_4 for unmanaged disposals.

	Paper/ cardboard dry	Paper/ cardboard wet	Plastics	Organic waste	Other combustible	Glass	Metal	Other, non-combus-tible	Hazardous waste
DOC weighted (after open burn-ing) fraction	0.40	0.20	0.00	0.20	0.20	0.00	0.00	0.00	0.00
Emission factor kg CH_4/tonnes[1]	53.3	26.7	0.0	26.7	26.7	0.0	0.0	0.0	0.0
[1]) based on:									
Methane correction factor				0.4					
Fraction of DOC dissimilated and emitted				0.5					
Fraction of CH_4 in gas emitted				0.5					

For managed and unmanaged disposals the default half life time of 14 years and a time lag of 0.5 years are used. For the oxidation factor and according to the GPG for managed disposal 0.1 and for unmanaged 0.0 are used.

In Tables 16.7.6 and 16.7.7 selected data and results are shown for 1990-2013 for managed and unmanaged disposal, respectively. The data in the tables are as follows. The AD for the FOD model as amounts of waste in fractions, the potential emission of CH_4 calculated with emission factors on waste amounts in fractions, the annual generated emission of CH_4 calculated with the FOD model using the potential emissions, the oxidized CH_4 and the actual annual CH_4 emission calculated as the annual generated emission minus the CH_4 oxidized. Calculations are performed since 1960 and are not shown.

Table 16.7.6 Managed disposal. AD for the FOD model (amounts of waste in fractions), the potential emission of CH_4, the oxidized CH_4 and the annual CH_4 emission for 1990-2013.

	Paper /cardboard dry	Paper /cardboard wet	Plastics	Organic waste	Other combustible	Glass	Metal	Other, non combustible	Hazardous waste	Waste total	Potential emission	Annual generated emission	Annual oxidized emission	Annual emission
Unit	Tonnes	Tonnes	Tonnes	Tonnes	Tonnes	Tonnes	Tonnes	Tonnes	Tonnes	Tonnes	Tonnes CH_4	Tonnes CH_4	Tonnes CH_4	Tonnes CH_4
1990	464	354	299	1 598	667	1 187	654	446	388	6 056	232.7	174.8	17.5	157.3
1991	469	358	303	1 616	674	1 200	661	451	392	6 124	236.4	177.8	17.8	160.0
1992	472	361	305	1 627	679	1 209	666	455	395	6 168	239.0	180.7	18.1	162.6
1993	477	364	308	1 644	686	1 221	673	459	399	6 232	240.8	183.6	18.4	165.3
1994	485	370	313	1 671	697	1 241	684	467	405	6 334	243.3	186.5	18.6	167.8
1995	492	376	318	1 696	708	1 260	694	474	412	6 428	247.2	189.4	18.9	170.5
1996	491	375	317	1 691	705	1 256	692	473	410	6 410	250.9	192.4	19.2	173.2
1997	491	375	317	1 693	706	1 257	693	473	411	6 416	250.2	195.2	19.5	175.7
1998	471	359	304	1 621	676	1 204	664	453	393	6 145	250.5	197.9	19.8	178.1
1999	436	333	281	1 503	627	1 116	615	420	365	5 697	239.9	199.9	20.0	179.9
2000	373	285	241	1 286	537	955	527	359	312	4 876	222.4	201.0	20.1	180.9
2001	378	289	244	1 304	544	969	534	364	316	4 943	190.3	200.5	20.0	180.4
2002	363	277	234	1 252	522	930	513	350	304	4 746	193.0	200.1	20.0	180.1
2003	341	260	220	1 174	490	872	481	328	285	4 451	185.3	199.4	19.9	179.4
2004	323	246	208	1 112	464	826	455	311	270	4 215	173.7	198.1	19.8	178.3
2005	325	248	210	1 120	467	832	459	313	272	4 246	164.5	196.5	19.7	176.9
2006	326	249	211	1 125	469	836	460	314	273	4 264	165.7	195.0	19.5	175.5
2007	329	251	212	1 133	473	841	464	316	275	4 293	166.4	193.6	19.4	174.3
2008	330	252	213	1 138	475	845	466	318	276	4 312	167.6	192.4	19.2	173.2
2009	333	254	215	1 147	478	852	469	320	278	4 346	168.3	191.2	19.1	172.1
2010	338	258	218	1 164	486	865	477	325	283	4 413	169.6	190.2	19.0	171.2
2011	343	262	221	1 181	493	877	483	330	287	4 476	172.3	189.3	18.9	170.4
2012	345	263	222	1 188	496	882	486	332	288	4 503	174.7	188.6	18.9	169.8
2013	346	264	223	1 192	497	885	488	333	289	4 518	175.8	188.0	18.8	169.2

Table 16.7.7 Unmanaged disposal. AD for the FOD model (amounts of waste in fractions), the potential emission of CH_4, the oxidized CH_4 and the annual CH_4 emission for 1990-2013.

	Paper /cardboard dry	Paper /cardboard wet	Plastics	Organic waste	Other combustible	Glass	Metal	Other, non combustible	Hazardous waste	Waste total	Potential emission	Annual generated emission	Annual oxidized emission	Annual emission
Unit	Tonnes	Tonnes	Tonnes	Tonnes	Tonnes	Tonnes	Tonnes	Tonnes	Tonnes	Tonnes	Tonnes CH_4	Tonnes CH_4	Tonnes CH_4	Tonnes CH_4
1990	104	80	67	359	150	267	147	100	87	1 362	21.2	15.8	0.0	15.8
1991	104	79	67	359	150	266	147	100	87	1 359	21.3	16.1	0.0	16.1
1992	104	79	67	358	149	266	147	100	87	1 358	21.2	16.3	0.0	16.3
1993	104	79	67	359	150	266	147	100	87	1 360	21.2	16.6	0.0	16.6
1994	103	78	66	354	148	263	145	99	86	1 341	21.2	16.8	0.0	16.8
1995	99	75	64	340	142	253	139	95	83	1 289	20.9	17.0	0.0	17.0
1996	93	71	60	321	134	238	131	90	78	1 217	20.1	17.1	0.0	17.1
1997	89	68	57	306	128	227	125	86	74	1 160	19.0	17.2	0.0	17.2
1998	81	62	52	280	117	208	115	78	68	1 060	18.1	17.3	0.0	17.3
1999	76	58	49	261	109	194	107	73	63	988	16.6	17.2	0.0	17.2
2000	70	53	45	240	100	178	98	67	58	910	15.4	17.2	0.0	17.2
2001	66	51	43	229	96	170	94	64	56	868	14.2	17.0	0.0	17.0
2002	65	49	42	222	93	165	91	62	54	843	13.6	16.8	0.0	16.8
2003	64	49	41	220	92	164	90	62	53	835	13.2	16.7	0.0	16.7
2004	63	48	41	218	91	162	89	61	53	828	13.0	16.5	0.0	16.5
2005	63	48	41	218	91	162	89	61	53	826	12.9	16.3	0.0	16.3
2006	63	48	40	216	90	160	88	60	52	818	12.9	16.2	0.0	16.2
2007	61	46	39	209	87	155	85	58	51	791	12.8	16.0	0.0	16.0
2008	58	45	38	201	84	150	82	56	49	763	12.4	15.8	0.0	15.8
2009	57	44	37	197	82	146	81	55	48	746	11.9	15.6	0.0	15.6
2010	55	42	36	191	80	142	78	53	46	722	11.6	15.4	0.0	15.4
2011	53	40	34	183	76	136	75	51	44	692	11.3	15.2	0.0	15.2
2012	50	38	32	174	72	129	71	48	42	658	10.8	15.0	0.0	15.0
2013	48	37	31	166	69	124	68	47	40	631	10.3	14.8	0.0	14.8

16.7.3 Incineration and open burning of waste

Source category description

In Greenland waste incineration is carried out both with and without energy recovery. According to IPCC Guidelines the emissions associated with waste incineration for energy production is included in the energy sector more specifically in the source category 1.A1a Public Electricity and Heat Production. The emissions from waste incineration without energy recovery is reported in source category 5.C. Waste Incineration. Additionally in Greenland open burning of waste occurs at landfill sites. Emissions associated with this are also reported under sector 5.C. Waste Incineration.

Methodological issues

The methodology used follows the IPCC Guidelines (IPCC, 2006). For waste incineration the Danish emission factors are used, as it is trusted that they are also a good representation of Greenlandic conditions.

The emission factors used for both waste incineration and open burning are included in Section 16.7.3.4.

Activity data

The amount of waste incinerated without energy recovery is presented in Table 16.7.8. The activity data is provided by the method described in Section 16.7.2.

Table 16.7.8 Activity data for waste incineration without energy recovery, Mg.

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Incinerated waste without energy recovery, Mg	NO	NO	NO	NO	56	225	795	1 240	2 663	2 896
continued	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Incinerated waste without energy recovery, Mg	3 148	3 306	3 391	3 415	3 437	3 461	3 485	3 468	3 444	3 466
continued	2010	2011	2012	2013						
Incinerated waste without energy recovery, Mg	3 486	3 488	3 501	3 523						

The open burning of waste is assumed to be 80 % of the waste deposited to landfills (Survey on waste by Carl Bro, 1996 and 2001). The activity data for open burning is presented in Table 16.7.9. The activity data for open burning is provided by the method described in Section 16.7.2.

Table 16.7.9 Activity data for open burning of waste, Mg.

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Open burning of waste, Mg	16 566	16 713	16 808	16 955	17 140	17 235	17 033	16 922	16 093	14 930
continued	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Open burning of waste, Mg	12 920	12 979	12 483	11 804	11 263	11 329	11 350	11 355	11 335	11 371
continued	2010	2011	2012	2013						
Open burning of waste, Mg	11 470	11 540	11 526	11 500						

Emission factors

Waste incineration

For waste incineration without energy recovery the same emission factors have been assumed as for waste incineration with energy recovery. The emission factors refer to the IPCC, 2006 and Danish emission factors (Nielsen et al., 2010). The greenhouse gas emission factors are shown in Table 16.7.10.

Table 16.7.10 Emission factors for greenhouse gases from waste incineration.

	Emission factor	Unit
CO_2	37	Kg pr GJ
CH_4	30	g pr GJ
N_2O	4	g pr GJ

The emission factors used for the indirect greenhouse gases are shown in table 16.7.11. The emission factors have been revised for this 2015 submission.

Table 16.7.11 Emission factors for indirect greenhouse gases from waste incineration.

	NO_x	SO_2	NMVOC	CO	Unit
Waste incineration	134	138	0.98	7.4	g pr GJ

Open burning

For open burning emissions are calculated using the methodology, standard parameters and emission factors provided by the IPCC 2006 Guidelines.

The CH_4 emission factor used is the recommended and default is 6,500 g per tonne MSW wet weight. This factor refers to US EPA (2001).

For N_2O a default emission factor of 150 g/t MSW dry weight is recommended (IPCC, 2006) this is corrected for the dry matter content to acquire an N_2O emission factor of 214 g per tonne MSW wet weight.

For calculating the CO_2 emission the dry matter content, carbon content and the fossil carbon content of the waste fractions are used. The parameters are included in Table 16.7.12.

Table 16.7.12 Parameter used in calculating CO_2 emissions from open burning.

	Dry matter content	Total carbon content, %	Fossil carbon content as percent of total carbon
Paper	0.90	46	1
Cardboard	0.90	46	1
Plastics	1.00	75	100
Organic waste	0.40	38	0
Other	0.85	3	100

Source: 2006 IPCC Guidelines, Volume 5, Chapter 2, Table 2.4

An oxidation factor of 58 % is assumed for open burning (IPCC, 2006).

The emission factors for NO_x, SO_2, NMVOC and CO are presented in Table 16.7.13. The source of these emission factors are EMEP/EEA2013 (Table 3-1). The emission factors have been revised for this 2015 submission.

Table 16.7.13 Emission factors for indirect greenhouse gases from open burning of waste.

	NO_x	SO_2	NMVOC	CO	Unit
Open burning of municipal waste	3.18	0.11	1.23	55.83	Kg pr Mg

Emissions

Total emission of greenhouse gases from sector 5.C. Incineration and open burning of waste is shown in Table 16.7.14. Figure 16.7.1 shows total emission of greenhouse gases from sector 5.C. Incineration and open burning.

Table 16.7.14 Greenhouse gas emissions from incineration and open burning.

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
CO_2, Gg	2.6	2.6	2.6	2.6	2.7	2.7	2.9	3.1	3.5	3.4
CH_4, Mg	107.7	108.6	109.2	110.2	111.4	112.1	111.0	110.4	105.4	98.0
N_2O, Mg	2.5	2.5	2.5	2.5	2.6	2.6	2.6	2.6	2.5	2.4
CO_2 eqv., Gg	6.0	6.0	6.1	6.1	6.2	6.3	6.5	6.6	6.9	6.6
continued	2001	2001	2002	2003	2004	2005	2006	2007	2008	2009
CO_2, Gg	3.2	3.3	3.2	3.1	3.1	3.1	3.1	3.1	3.1	3.1
CH_4, Mg	85.0	85.4	82.2	77.8	74.3	74.7	74.9	74.9	74.8	75.0
N_2O, Mg	2.1	2.1	2.0	1.9	1.8	1.8	1.8	1.8	1.8	1.9
CO_2 eqv., Gg	6.0	6.0	5.9	5.7	5.5	5.5	5.5	5.5	5.5	5.5
continued	2010	2011	2012	2013						
CO_2, Gg	3.1	3.1	3.1	3.1						
CH_4, Mg	75.7	76.1	76.0	75.9						
N_2O, Mg	1.9	1.9	1.9	1.9						
CO_2 eqv., Gg	5.6	5.6	5.6	5.6						

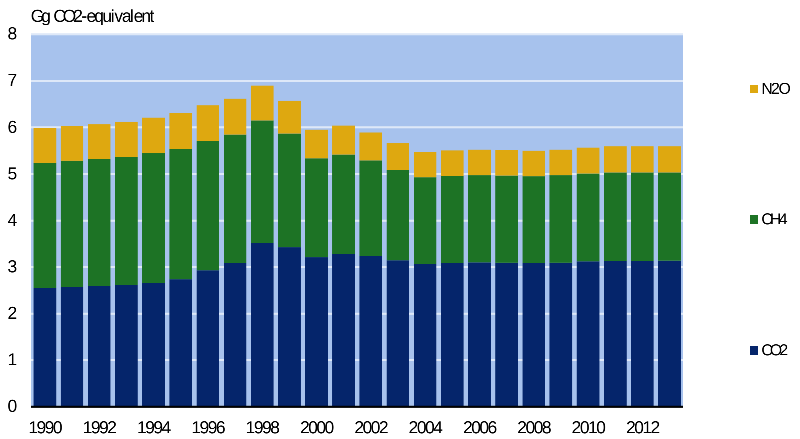

Figure 16.7.1 Emission of greenhouse gases from incineration and open burning.

The emissions of indirect greenhouse gases from incineration and open burning are shown in Table 16.7.15.

Table 16.7.15 Emissions of indirect greenhouse gases from incineration and open burning, Mg.

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
NO_x	52.7	53.1	53.4	53.9	54.6	55.1	55.3	55.6	54.9	51.6
SO_2	1.8	1.8	1.8	1.9	2.0	2.2	3.0	3.7	5.6	5.8
NMVOC	20.4	20.6	20.7	20.9	21.1	21.2	21.0	20.8	19.8	18.4
CO	924.9	933.1	938.4	946.6	956.9	962.3	951.0	944.8	898.7	833.8
continued	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
NO_x	45.5	45.9	44.5	42.3	40.7	40.9	41.0	41.0	40.9	41.0
SO_2	6.0	6.2	6.3	6.2	6.2	6.3	6.3	6.3	6.2	6.3
NMVOC	15.9	16.0	15.4	14.6	13.9	14.0	14.0	14.0	14.0	14.0
CO	721.6	724.9	697.2	659.3	629.1	632.8	634.0	634.2	633.1	635.1
continued	2010	2011	2012	2013						
NO_x	41.4	41.6	41.6	41.5						
SO_2	6.3	6.3	6.3	6.4						
NMVOC	14.1	14.2	14.2	14.2						
CO	640.6	644.6	643.8	642.3						

16.7.4 Wastewater treatment and discharge

Source category description

In Greenland no wastewater treatment occurs; although it should be mentioned some filtering of solid residues from industry may occur and likewise there are ongoing projects focussing on septic tanks at household levels. N_2O emission from human sewage is estimated. It is assumed that no methane emission occurs.

Methodological issues

According to the IPCC Guidelines (IPCC, 2006) the important factors for CH_4 production from handling of wastewater are: wastewater characteristics; especially the quantity of degradable organic material in the wastewater, handling systems, temperature and BOD vs. COD.

The Guidelines state that production of CH_4 generally requires temperatures above 15˚C, and at temperatures below this the lagoon is principally a sedimentation tank (IPCC2006). Temperatures in Greenland rarely exceed 15˚C, and the monthly average temperature has not exceeded 12˚C during the period 1993-2013. Therefore CH_4 is reported as Not Applicable in the CRF.

N_2O emission from wastewater handling

The IPCC default methodology only includes N_2O emissions from human sewage based on annual per capita protein intake. The methodology account for nitrogen intake ("outcome"), i.e. faeces and urine, only and neither the industrial nitrogen input nor non-consumption protein from kitchen, bath and laundry discharges are included.

Total nitrogen in the effluent discharges is calculated by the following formula from IPCC, 2006 (Equation 6.8):

$$N_{EFFLUENT} = (P \times Protein \times F_{NPR} \times F_{NON-CON} \times F_{IND-CON}) - N_{SLUDGE}$$

where *P* is the Greenlandic population (source: Statistics Greenland).

Protein is the annual per capita protein consumption (kg/person/yr) set contant to 171.5 g/day (see text below).

F_{NPR} is the fraction of nitrogen in protein, default 0.16 kg N/kg protein (IPCC, 2006).

$F_{NON\text{-}CON}$ is the factor for non-consumed protein added to wastewater, default 1.1 (IPCC, 2006).

$F_{IND\text{-}CON}$ is the factor for industrial and commercial co-discharged protein into the sewer system, default 1.25 (IPCC, 2006).

N_{SLUDGE} is nitrogen removed with sludge, default zero kg N/yr.

Thus, total N_2O emission from effluent discharges is calculated by the formula:

$$N_2O_{EFFLUENT} = N_{EFFLUENT} \times EF_{N_2O-N} \times \frac{44}{28}$$

The new default IPCC emission factor for N_2O emissions from domestic wastewater nitrogen effluent is 0.005 kg N_2O-N/kg N. This emission factor is based on limited field data and on specific assumptions regarding the occurrence of nitrification and denitrification in rivers and in estuaries. This emission factor has been revised for the 2015 submission. To convert total N in effluents to emissions in N_2O the mass ratio 44/28 is used.

For households

A large part of the diet originates from seafood, fish or sea mammals, but imported fabricated foods are expected to continue to take over an increasing part of human energy consumption. Due to weather conditions most of fresh food comes from wild animals or fish. Greenland has a production of lamb and a limited supply of vegetables; still most of the produced foods are imported from outside (Mulvad et al., 2007).

In Greenland, the traditional diet based on meat and fish has undergone diversification towards more carbohydrates with the development of a monetary economy; in 1855 the protein content of a mean diet was 377 g protein, whereas 80 years later, in 1935 – 43, the protein content of a mean diet was 257 g protein (Périssé and François, 1981). Today, the majority of young urbanised Greenlandic Inuit have Western dietary habits and consume less meat from marine mammals, terrestrial mammals and birds than Inuit from the hunting districts; Dietary profiles of Canadian Baffin Island Inuit with a high consumption of traditional foods have shown a mean daily protein intake of 144-199 g/day in 41- to 61-year-old (Laursen et al, 2001).

As no data on the protein intake are available a protein intake of 171.5 g/day, i.e. the average of the Canadian Inuit were adopted, as it is assumed that the protein intake has declined even more since 1935 due to increased number of urbanised Greenlandic Inuit. For comparison the Danish yearly protein consumption according to FAOSTAT has increased from 98 g/day in 1990 to 112 g/day in 2005. Using this number, the yearly protein intakes may be derived by multiplying with the population number and days in a year. Based on the above it was decided to set the protein intake to the average value of the Canadian Inuit data, 171.5 g/day. The N-content in effluent wastewater in Greenland was calculated the equation shown above.

From industries

The production of residue products from the fish industry in Greenland amounts to around 14,000 tons per year (Nielsen et al, 2005). Overall the waste amount from the Greenland halibut production is around 40 %, while the waste amount from codfish production is 50 %; this governs only the fish production including pre-processing.

According to IPCC, the fraction of nitrogen in protein is 0.16 (IPCC, 2006). The IPCC reports a range of 0.3 to 3.1 kg total N/ton fish referring to effluent loads from cod filleting; i.e. 0.0031. The report also presents values of the total N content of untreated wastewater from the fish industry in the range of 400-1000 mg/l corresponding to a fraction of corresponding. However, as it was not possible to find data for all fish groups, and as it was not possible to determine that fraction of fish, which was pre-processed and how big a fraction that was sold without pre-processing, the below approach was adopted.

From the EC BAT note (EC, 2003) the total N-content of untreated wastewater from the fishing industry was reported to be between 400 and 1000 mg/L with an average value of 700 mg/L. The number was multiplied by the water used within the fishing industry reported for 2004 to 2013 by Statistics Greenland. The effluent N-content for 1990 to 2002 was set equal to the estimated value for 2003.

Emissions

Emission of N_2O from wastewater discharges is shown in Table 16.7.16.

Table 16.7.16 N_2O emissions in wastewater from households and industries 1990-2013.

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
N_2O emission, effluents households, Gg	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005
N_2O emission, effluents industries, Gg	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019
N_2O emission, effluents sum, Gg	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024
continued	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
N_2O emission, effluents households, Gg	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005
N_2O emission, effluents industries, Gg	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.020	0.021	0.016
N_2O emission, effluents sum, Gg	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.025	0.021
continued	2010	2011	2012	2013						
N_2O emission, effluents households, Gg	0.005	0.005	0.005	0.005						
N_2O emission, effluents industries, Gg	0.015	0.016	0.014	0.010						
N_2O emission, effluents sum, Gg	0.020	0.020	0.019	0.015						

Total emission of N_2O increased slightly until 2008 due to an increase in the emission from industrial effluents. However, in 2009-2013 total emission of N_2O has decreased to a total level of 0.015-0.020 Gg (which is lower than 1990) due to a temporarily decrease in industrial effluents primaryly caused by a decrease in the catches of shrimps.

16.7.5 Uncertainties

A tier 1 uncertainty assessment has been carried out in accordance with the IPCC Guidelines (IPCC, 2006). The uncertainty has been estimated for all sources included in the reporting for the waste sector. The uncertainties for the activity data and emission factors are shown in Table 16.7.17.

Table 16.7.17 Uncertainties for activity data and emission factors for the waste sector.

Subsector	Pollutant	Activity data uncertainty	Emission factor uncertainty
5C Waste incineration	CO_2	10	25
5A Solid Waste Disposals sites	CH_4	10	100
5C Waste incineration	CH_4	10	50
5D Wastewater Handling	N_2O	30	100
5C Waste incineration	N_2O	10	100

The amount of waste incinerated and open burned is relatively well known and the uncertainty is set to 10 %. The same is the case for the waste deposited to landfills. For waste water handling an uncertainty of 30 % on the activity data has been assumed.

Regarding the emission factor uncertainty, a value of 100 % has been used for CH_4 from solid waste disposal, N_2O from wastewater treatment and N_2O from waste incineration. This is in the same range as recommended by the IPCC Guidelines (IPCC, 2000). For CO_2 and CH_4 from waste incineration emission factor uncertainties of 25 % and 50 % respectively have been chosen.

The resulting uncertainties for the individual greenhouse gases and the total uncertainty on the greenhouse gas emission are shown in Table 16.7.18.

Table 16.7.18 Uncertainties for the emission estimates.

	Uncertainty %	Trend 1990-2013 %	Trend uncertainty %
GHG	± 46	-15.6	± 15.8
CO_2	± 27	23.1	± 17.4
CH_4	± 73	-7.5	± 13.8
N_2O	± 94	-35.3	± 24.5

16.7.6 Source specific QA/QC

The elaboration of a formal QA/QC plan is to be completed.

However, data on solid waste disposals, waste water handling and waste incineration has gone through a great deal of quality work with regard to accuracy, comparability and completeness.

All external data used for the emission inventory submission are archived in spreadsheets. Data are archived annually in order to ensure that the basic data for a given report are always available in their original form.

Annual data on solid waste disposal, waste water handling and waste incineration are compared with previous years and large discrepancies are checked.

Safely stored and quality checked activity data are then processed by using a methodological approach consistent with international guidelines.

Calculated emission factors are compared with guideline emission factors to ensure that they are reasonable. The calculations follow the principle in international guidelines.

During data processing, it is checked that calculations are being carried out correctly.

Time-series for activity data, emission factors and calculated emissions are used to identify possible errors in the calculation procedure. In fact, during the calculation, numerous controls take place to ensure correctness. Sums are checked in the various stages in the calculation procedure. Implied emission factors are compared to emission factors.

Every single time-series imported to the CRF Reporter is checked for annual activity, units for activity, emission factor and emissions. Additional checks are performed on the database. The database encloses every single activity data, emission factors, emission, notation key and comment imported to the CRF Reporter. In other words, no information is typed manually into the CRF Reporter. Instead, all information is imported to the CRF Reporter through a XML-file to ensure maximum accuracy and completeness.

16.7.7 Source specific recalculations and improvements

For this 2015 submission several emission factors have been revised according to the IPCC 2006 Guidelines. Besides from these revisions there has been no changes in the activitydata neither the methodological standards for calculating emissions from the waste sector.

Recalculations have not been performed in this 2015-submission.

16.7.8 Source specific planned improvements

Some planned improvements to the emission inventories are discussed below.

1) Improved data on solid waste disposals

In future inventories attempts will be made in order to improve data on solid waste disposals in general. Statistics Greenland has encouraged the municipal technical departments with responsibility for waste handling to start gathering data on the yearly amounts of waste handled.

2) Improved data on waste water handling

In future inventories attempts will be made in order to improve data on waste water handling in general. However, at the moment the municipal technical departments seem to have no data on waste water handling at all.

16.7.9 References

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16.8 Other

In CRF Sector 7, there are no activities and emissions or removals for the inventory of Greenland.

16.9 Recalculations and improvements

The 2015 submission is the sixth year where Greenland on the request of the ERT submits a full CRF.

For recalculations and improvements please refer to Sections 16.3 - 16.7 and Section 16.10. However, in this 2015 submission there has not been performed any recalculations.

16.10 KP-LULUCF

The KP-LULUCF emission estimates are made in accordance with the Revised Supplementary Methods and Good Practice Guidance Arising from the Kyoto Protocol (IPCC 2014) and the 2006 IPCC guidelines.

Due to the current problem with the CRF-reporter no emission estimates for 2013 under the second Commitment Period has been made.

16.10.1 General information

In the following text, the abbreviations used are in accordance with definitions in the IPCC guidelines:

A:	Afforestation
R:	Reforestation
D:	Deforestation
FF:	Forest remaining Forest, areas remaining forest after 1990
FL:	Forest Land meeting the Danish definition of forests
CL:	Cropland
GL:	Grassland
SE:	Settlements
OL:	Other land, unclassified land
FM:	Forest Management, areas managed under article 3.4
CM:	Cropland Management, areas managed under article 3.4
GM:	Grazing land Management, areas managed under article 3.4
RE:	Revegetation
WDR:	Wetland Drainage and Rewetting

Definition of forest and any other criteria

For the estimation of anthropogenic emissions by sources and removals by sinks associated with afforestation (A), reforestation (R) and deforestation (D) since 1990 under Article 3.3 and forest management (FM) under Article 3.4 of the Kyoto Protocol, the following forest definition will be applied:

- Minimum values for tree crown cover: 10 % tree crown cover for forests.
- Minimum values for land area: 0.5 ha.
- Minimum value for tree height: trees must be able to reach a minimum height of 5 m in the site.

In addition, the forest area includes temporarily unstocked areas, smaller open areas in the forest needed for management purposes and fire breaks. Forests in national parks, reserves or areas under special protection are included. Windbreaks and groves covering more than 0.5 ha and with a minimum width of 20 m are also considered as forests.

Woody biomass does not exist outside the forest and hence not reported under Cropland and Grassland.

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

As regards the possibility of including in the first commitment period emissions and removals associated with land use, land-use change and forestry activities under Article 3.4 of the Kyoto Protocol, it has been decided to include emissions and removals from forest management (FM), cropland management (CM) and grazing land management (GM).

The national system has identified land areas associated with the activities under Article 3.4 of the Kyoto Protocol in accordance with definitions, modalities, rules and guidelines relating to land use, land-use change and forestry activities under the protocol by satellite monitoring, use of Greenlandic agricultural subsidiary system and forest information.

Inventories of emissions and removals under Article 3.3 and Article 3.4 are prepared and reported annually together with the other greenhouse gas inventory information.

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

The definition of afforestation, reforestation and deforestation is in accordance with the IPCC 2006 and the Revised Supplementary Methods and Good Practice Guidance Arising from the Kyoto Protocol (IPCC 2014).

Afforestation or reforestation is identified when areas have wooded treecover and fulfils the forest definition given above. The time of the AF is given by the time of action, i.e. planting of trees. No deforestation and reforestation is reported for Greenland as this is not occurring. All types of establishment of forest (AF or RF) are considered human induced.

As for the forest management (Article 3.4), the forest areas fulfilling the definition given above are included under this activity. All forest areas are considered managed except for the remote Qinngua-valley.

For Cropland and Grassland the area accounted for under Art. 3.4 have been estimated with the best knowledge from the Greenlandic Agricultural Consulting Services. As the agriculture in Greenland is economically subsidized the area is estimated with a high accuracy. Only areas that are reported as CL and GL are included in the accounted area.

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

All Forest activities have precedence, after this Cropland activities and then Grassland activities.

Afforestation has precedence. All land converted to forest are included as afforested area. Deforestated areas are not reported as this is not occurring. The following categories in the Convention reporting are included under afforestation:

- 4A25 OL to A

FM activities are only related to:

- 4A1 Forest remaining Forest

CM activities are related to:

- 4B22 GL to CL

GM activities area related to:

- 4C1 GL remaining GL

No elected land has left land that is not accounted for. Land conversion between elected activities (FM, CM and GM) has been allowed but is currently not occurring. No land elected under article 3.4 activities has been converted to Other Land. Other land converted to elected activities is included in the respective category. As the small increase in CL is made on elected GL areas the total reported area under CL and GL under article 3.4 is constant.

16.10.2 Spatial assessment unit used for determining the areas of the units of land under Article 3.3

Afforestation and reforestation are identified as areas which not were covered by forest in 1990. The increase in the forest area is planted.

Methodology used to develop the land transition matrix

The land use matrix is based on the best available data. No vector maps exist of the individual forests, cropland and grassland.

Maps and/or database to identify the geographical locations, and the system of identification codes for the geographical locations

The forests have been given individual names. For the Cropland and Grassland area no identification has been made.

16.10.3 Afforestation, Reforestation & Deforestation (ARD)

Methods for carbon stock change and GHG emission and removal estimates

For afforestation the carbon stock change in the period 1990 - 2013 is based both on the area of afforestation and the information on species composition.

Description of the methodologies and the underlying assumptions used

See Chapter 16.6.

Justification when omitting any carbon pool or GHG emissions/removals from ARD

C stock changes in the soil are not expected due to the cold climate to occur and hence following the guidelines for a Tier 1 approach. As the afforestation is made by hand planting no damages of the existing soil C is expected to take place.

Information on whether or not indirect and natural GHG emissions and removals have been factored out

No factoring out has been performed in the emission and removal estimates.

Changes in data and methods since the previous submission (recalculations)

No recalculation has been performed.

Uncertainty estimates

Not given in the current reporting.

Information on other methodological issues

See Chapter 16.6.

The year of the onset of an activity, if after 2008

Not applicable.

16.10.4 Forest Management (FM)

Methods for carbon stock change and GHG emission and removal estimates
See Chapter 16.6 in LULUCF on "Forest remaining forest (4.A.1)".

Methodologies and the underlying assumptions
See Chapter 16.6 in LULUCF on "Forest remaining forest (4.A.1)".

Omission of pools from FM
C changes in forest soils are omitted and hereby following IPCC 2006 guidelines at a Tier 1 level and the Revised Supplementary Methods and Good Practice Guidance Arising from the Kyoto Protocol (IPCC 2014).

Factoring out
No factoring out has been performed.

Recalculations
No recalculation has been performed.

Uncertainty estimates
See Table 16.11.2

Information on other methodological issues
See Chapter 16.7 in LULUCF on "Forest remaining forest (4.A.1)".

The year of the onset of an activity, if after 2008
Not applicable.

16.10.5 Cropland Management (CM)

Methods for carbon stock change and GHG emission and removal estimates
Methodologies and the underlying assumptions used

The area with agricultural CM is reported as the area given in Statistics Greenland.

The same methodology as used in the Convention reporting is used in the KP reporting.

Omission of pool from CM
Aboveground and belowground living biomass, litter and dead organic are only reported for perennial woody crops in accordance with IPCC 2006 guidelines. No litter and dead organic matter are reported under CM as these are not occurring. Therefore only aboveground living biomasses are reported under CM. Below-ground biomass is included in above-ground biomass.

Factoring out
No factoring out has been made.

Recalculations
None.

Uncertainty estimates
See Table 16.10.1.

Information on other methodological issues
None.

The year of the onset of an activity, if after 2008
Not applicable.

16.10.6 Grazing land management (GM)

Methods for carbon stock change and GHG emission and removal estimates
Grazing land is defined as land improved grassland and unmanaged grassland.

Description of the methodologies and the underlying assumptions used
The major part of the grassland is unmanaged (241,000 hectare). Only 1069 hectares is improved grassland with occasional reseeding and fertilizer application. The methodology used is the default Tier 1. This is in accordance with IPCC 2006 guidelines as the total emission from LULUCF consists of less than 0.14 % of the total emission from Greenland.

Omission of pools from GM
Aboveground and belowground living biomass, litter and dead organic are only reported for perennial woody crops in accordance with IPCC 2006 guidelines. No litter and dead organic matter are reported under GM as these are not occurring. Therefore only aboveground living biomasses are reported under GM. Below-ground biomass is included in above-ground biomass.

Factoring out
No factoring out has been made.

Recalculations
No recalculation has been performed.

Uncertainty estimates
See Table 16.11.2.

Information on other methodological issues
None.

The year of the onset of an activity, if after 2008
Not applicable.

16.10.7 Revegation

Not elected.

16.10.8 Wetland drainage and rewetting

Not elected.

16.10.9 Article 3.3

Information that demonstrates that activities under Article 3.3 began on or after 1 January 1990 and before 31 December 2012 and are direct human-induced
All forests in Greenland are planted except for the Qinngua valley, which is in a remote area.

Information on how harvesting or forest disturbance that is followed by the re-establishment of forest is distinguished from deforestation

No deforestation is occurring and therefore not applicable.

Information on the size and geographical location of forest areas that have lost forest cover but which are not yet classified as deforested

Not applicable.

16.10.10 Article 3.4

Information that demonstrates that activities under Article 3.4 have occurred since 1 January 1990 and are human-induced

Forest Management

In Forest Management all forest areas are under management and changes in carbon stock are hence seen as human induced.

Cropland Management

Due to the cold climate and the recent increase in temperature it has only very recently been possible to grow agricultural crops in Greenland with the first fields established around 2001. Today it is estimated that 10.5 hectares are regularly ploughed.

Grassland Management

Due to the cold climate in Greenland and the recent increase in temperature it has only recently been valuable to introduce management activities in the grassland to increase the crop yield. This is well documented in the Greenlandic subsidiary system to the farmers.

Information relating to Cropland Management, Grazing Land Management and Revegetation, if elected, for the base year

No further information is available.

Information relating to Forest Management

No further information is available.

16.10.11 Other information

Key category analysis for Article 3.3 activities and any elected activities under Article 3.4

According to the IPCC Good Practice Guidance for LULUCF a category that is identified as key in the UNFCCC inventory should also be considered key under the Kyoto Protocol (IPCC, 2014).

No LULUCF categories are reported as a key source. The total emission from the LULUCF sector is only 0.2 % of the total emission from Greenland.

16.10.12 Information relating to Article 6

There are no Article 6 projects (Joint Implementation) on the Greenlandic territory.

Literature

IPCC 2014, 2013 Revised Supplementary Methods and Good Practice Guidance Arising from the Kyoto Protocol, Hiraishi, T., Krug, T., Tanabe, K., Srivastava, N., Baasansuren, J., Fukuda, M. and Troxler, T.G. (eds). Published: IPCC, Switzerland.

16.11 Annex 1 Key categories

A Key Category Analysis (KCA) for year 1990 and 2013 for Greenland has been carried out in accordance with the IPCC Good Practice Guidance. For 1990 a level KCA has been carried out.

The base year in the analysis is the year 1990 for the greenhouse gases CO_2, CH_4, N_2O and 1995 for the greenhouse F-gases HFC, PFC and SF_6. The KCA approach is a Tier 1 quantitative analysis.

The level assessment of the Tier 1 KCA is a ranking of the source categories in accordance to their relative contribution to the national total of greenhouse gases calculated in CO_2 equivalents. The level key categories are found from the list of source categories ranked according to their contribution in descending order. Level key categories are those from the top of the list and of which the sum constitutes 95 % of the national total.

The trend assessment of the Tier 1 KCA is a ranking of the source categories according to their contribution to the trend of the national total of greenhouse gases, calculated in CO_2 equivalents, from the base year to the year under consideration. The trend of the source category is calculated relative to that of the national totals and the trend is then weighted with the contribution, according to the level assessment. The ranking is in descending order. As for the level assessment, the cut-off point for the sum of contribution to the trend is 95 % and the source categories from the top of the list to the cut-off line are trend key categories.

Result of the Key Category Analysis for Greenland for the year 1990 and 2013

The entries in the results of KCA in Tables 16.11.1 to 16.11.3 for the years 1990 and 2013 are composed from CRFs for those years in this report. Note that base-year estimates are not used in the level assessment analysis for year 2013, but are only included in Table 16.11.2 to make it more uniform with Tables 16.11.1 and 16.11.3.

The result of the Tier 1 KCA level assessment for Greenland for 1990 is shown in Table 16.11.1. For the assessment, 5 categories were identified as key categories and marked as shaded, refer Table 16.11.1.

The result of the Tier 1 KCA level assessment for Greenland for 2013 is shown in Table 16.11.2. For the assessment, 6 categories were identified as key categories, refer Table 16.11.2.

The result of the Tier 1 KCA trend assessment for Greenland for 1990/1995-2013 is shown in Table 16.11.3. For the trend assessment, 8 categories were identified as key categories, refer Table 16.11.3. Note that according to the GPG, the analysis implies that contributions to the trend are all calculated as mathematically positive to be able to perform the ranking. The LULUCF activities are in the table included with their sign, i.e. emissions: +, removals: -.

In Table 16.11.4 a summary of Key Category Analysis for Greenland is given for level assessment for year 1990/95 and 2013 and for trend for years 1990-2013. All the categories are listed by sector and key sources are shown with their ranking.

Table 16.11.1 Key Category Analysis base year 1990/1995, level assessment, Tier 1.

Table 7.A1 (of Good Practice Guidance)

Tier 1 Analysis - Level Assessment GRL – inventory

A			B	C	D	E
IPCC Source Categories (LULUCF included)			Direct GHG	Base Year Estimate Ex,o Gg CO_2 eqv.	Base Year Level Assessment Lx,o	Base Year Cumulative total of Col. D
Energy	Combustion excluding transport	Liquid fuels	CO_2	523.042	0.802	0.802
Energy	Domestic aviation		CO_2	38.709	0.059	0.862
Energy	Road transportation		CO_2	36.423	0.056	0.917
Energy	Domestic navigation		CO_2	20.941	0.032	0.950
Agriculture	Enteric fermentation		CH_4	7.627	0.012	0.961
Waste	Wastewater treatment and discharge		N_2O	7.154	0.011	0.972
Waste	Solid waste disposal		CH_4	4.328	0.007	0.979
Waste	Incineration and open burning of waste		CH_4	2.692	0.004	0.983
Waste	Incineration and open burning of waste		CO_2	2.550	0.004	0.987
Energy	Combustion excluding transport	Other fuels	CO_2	1.674	0.003	0.990
Energy	Combustion excluding transport		N_2O	1.338	0.002	0.992
Energy	Combustion excluding transport		CH_4	1.131	0.002	0.993
Agriculture	Agricultural soils		N_2O	0.891	0.001	0.995
Agriculture	Manure management		N_2O	0.869	0.001	0.996
Waste	Incineration and open burning of waste		N_2O	0.741	0.001	0.997
Energy	Road transportation		N_2O	0.627	0.001	0.998
Energy	Domestic aviation		N_2O	0.323	0.000	0.999
Industry	Solvent use		CO_2	0.263	0.000	0.999
LULUCF	Grassland remaining grassland		CO_2	0.206	0.000	0.999
Agriculture	Manure management		CH_4	0.167	0.000	1.000
Energy	Road transportation		CH_4	0.068	0.000	1.000
Energy	Domestic navigation		N_2O	0.051	0.000	1.000
Industry	Paraffin wax use		CO_2	0.043	0.000	1.000
Energy	Domestic navigation		CH_4	0.036	0.000	1.000
Industry	Consumption of SF6		SF_6	0.034	0.000	1.000
Industry	Consumption of HFC's		HFCs	0.027	0.000	1.000
Agriculture	Liming		CO_2	0.008	0.000	1.000
Energy	Domestic aviation		CH_4	0.007	0.000	1.000
Industry	Road paving with asphalt		CO_2	0.000	0.000	1.000
Industry	Asphalt roofing		CO_2	0.000	0.000	1.000
Industry	Limestone and dolomite use		CO_2	0.000	0.000	1.000
LULUCF	Forest land remaining forest land		CO_2	0.000	0.000	1.000
LULUCF	Land converted to cropland		CO_2	0.000	0.000	1.000
Total				651.971	1.000	

Table 16.11.2 Key Category Analysis year 2013, level assessment, Tier 1.

Table 7.A1 (of Good Practice Guidance)

Tier 1 Analysis - Level Assessment GRL – inventory

A			B	C	D	E	F
IPCC Source Categories (LULUCF included)			Direct GHG	Base Year Estimate Ex,o Gg CO_2 eqv	Year 2013 Estimate Ex,t Gg CO_2-eqv	Year 2013 Level Assessment Lx,t	Year 2013 Cumulative total of Col. E
Energy	Combustion excluding transport	Liquid fuels	CO_2	523.042	440.649	0.740	0.740
Energy	Domestic aviation		CO_2	38.709	42.411	0.071	0.811
Energy	Domestic navigation		CO_2	20.941	34.644	0.058	0.869
Energy	Road transportation		CO_2	36.423	33.077	0.056	0.925
Industry	Consumption of HFC's		HFCs	0.027	8.303	0.014	0.939
Energy	Combustion excluding transport	Other fuels	CO_2	1.674	7.044	0.012	0.950
Agriculture	Enteric fermentation		CH_4	7.627	6.845	0.011	0.962
Waste	Solid waste disposal		CH_4	4.328	4.600	0.008	0.970
Waste	Wastewater treatment and discharge		N_2O	7.154	4.553	0.008	0.977
Waste	Incineration and open burning of waste		CO_2	2.550	3.139	0.005	0.983
Waste	Incineration and open burning of waste		CH_4	2.692	1.896	0.003	0.986
Agriculture	Agricultural soils		N_2O	0.891	1.613	0.003	0.988
Energy	Combustion excluding transport		N_2O	1.338	1.309	0.002	0.991
LULUCF	Grassland remaining grassland		CO_2	0.206	1.117	0.002	0.993
Energy	Combustion excluding transport		CH_4	1.131	1.096	0.002	0.994
Agriculture	Manure management		N_2O	0.869	0.848	0.001	0.996
Energy	Road transportation		N_2O	0.627	0.752	0.001	0.997
Waste	Incineration and open burning of waste		N_2O	0.741	0.558	0.001	0.998
Energy	Domestic aviation		N_2O	0.323	0.354	0.001	0.999
Industry	Solvent use		CO_2	0.263	0.224	0.000	0.999
Agriculture	Manure management		CH_4	0.167	0.149	0.000	0.999
Energy	Road transportation		CH_4	0.068	0.138	0.000	0.999
Industry	Paraffin wax use		CO_2	0.043	0.091	0.000	1.000
Energy	Domestic navigation		N_2O	0.051	0.084	0.000	1.000
Energy	Domestic navigation		CH_4	0.036	0.059	0.000	1.000
LULUCF	Land converted to cropland		CO_2	0.000	0.048	0.000	1.000
LULUCF	Forest land remaining forest land		CO_2	0.000	-0.045	0.000	1.000
Energy	Domestic aviation		CH_4	0.007	0.007	0.000	1.000
Agriculture	Liming		CO_2	0.008	0.004	0.000	1.000
Industry	Consumption of SF6		SF_6	0.034	0.003	0.000	1.000
Industry	Road paving with asphalt		CO_2	0.000	0.000	0.000	1.000
Industry	Asphalt roofing		CO_2	0.000	0.000	0.000	1.000
Industry	Limestone and dolomite use		CO_2	0.000	0.000	0.000	1.000
Total				651.971	595.570	1.000	

Table 16.11.3 Key Category Analysis years 1990/1995-2013, trend assessment, Tier 1.

Table 7.A1 (of Good Practice Guidance)

Tier 1 Analysis - Trend Assessment GRL – inventory

A			B	C	D	E	F	G
IPCC Source Categories (LULUCF included)			Direct GHG	Base Year Estimate Ex,o Gg CO_2-eq	Year 2013 Estimate Ex,t Gg CO_2-eq	Trend Assess-ment Tx,t	Contri bution to Trend	Cumul. total of col. F
Energy	Combustion excluding transport	Liquid fuels	CO_2	523.042	440.649	0.057	0.462	0.462
Energy	Domestic navigation		CO_2	20.941	34.644	0.024	0.193	0.655
Industry	Consumption of HFC's		HFCs	0.027	8.303	0.013	0.103	0.758
Energy	Domestic aviation		CO_2	38.709	42.411	0.011	0.088	0.845
Energy	Combustion excluding transport	Other fuels	CO_2	1.674	7.044	0.008	0.069	0.914
Waste	Wastewater treatment and discharge		N_2O	7.154	4.553	0.003	0.025	0.938
LULUCF	Grassland remaining grassland		CO_2	0.206	1.117	0.001	0.012	0.950
Waste	Incineration and open burning of waste		CO_2	2.550	3.139	0.001	0.010	0.960
Agriculture	Agricultural soils		N_2O	0.891	1.613	0.001	0.010	0.970
Waste	Solid waste disposal		CH_4	4.328	4.600	0.001	0.008	0.978
Waste	Incineration and open burning of waste		CH_4	2.692	1.896	0.001	0.007	0.985
Energy	Road transportation		CO_2	36.423	33.077	0.000	0.002	0.987
Energy	Road transportation		N_2O	0.627	0.752	0.000	0.002	0.990
Agriculture	Enteric fermentation		CH_4	7.627	6.845	0.000	0.002	0.991
Waste	Incineration and open burning of waste		N_2O	0.741	0.558	0.000	0.001	0.993
Energy	Combustion excluding transport		N_2O	1.338	1.309	0.000	0.001	0.994
Energy	Road transportation		CH_4	0.068	0.138	0.000	0.001	0.995
Energy	Combustion excluding transport		CH_4	1.131	1.096	0.000	0.001	0.995
Energy	Domestic aviation		N_2O	0.323	0.354	0.000	0.001	0.996
Agriculture	Manure management		N_2O	0.869	0.848	0.000	0.001	0.997
Industry	Paraffin wax use		CO_2	0.043	0.091	0.000	0.001	0.997
LULUCF	Land converted to cropland		CO_2	0.000	0.048	0.000	0.001	0.998
LULUCF	Forest land remaining forest land		CO_2	0.000	-0.045	0.000	0.001	0.999
Energy	Domestic navigation		N_2O	0.051	0.084	0.000	0.000	0.999
Industry	Consumption of SF6		SF_6	0.034	0.003	0.000	0.000	0.999
Energy	Domestic navigation		CH_4	0.036	0.059	0.000	0.000	1.000
Industry	Solvent use		CO_2	0.263	0.224	0.000	0.000	1.000
Agriculture	Manure management		CH_4	0.167	0.149	0.000	0.000	1.000
Agriculture	Liming		CO_2	0.008	0.004	0.000	0.000	1.000
Energy	Domestic aviation		CH_4	0.007	0.007	0.000	0.000	1.000
Industry	Road paving with asphalt		CO_2	0.000	0.000	0.000	0.000	1.000
Industry	Asphalt roofing		CO_2	0.000	0.000	0.000	0.000	1.000
Industry	Limestone and dolomite use		CO_2	0.000	0.000	0.000	0.000	1.000
Total				651.971	595.570		1.000	

Table 16.11.4 Summary of Key Category Analysis for Greenland for level assessment for year 1990/95 and 2013 and for trend for years 1990-2013.

Summary of Key Category analysis for Greenland IPCC Source Categories (LULUCF included)			GHG	Key categories with number according to ranking in analysis Identification criteria		
				Level Tier1 1990	Level Tier1 2013	Trend Tier1 1990-2013
Energy	Combustion excluding transport	Liquid fuels	CO_2	1	1	1
Energy	Combustion excluding transport	Other fuels	CO_2		6	5
Energy	Combustion excluding transport		CH_4			
Energy	Combustion excluding transport		N_2O			
Energy	Domestic aviation		CO_2	2	2	4
Energy	Domestic aviation		CH_4			
Energy	Domestic aviation		N_2O			
Energy	Road transportation		CO_2	3	4	
Energy	Road transportation		CH_4			
Energy	Road transportation		N_2O			
Energy	Domestic navigation		CO_2	4	3	2
Energy	Domestic navigation		CH_4			
Energy	Domestic navigation		N_2O			
Industry	Limestone and dolomite use		CO_2			
Industry	Paraffin wax use		CO_2			
Industry	Solvent use		CO_2			
Industry	Road paving with asphalt		CO_2			
Industry	Asphalt roofing		CO_2			
Industry	Consumption of HFC's		HFCs		5	3
Industry	Consumption of SF6		SF_6			
Agriculture	Enteric fermentation		CH_4	5		
Agriculture	Manure management		CH_4			
Agriculture	Manure management		N_2O			
Agriculture	Agricultural soils		N_2O			
Agriculture	Liming		CO_2			
Waste	Solid waste disposal		CH_4			
Waste	Incineration and open burning of waste		CO_2			8
Waste	Incineration and open burning of waste		CH_4			
Waste	Incineration and open burning of waste		N_2O			
Waste	Wastewater treatment and discharge		N_2O			6
LULUCF	Forest land remaining forest land		CO_2			
LULUCF	Land converted to cropland		CO_2			
LULUCF	Grassland remaining grassland		CO_2			7

16.12 Annex 2 Detailed discussion of methodology and data for estimating CO_2 emission from fossil fuel combustion

Detailed information regarding the methodology and input data used to calculate CO_2 emissions from fossil fuel combustion is included in Section 16.3.

16.13 Annex 3 Other detailed methodological descriptions for individual source or sink categories

All methodological descriptions are included in Sections 16.3 – 16.7 and Section 16.10.

16.14 Annex 4 CO_2 reference approach and comparison with sectoral approach, and relevant information on the national energy balance

See Section 16.3.6 of this annex for the results of the comparison between the sectoral and reference approach.

16.15 Annex 5 Assessment of completeness and (potential) sources and sinks of greenhouse gas emissions and removals excluded

16.15.1 GHG inventory

The Greenlandic greenhouse gas emission inventories for 1990-2013 include all sources identified by the 2006 IPCC Guidelines and the 2000 IPCC Good Practice Guidance except the following:

In the Industrial Processes and Product Use sector no N_2O emissions are included in CRF category 2D3 Solvent Use. Priorily the notation key NE has been used regarding N_2O from fire extinguishers. However, a Danish research on the matter has showed that N_2O is not used in fire extinguishers. Since Greenland imports all fireextinguishers from Denmark, the notation key on N_2O in fire extinguishers has been changed from NE to NO concerning every year in the time-series 1990-2013. With regard to aerosol cans, we are aware that N_2O is found in the products. Since we can not find any activity data on aerosol cans, we continue to report the notation key NE for N_2O in aerosol cans.

Direct and indirect CH_4 emissions from agricultural soils are not estimated. Direct and indirect soil emissions are considered of minor importance for CH_4.

In the LULUCF sector emissions/removals from wetlands, settlements and other land are currently not estimated due to the lack of available data. The lack of data availability is also an issue for other aspects of LULUCF, e.g. harvested wood products. For more detail please see Section 16.6.

In the Waste sector CO_2 emissions from managed waste disposal on land are not estimated. According to the 2006 IPCC Guidelines: "Decomposition of organic material derived from biomass sources (e.g., crops, wood) is the primary source of CO_2 release from waste. These CO_2 emissions are not included in national totals, because the carbon is of biogenic origin and net emissions are accounted for under the AFOLU Sector."

16.15.2 KP-LULUCF inventory

The KP-LULUCF inventory is considered complete. The carbon pools not estimated has been documented as not being sources, please see Section 16.10 for further documentation.

16.16 Annex 6 Additional information to be considered as part of the annual inventory submission and the supplementary information required under Article 7, paragraph 1, of the Kyoto Protocol or other useful reference information

No additional information for Greenland is deemed relevant.

16.17 Annex 7 Tables 6.1 and 6.2 of the IPCC good practice guidance.

IPCC Source category	Gas	Base year emission	Year t emission	Activity data uncertainty	Emission factor uncertainty	Combined uncertainty	Combined uncertainty as % of total national emissions in year t	Type A sensitivity	Type B sensitivity	Uncertainty in trend in national emissions introduced by emission factor uncertainty	Uncertainty in trend in national emissions introduced by activity data uncertainty	Uncertainty introduced into the trend in total national emissions
		Input data Gg CO_2 eq	Input data Gg CO_2 eq	Input data %	Input data %	%	%	%	%	%	%	%
1A Liquid fuels	CO_2	619	551	3	2	3.606	11.118	0.022	0.845	0.045	3.584	12.848
1A Municipal waste	CO_2	2	7	3	25	25.179	0.089	0.008	0.011	0.211	0.046	0.047
1A Liquid fuels	CH_4	1	1	3	100	100.045	0.038	0.000	0.002	0.008	0.008	0.000
1A Municipal waste	CH_4	0	0	3	100	100.045	0.000	0.000	0.000	0.008	0.000	0.000
1A Biomass	CH_4	0	0	3	100	100.045	0.000	0.000	0.000	0.009	0.001	0.000
1A Liquid fuels	N_2O	2	2	3	500	500.009	3.638	0.000	0.003	0.141	0.015	0.020
1A Municipal waste	N_2O	0	0	3	500	500.009	0.007	0.000	0.000	0.061	0.001	0.004
1A Biomass	N_2O	0	0	3	200	200.022	0.002	0.000	0.000	0.030	0.001	0.001
1B2 Oil exploration	CO_2	0	0	3	1 000	1 000.004	0.000	0.000	0.000	0.000	0.000	0.000
1B2 Oil exploration	CH_4	0	0	3	1 000	1 000.004	0.000	0.000	0.000	0.000	0.000	0.000
1B2 Oil exploration	N_2O	0	0	3	1 000	1 000.004	0.000	0.000	0.000	0.000	0.000	0.000
2A4 Limestone and dolomite use	CO_2	0	0	5	5	7.071	0.000	0.000	0.000	0.000	0.000	0.000
2D2 Paraffin wax use	CO_2	0	0	5	25	25.495	0.000	0.000	0.000	0.002	0.001	0.000
2D3 Solvent use	CO_2	0	0	5	25	25.495	0.000	0.000	0.000	0.001	0.002	0.000
2D3 Road paving with asphalt	CO_2	0	0	5	25	25.495	0.000	0.000	0.000	0.000	0.000	0.000
2D3 Asphalt roofing	CO_2	0	0	5	25	25.495	0.000	0.000	0.000	0.000	0.000	0.000
2F Consumption of HFC	HFC	0	8	10	50	50.990	0.505	0.013	0.013	0.635	0.180	0.436
2G Consumption of SF_6	SF_6	0	0	10	50	50.990	0.000	0.000	0.000	0.002	0.000	0.000
3A Enteric Fermentation	CH_4	8	7	10	100	100.499	1.334	0.000	0.010	0.019	0.148	0.022
3B Manure Management	CH_4	0	0	10	100	100.499	0.001	0.000	0.000	0.001	0.003	0.000
3B Manure Management	N_2O	1	1	10	100	100.499	0.020	0.000	0.001	0.008	0.018	0.000
3D Agricultural soils	N_2O	1	2	20	50	53.852	0.021	0.001	0.002	0.061	0.070	0.009
3G Liming	CO_2	0	0	5	50	50.249	0.000	0.000	0.000	0.000	0.000	0.000

IPCC Source category	Gas	Base year emission	Year t emission	Activity data uncertainty	Emission factor uncertainty	Combined uncertainty	Combined uncertainty as % of total national emissions in year t	Type A sensitivity	Type B sensitivity	Uncertainty in trend in national emissions introduced by emission factor uncertainty	Uncertainty in trend in national emissions introduced by activity data uncertainty	Uncertainty introduced into the trend in total national emissions
		Input data	Input data	Input data	Input data							
		Gg CO_2 eq	Gg CO_2 eq	%	%	%	%	%	%	%	%	%
continued												
4A Forest	CO_2	0	0	5	50	50.249	0.000	0.000	0.000	0.003	0.000	0.000
4B Cropland	CO_2	0	0	5	50	50.249	0.000	0.000	0.000	0.004	0.001	0.000
4C Grassland	CO_2	0	1	5	50	50.249	0.009	0.001	0.002	0.071	0.012	0.005
5A Solid Waste Disposal	CH_4	4	5	10	100	100.499	0.602	0.001	0.007	0.099	0.100	0.020
5C Incineration and open burning of waste	CO_2	3	3	10	25	26.926	0.020	0.001	0.005	0.031	0.068	0.006
5C Incineration and open burning of waste	CH_4	3	2	10	50	50.990	0.026	0.001	0.003	0.043	0.041	0.004
5C Incineration and open burning of waste	N_2O	1	1	10	100	100.499	0.009	0.000	0.001	0.018	0.012	0.000
5D Wastewater treatment and discharge	N_2O	7	5	30	100	104.403	0.637	0.003	0.007	0.304	0.296	0.180
Total		652	596				18,078					13,602
Total uncertainties				Overall uncertainty in the year (%):			4.252			Trend uncertainty (%):		3.688

16.18 Annex 8 Results of a technical analysis conducted on the Greenlandic gasoil

In 2013 a technical analysis has been conducted on the arctic gasoil that is by far the most dominant type of fuel in Greenland. The analysis was conducted by the Danish Technological Institute in order to gain a country specific emission factor on the Greenlandic gasoil.

Table 16.18.1 shows the results of the technological analysis on the Greenlandic gasoil. The CO2 emission factor has been revised in this 2015 submission due to an increase in the recommended oxidation factor from 0.99 to 1.0.

Table 16.18.1 Results on the technical analysis on the Greenlandic gasoil

	Test result	Method
C, %	85.4	Elementaranalyse
Upper calorific, J/g	45860	DS/CEN/TS 14918
Lower calorific, J/g	42900	Calculation
CO_2 emission factor, kg CO_2/GJ	72.967	Calculation

17 Information regarding the aggregated submission for Denmark and Greenland

This chapter will be included for the submission to the UNFCCC due April 15 2016.

Annex 1 - Key category analysis

Description of the methodology used for identifying key categories

Key Category Analysis (KCA) approach 1 and 2 for year 1990 and 2013 for Denmark (excluding Greenland and Faroe Islands) has been carried out in accordance with the IPCC Guidelines (2006). The KCA has been carried out excluding and including the LULUCF sector. A approach 1 KCA has also been worked out for Greenland and for Denmark and Greenland; refer to Chapter 16 and Chapter 17, respectively.

The base year in the analysis is the year 1990 for the greenhouse gases CO_2, CH_4, N_2O and 1995 for the F-gases HFC, PFC and SF_6. The KCA approaches are:

- A quantitative analysis, approach 1 KCA.
- An analysis based on uncertainties, approach 2 KCA.

The level assessment of the approach 1 KCA is a ranking of the source categories in accordance to their relative contribution to the national total of greenhouse gases calculated in CO_2 equivalent units. The level key categories are found from the list of source categories ranked according to their contribution in descending order. Level key categories are those from the top of the list and of which the sum constitutes 95 % of the national total.

The trend assessment of the approach 1 KCA is a ranking of the source categories according to their contribution to the trend of the national total of greenhouse gases, calculated in CO_2 equivalents, from the base year to the latest year. The trend of the source category is calculated relative to that of the national totals and the trend is then weighted with the contribution, according to the level assessment. The ranking is in descending order. As for the level assessment, the cut-off point for the sum of contribution to the trend is 95 % and the source categories from the top of the list to the cut-off line are trend key categories.

In addition, an approach 2 KCA has been carried out to provide additional insight into categories being key sources. The categorisation used is as for the approach 1 analysis and the uncertainties used are approach 1 uncertainties as listed in Annex 7.

The level approach 2 KCA is a ranking of the categories according to their relative contribution to the national total multiplied by the uncertainty of the emission of the category as the combined uncertainty on activity data and on emission factor. Chosen for cut of for key categories in the analysis is 90 %.

The trend approach 2 KCA is a ranking of the categories according to their relative contribution to the trend 1990-2013 of the national total multiplied by the uncertainty of the emission of the category. Chosen for cut of for key categories in the analysis is 90 %.

Since the level KCA is carried out for 1990, 2013 and trend, for data exclusive and inclusive LULUCF and based on approach 1 and approach 2 a total of 12

KCA tables for Denmark (excluding Greenland and Faroe Islands) has been worked out.

In addition, two[1] overview tables based on the Guidebook (2006), Vol. 1, Table 4.4 are shown. The overview table shows summary results of the KCA for 1990, for 2013, and for the trend 1990-2013.

The inclusion of the LULUCF sector in the level analysis implies that the emissions in this sector are all calculated positive, i.e. the absolute value of removals are included. Note also that according to the Guidebook, the analysis implies that contributions to the trend are all calculated as mathematically positive to be able to perform the ranking.

Emission source categories

The emission source categories are identical to the emission source categories applied in the uncertainty analysis. The categorisation has been somewhat revised compared to last year. The KCA is based on 210 emission source categories including 28 LULUCF source categories.

Result of the Key Category Analysis for Denmark

An overview of results of the KCA excluding LULUCF is shown in Table A1-1 and results of the KCA including LULUCF is shown in Table A1-2. The number of key source categories for each of the KCA are shown in Table A1-3.

The 12 different KCA for Denmark point out 25-52 key source categories each and a total of 72 different key source categories. The number of key categories in each of the main sectors is: energy 40, IPPU 6, agriculture 14, LULUCF 9 and waste 3.

Approach 1 point out mainly the large emission sources as key categories and thus CO_2 emission from stationary and mobile combustion are important key categories. Approach 2 point out some of the sources with larger uncertainty rates.

The list below gives an overview of the different KCA for Denmark (not including Greenland and Faroe Islands) that are presented in Table A1-4 – Table A1-15.

Table A1-4 KCA for Denmark, level assessment, base year excl. LULUCF, approach 1.
Table A1-5 KCA for Denmark, level assessment base year incl. LULUCF, approach 1.
Table A1-6 KCA for Denmark, level assessment 2013 excl. LULUCF, approach 1.
Table A1-7 KCA for Denmark, level assessment 2013 incl. LULUCF, approach 1.
Table A1-8 KCA for Denmark, trend assessment 1990-2013 excl. LULUCF, approach 1.
Table A1-9 KCA for Denmark, trend assessment 1990-2013 incl. LULUCF, approach 1.
Table A1-10 KCA for Denmark, level assessment base year excl. LULUCF, approach 2.
Table A1-11 KCA for Denmark, level assessment base year incl. LULUCF, approach 2.
Table A1-12 KCA for Denmark, level assessment 2013 excl. LULUCF, approach 2.
Table A1-13 KCA for Denmark, level assessment 2013 incl. LULUCF, approach 2.
Table A1-14 KCA for Denmark, trend assessment 1990-2013 excl. LULUCF, approach 2.
Table A1-15 KCA for Denmark, trend assessment 1990-2013 incl. LULUCF, approach 2.

[1] Including and excluding LULUCF

Table A1-1 Summary of KCA for Denmark, level and trend for 1990-2013, excl. LULUCF, approach 1 and approach 2.

IPCC Source Categories (LULUCF excluded)		**GHG**	**Key categories with number according to ranking in analysis Identification criteria**					
			Level Approach 1 1990	**Level Approach 1 2013**	**Trend Approach 1 1990-2013**	**Level Approach 2 1990**	**Level Approach 2 2013**	**Trend Approach 2 1990-2013**
Energy	1A Stationary combustion, Coal, ETS data	CO_2		1	2		34	22
Energy	1A Stationary combustion, Coal, no ETS data	CO_2	1	23	1	14		4
Energy	1A Stationary combustion, BKB	CO_2						
Energy	1A Stationary combustion, Coke oven coke	CO_2						
Energy	1A Stationary combustion, Fossil waste, ETS data	CO_2		10	7			26
Energy	1A Stationary combustion, Fossil waste, no ETS data	CO_2	19	18			35	
Energy	1A Stationary combustion, Petroleum coke, ETS data	CO_2		20	13			
Energy	1A Stationary combustion, Petroleum coke, no ETS data	CO_2	25		18			
Energy	1A Stationary combustion, Residual oil, ETS data	CO_2		25	17			
Energy	1A Stationary combustion, Residual oil, no ETS data	CO_2	6		6			32
Energy	1A Stationary combustion, Gas oil	CO_2	3	15	5	25		20
Energy	1A Stationary combustion, Kerosene	CO_2	26		19			
Energy	1A Stationary combustion, LPG	CO_2						
Energy	1A1b Stationary combustion, Petroleum refining, Refinery gas	CO_2	15	12	20			
Energy	1A Stationary combustion, Natural gas, onshore	CO_2	5	3	4		31	31
Energy	1A1c_ii Stationary combustion, Oil and gas extraction, Off shore gas turbines, Natural gas	CO_2	23	6	8			
Energy	1A1 Stationary Combustion, Solid fuels	CH_4						
Energy	1A1 Stationary Combustion, Liquid fuels	CH_4						
Energy	1A1 Stationary Combustion, not engines, gaseous fuels	CH_4						
Energy	1A1 Stationary Combustion, Waste	CH_4						
Energy	1A1 Stationary Combustion, not engines, Biomass	CH_4						
Energy	1A2 Stationary Combustion,solid fuels	CH_4						
Energy	1A2 Stationary Combustion,Liquid fuels	CH_4						
Energy	1A2 Stationary Combustion, not engines, gaseous fuels	CH_4						
Energy	1A2 Stationary Combustion, Waste	CH_4						
Energy	1A2 Stationary Combustion, not engines, Biomass	CH_4						
Energy	1A4 Stationary Combustion, Solid fuels	CH_4						
Energy	1A4 Stationary Combustion, Liquid fuels	CH_4						
Energy	1A4 Stationary Combustion, not engines, gaseous fuels	CH_4						
Energy	1A4 Stationary Combustion, Waste	CH_4						
Energy	1A4 Stationary Combustion, not engines, not residential wood and not residential/agricultural straw, Biomass	CH_4						
Energy	1A4b_i Stationary combustion, Residential wood combustion	CH_4				28	24	29
Energy	1A4b_i/1A4c_i Stationary Combustion, Residential and agricultural straw combustion	CH_4				31		
Energy	1A Stationary combustion, Natural gas fuelled engines, gaseous fuels	CH_4						
Energy	1A Stationary combustion, Biogas fuelled engines, Biomass	CH_4						
Energy	1A1 Stationary Combustion, Solid fuels	N_2O				20	28	25
Energy	1A1 Stationary Combustion, Liquid fuels	N_2O						
Energy	1A1 Stationary Combustion, Gaseous fuels	N_2O				32	21	23

Energy	1A1 Stationary Combustion, Waste	N_2O						37
Energy	1A1 Stationary Combustion, Biomass	N_2O					26	16
Energy	1A2 Stationary Combustion, Solid fuels	N_2O						
Energy	1A2 Stationary Combustion, Liquid fuels	N_2O				18	32	11
Energy	1A2 Stationary Combustion, Gaseous fuels	N_2O					36	41
Energy	1A2 Stationary Combustion, Waste	N_2O						
Energy	1A2 Stationary Combustion, Biomass	N_2O						
Energy	1A4 Stationary Combustion, Solid fuels	N_2O						
Energy	1A4 Stationary Combustion, Liquid fuels	N_2O				26		21
Energy	1A4 Stationary Combustion, Gaseous fuels	N_2O					30	34
Energy	1A4 Stationary Combustion, Waste	N_2O						
Energy	1A4 Stationary Combustion, not residential wood and not residential/agricultural straw, Biomass	N_2O						
Energy	1A4b_i Stationary Combustion, Residential wood combustion	N_2O					17	12
Energy	1A4b_i/1A4c_i Stationary Combustion, Residential and agricultural straw combustion	N_2O						
Energy	1.A.2.g Industry (mobile)	CO_2	14	8	16	13	8	10
Energy	1.A.3.a Civil aviation	CO_2						
Energy	1.A.3.b Road Transport	CO_2	2	2	3	11	7	5
Energy	1.A.3.c Railways	CO_2		27				
Energy	1.A.3.d Navigation (large vessels)	CO_2	17	22	23	33		
Energy	1.A.4.a Commercial/Institutional (mobile)	CO_2		31			37	35
Energy	1.A.4.b Residential (mobile)	CO_2						
Energy	1.A.4.c ii Agriculture (mobile)	CO_2	10	7		16	14	39
Energy	1.A.4.c ii Forestry (mobile)	CO_2						
Energy	1.A.4.c iii Fisheries	CO_2	18	21				
Energy	1.A.5.b Other (military)	CO_2						
Energy	1.A.5.b Other (small boats)	CO_2		34				
Energy	1.A.2.g Industry (mobile)	CH_4						
Energy	1.A.3.a Civil aviation	CH_4						
Energy	1.A.3.b Road Transport	CH_4						
Energy	1.A.3.c Railways	CH_4						
Energy	1.A.3.d Navigation (large vessels)	CH_4						
Energy	1.A.4.a Commercial/Institutional (mobile)	CH_4						
Energy	1.A.4.b Residential (mobile)	CH_4						
Energy	1.A.4.c ii Agriculture (mobile)	CH_4						
Energy	1.A.4.c ii Forestry (mobile)	CH_4						
Energy	1.A.4.c iii Fisheries	CH_4						
Energy	1.A.5.b Other (military)	CH_4						
Energy	1.A.5.b Other (small boats)	CH_4						
Energy	1.A.2.g Industry (mobile)	N_2O				29	27	28
Energy	1.A.3.a Civil aviation	N_2O						
Energy	1.A.3.b Road Transport	N_2O					39	
Energy	1.A.3.c Railways	N_2O						
Energy	1.A.3.d Navigation (large vessels)	N_2O				24	33	36
Energy	1.A.4.a Commercial/Institutional (mobile)	N_2O						
Energy	1.A.4.b Residential (mobile)	N_2O						
Energy	1.A.4.c ii Agriculture (mobile)	N_2O				23	20	
Energy	1.A.4.c ii Forestry (mobile)	N_2O						

Energy	1.A.4.c iii Fisheries	N_2O				27	29	
Energy	1.A.5.b Other (military)	N_2O						
Energy	1.A.5.b Other (small boats)	N_2O						
Energy	1.B.2.a.1 Exploration, oil	CO_2						
Energy	1.B.2.a.2 Production, oil	CO_2						
Energy	1.B.2.a.3 Transport, oil	CO_2						
Energy	1.B.2.b.1 Exploration, gas	CO_2						
Energy	1.B.2.b.2 Production, gas	CO_2						
Energy	1.B.2.b.4 Transmission and storage, gas	CO_2						
Energy	1.B.2.b.5 Distribution, gas	CO_2						
Energy	1.B.2.c.1.ii Venting, gas	CO_2						
Energy	1.B.2.c.2.i Flaring, oil	CO_2						
Energy	1.B.2.c.2.ii Flaring, gas	CO_2	28	29				
Energy	1.B.2.a.1 Exploration, oil	CH_4						
Energy	1.B.2.a.2 Production, oil	CH_4						
Energy	1.B.2.a.3 Transport, oil	CH_4						
Energy	1.B.2.a.4 Refining/storage	CH_4						
Energy	1.B.2.b.1 Exploration, gas	CH_4						
Energy	1.B.2.b.2 Production, gas	CH_4						
Energy	1.B.2.b.4 Transmission and storage, gas	CH_4						
Energy	1.B.2.b.5 Distribution, gas	CH_4						
Energy	1.B.2.c.1.ii Venting, gas	CH_4						
Energy	1.B.2.c.2.i Flaring, oil	CH_4						
Energy	1.B.2.c.2.ii Flaring, gas	CH_4						
Energy	1.B.2.a.1 Exploration, oil	N_2O						
Energy	1.B.2.b.1 Exploration, gas	N_2O						
Energy	1.B.2.c.2.i Flaring, oil	N_2O						
Energy	1.B.2.c.2.ii Flaring, gas	N_2O				10	9	
IPPU	2A1 Cement production	CO_2	13	13				
IPPU	2A2 Lime production	CO_2						
IPPU	2A3 Glass production	CO_2						
IPPU	2A4a Ceramics	CO_2						
IPPU	2A4b Other uses of soda ash	CO_2						
IPPU	2A4d Other process uses of carbonates	CO_2						
IPPU	2B10 Production of catalysts	CO_2						
IPPU	2C1a Steel	CO_2						
IPPU	2C5 Lead production	CO_2						
IPPU	2D1 Lubricant use	CO_2						
IPPU	2D2 Paraffin wax use	CO_2						33
IPPU	2D3 Paint Application	CO_2						
IPPU	2D3 Degreasing, dry cleaning and electronics	CO_2						
IPPU	2D3 Chemical products manufacturing or processing	CO_2						
IPPU	2D3 Other use of solvents and related activities	CO_2						
IPPU	2D3 Road paving with asphalt	CO_2						
IPPU	2D3 Asphalt roofing	CO_2						
IPPU	2D3 Urea based catalysts	CO_2						
IPPU	2G4 Fireworks	CO_2						
IPPU	2D2 Paraffin wax use	CH_4						
IPPU	2D3 Road paving with asphalt	CH_4						

IPPU	2G4 Fireworks	CH_4						
IPPU	2G4 Tobacco	CH_4						
IPPU	2G4 Charcoal	CH_4						
IPPU	2B2 Nitric acid production	N_2O	11		9	19		8
IPPU	2D2 Paraffin wax use	N_2O						
IPPU	2G3a Medical application of N2O	N_2O						
IPPU	2G3b N2O as propellant for pressure and aerosol products	N_2O						
IPPU	2G4 Fireworks	N_2O						
IPPU	2G4 Tobacco	N_2O						
IPPU	2G4 Charcoal	N_2O						
IPPU	2F1 Refrigeration and air conditioning	HFCs		16	10		12	3
IPPU	2F2 Foam blowing agents	HFCs				30		30
IPPU	2F4 Aerosols	HFCs						
IPPU	2E Electronics industry	PFCs						
IPPU	2F1 Refrigeration and air conditioning	PFCs						
IPPU	2C4 Magnesium production	SF_6						
IPPU	2G1 Electrical equipment	SF_6						
IPPU	2G2 SF6 and PFCs from other product use	SF_6					38	38
Agriculture	3A Enteric Fermentation	CH_4	4	4	15	5	4	18
Agriculture	3B Manure Management	CH_4	9	5	12	12	10	14
Agriculture	3F Field Burning of Agricultural Residues	CH_4						
Agriculture	3B Manure Management	N_2O	16	19		4	6	
Agriculture	3B5 Atmospheric deposition	N_2O				22	22	
Agriculture	3Da1 Inorganic N fertilizer	N_2O	7	11	11	2	3	2
Agriculture	3Da2a Animal manure applied to soils	N_2O	12	9	24	3	1	9
Agriculture	3Da2b Sewage sludge applied to soils	N_2O						
Agriculture	3Da2c Other organic fertilizer applied to soils	N_2O						
Agriculture	3Da3 Urine and dung deposited by grazing animals	N_2O	29	30		17	18	27
Agriculture	3Da4 Crop Residues	N_2O	20	17	22	6	5	7
Agriculture	3Da5 Mineralization	N_2O		32		21	16	
Agriculture	3Da6 Cultivation of organic soils	N_2O	24	24		9	11	24
Agriculture	3Db1 Atmospheric deposition	N_2O	27	33		15	19	19
Agriculture	3Db2 Leaching	N_2O	22	26		8	13	17
Agriculture	3F Field Burning of Agricultural Residues	N_2O						
Agriculture	3G Liming	CO_2	21	28	21	7	15	6
Agriculture	3H Urea applicaton	CO_2						
Agriculture	3I Other carbon-containing fertilizers	CO_2						40
Waste	5.E Accidental fires	CO_2						
Waste	5.A Solid waste disposal	CH_4	8	14	14	1	2	1
Waste	5.B.1 Composting	CH_4					23	15
Waste	5.C.1 Incineration of corpses	CH_4						
Waste	5.C.2 Incineration of carcasses	CH_4						
Waste	5.D Wastewater treatment and discharge	CH_4						
Waste	5.E Accidental fires	CH_4						
Waste	5.B.1 Composting	N_2O					25	13
Waste	5.C.1 Incineration of corpses	N_2O						
Waste	5.C.2 Incineration of carcasses	N_2O						
Waste	5.D Wastewater treatment and discharge	N_2O						

Table A1-2 Summary of KCA for Denmark, level and trend for 1990-2013, incl. LULUCF, approach 1 and approach 2.

IPCC Source Categories (LULUCF included)		**GHG**	**Key categories with number according to ranking in analysis Identification criteria**					
			Level Approach 1 1990	**Level Approach 1 2013**	**Trend Approach 1 1990-2013**	**Level Approach 2 1990**	**Level Approach 2 2013**	**Trend Approach 2 1990-2013**
Energy	1A Stationary combustion, Coal, ETS data	CO_2		1	2		39	25
Energy	1A Stationary combustion, Coal, no ETS data	CO_2	1	28	1	17		4
Energy	1A Stationary combustion, BKB	CO_2						
Energy	1A Stationary combustion, Coke oven coke	CO_2						
Energy	1A Stationary combustion, Fossil waste, ETS data	CO_2		13	8			30
Energy	1A Stationary combustion, Fossil waste, no ETS data	CO_2	22	21	26		40	
Energy	1A Stationary combustion, Petroleum coke, ETS data	CO_2		23	14			
Energy	1A Stationary combustion, Petroleum coke, no ETS data	CO_2	28		21			
Energy	1A Stationary combustion, Residual oil, ETS data	CO_2		30	19			
Energy	1A Stationary combustion, Residual oil, no ETS data	CO_2	7		7			36
Energy	1A Stationary combustion, Gas oil	CO_2	3	18	6	29		24
Energy	1A Stationary combustion, Kerosene	CO_2	29		23			
Energy	1A Stationary combustion, LPG	CO_2						
Energy	1A1b Stationary combustion, Petroleum refining, Refinery gas	CO_2	17	15	22			
Energy	1A Stationary combustion, Natural gas, onshore	CO_2	6	3	4		36	31
Energy	1A1c_ii Stationary combustion, Oil and gas extraction, Off shore gas turbines, Natural gas	CO_2	26	8	9			
Energy	1A1 Stationary Combustion, Solid fuels	CH_4						
Energy	1A1 Stationary Combustion, Liquid fuels	CH_4						
Energy	1A1 Stationary Combustion, not engines, gaseous fuels	CH_4						
Energy	1A1 Stationary Combustion, Waste	CH_4						
Energy	1A1 Stationary Combustion, not engines, Biomass	CH_4						
Energy	1A2 Stationary Combustion,solid fuels	CH_4						
Energy	1A2 Stationary Combustion,Liquid fuels	CH_4						
Energy	1A2 Stationary Combustion, not engines, gaseous fuels	CH_4						
Energy	1A2 Stationary Combustion, Waste	CH_4						
Energy	1A2 Stationary Combustion, not engines, Biomass	CH_4						
Energy	1A4 Stationary Combustion, Solid fuels	CH_4						
Energy	1A4 Stationary Combustion, Liquid fuels	CH_4						
Energy	1A4 Stationary Combustion, not engines, gaseous fuels	CH_4						
Energy	1A4 Stationary Combustion, Waste	CH_4						
Energy	1A4 Stationary Combustion, not engines, not residential wood and not residential/agricultural straw, Biomass	CH_4						
Energy	1A4b_i Stationary combustion, Residential wood combustion	CH_4				32	28	29
Energy	1A4b_i/1A4c_i Stationary Combustion, Residential and agricultural straw combustion	CH_4				35		
Energy	1A Stationary combustion, Natural gas fuelled engines, gaseous fuels	CH_4						
Energy	1A Stationary combustion, Biogas fuelled engines, Biomass	CH_4						
Energy	1A1 Stationary Combustion, Solid fuels	N_2O				23	33	32

IPCC Source Categories (LULUCF included)		GHG	Key categories with number according to ranking in analysis Identification criteria					
			Level Approach 1 1990	Level Approach 1 2013	Trend Approach 1 1990-2013	Level Approach 2 1990	Level Approach 2 2013	Trend Approach 2 1990-2013
Energy	1A1 Stationary Combustion, Liquid fuels	N_2O						
Energy	1A1 Stationary Combustion, Gaseous fuels	N_2O					25	23
Energy	1A1 Stationary Combustion, Waste	N_2O						42
Energy	1A1 Stationary Combustion, Biomass	N_2O					30	20
Energy	1A2 Stationary Combustion, Solid fuels	N_2O						
Energy	1A2 Stationary Combustion, Liquid fuels	N_2O				21	37	15
Energy	1A2 Stationary Combustion, Gaseous fuels	N_2O					42	50
Energy	1A2 Stationary Combustion, Waste	N_2O						
Energy	1A2 Stationary Combustion, Biomass	N_2O						
Energy	1A4 Stationary Combustion, Solid fuels	N_2O						
Energy	1A4 Stationary Combustion, Liquid fuels	N_2O				30		26
Energy	1A4 Stationary Combustion, Gaseous fuels	N_2O					35	34
Energy	1A4 Stationary Combustion, Waste	N_2O						
Energy	1A4 Stationary Combustion, not residential wood and not residential/agricultural straw, Biomass	N_2O						
Energy	1A4b_i Stationary Combustion, Residential wood combustion	N_2O					20	14
Energy	1A4b_i/1A4c_i Stationary Combustion, Residential and agricultural straw combustion	N_2O						
Energy	1.A.2.g Industry (mobile)	CO_2	16	11	18	16	10	11
Energy	1.A.3.a Civil aviation	CO_2	34					
Energy	1.A.3.b Road Transport	CO_2	2	2	3	13	9	7
Energy	1.A.3.c Railways	CO_2	33	33				
Energy	1.A.3.d Navigation (large vessels)	CO_2	19	27				
Energy	1.A.4.a Commercial/Institutional (mobile)	CO_2		37			43	38
Energy	1.A.4.b Residential (mobile)	CO_2						
Energy	1.A.4.c ii Agriculture (mobile)	CO_2	12	10	30	19	16	35
Energy	1.A.4.c ii Forestry (mobile)	CO_2						
Energy	1.A.4.c iii Fisheries	CO_2	21	26				
Energy	1.A.5.b Other (military)	CO_2						
Energy	1.A.5.b Other (small boats)	CO_2		40				
Energy	1.A.2.g Industry (mobile)	CH_4						
Energy	1.A.3.a Civil aviation	CH_4						
Energy	1.A.3.b Road Transport	CH_4						
Energy	1.A.3.c Railways	CH_4						
Energy	1.A.3.d Navigation (large vessels)	CH_4						
Energy	1.A.4.a Commercial/Institutional (mobile)	CH_4						
Energy	1.A.4.b Residential (mobile)	CH_4						
Energy	1.A.4.c ii Agriculture (mobile)	CH_4						
Energy	1.A.4.c ii Forestry (mobile)	CH_4						
Energy	1.A.4.c iii Fisheries	CH_4						
Energy	1.A.5.b Other (military)	CH_4						
Energy	1.A.5.b Other (small boats)	CH_4						
Energy	1.A.2.g Industry (mobile)	N_2O				33	31	28
Energy	1.A.3.a Civil aviation	N_2O						

IPCC Source Categories (LULUCF included)		GHG	Key categories with number according to ranking in analysis Identification criteria					
			Level Approach 1 1990	Level Approach 1 2013	Trend Approach 1 1990-2013	Level Approach 2 1990	Level Approach 2 2013	Trend Approach 2 1990-2013
Energy	1.A.3.b Road Transport	N_2O						
Energy	1.A.3.c Railways	N_2O						
Energy	1.A.3.d Navigation (large vessels)	N_2O				27	38	48
Energy	1.A.4.a Commercial/Institutional (mobile)	N_2O						
Energy	1.A.4.b Residential (mobile)	N_2O						
Energy	1.A.4.c ii Agriculture (mobile)	N_2O				26	24	45
Energy	1.A.4.c ii Forestry (mobile)	N_2O						
Energy	1.A.4.c iii Fisheries	N_2O				31	34	
Energy	1.A.5.b Other (military)	N_2O						
Energy	1.A.5.b Other (small boats)	N_2O						
Energy	1.B.2.a.1 Exploration, oil	CO_2						
Energy	1.B.2.a.2 Production, oil	CO_2						
Energy	1.B.2.a.3 Transport, oil	CO_2						
Energy	1.B.2.b.1 Exploration, gas	CO_2						
Energy	1.B.2.b.2 Production, gas	CO_2						
Energy	1.B.2.b.4 Transmission and storage, gas	CO_2						
Energy	1.B.2.b.5 Distribution, gas	CO_2						
Energy	1.B.2.c.1.ii Venting, gas	CO_2						
Energy	1.B.2.c.2.i Flaring, oil	CO_2						
Energy	1.B.2.c.2.ii Flaring, gas	CO_2	31	35				
Energy	1.B.2.a.1 Exploration, oil	CH_4						
Energy	1.B.2.a.2 Production, oil	CH_4						
Energy	1.B.2.a.3 Transport, oil	CH_4						
Energy	1.B.2.a.4 Refining/storage	CH_4						
Energy	1.B.2.b.1 Exploration, gas	CH_4						
Energy	1.B.2.b.2 Production, gas	CH_4						
Energy	1.B.2.b.4 Transmission and storage, gas	CH_4						
Energy	1.B.2.b.5 Distribution, gas	CH_4						
Energy	1.B.2.c.1.ii Venting, gas	CH_4						
Energy	1.B.2.c.2.i Flaring, oil	CH_4						
Energy	1.B.2.c.2.ii Flaring, gas	CH_4						
Energy	1.B.2.a.1 Exploration, oil	N_2O						
Energy	1.B.2.b.1 Exploration, gas	N_2O						
Energy	1.B.2.c.2.i Flaring, oil	N_2O						
Energy	1.B.2.c.2.ii Flaring, gas	N_2O				12	11	
IPPU	2A1 Cement production	CO_2	15	16	27			
IPPU	2A2 Lime production	CO_2						
IPPU	2A3 Glass production	CO_2						
IPPU	2A4a Ceramics	CO_2						
IPPU	2A4b Other uses of soda ash	CO_2						
IPPU	2A4d Other process uses of carbonates	CO_2						
IPPU	2B10 Production of catalysts	CO_2						
IPPU	2C1a Steel	CO_2						
IPPU	2C5 Lead production	CO_2						

IPCC Source Categories (LULUCF included)		GHG	Key categories with number according to ranking in analysis Identification criteria					
			Level Approach 1 1990	Level Approach 1 2013	Trend Approach 1 1990-2013	Level Approach 2 1990	Level Approach 2 2013	Trend Approach 2 1990-2013
IPPU	2D1 Lubricant use	CO_2						
IPPU	2D2 Paraffin wax use	CO_2						37
IPPU	2D3 Paint Application	CO_2						
IPPU	2D3 Degreasing, dry cleaning and electronics	CO_2						
IPPU	2D3 Chemical products manufacturing or processing	CO_2						
IPPU	2D3 Other use of solvents and related activities	CO_2						
IPPU	2D3 Road paving with asphalt	CO_2						
IPPU	2D3 Asphalt roofing	CO_2						
IPPU	2D3 Urea based catalysts	CO_2						
IPPU	2G4 Fireworks	CO_2						
IPPU	2D2 Paraffin wax use	CH_4						
IPPU	2D3 Road paving with asphalt	CH_4						
IPPU	2G4 Fireworks	CH_4						
IPPU	2G4 Tobacco	CH_4						
IPPU	2G4 Charcoal	CH_4						
IPPU	2B2 Nitric acid production	N_2O	13		10	22		8
IPPU	2D2 Paraffin wax use	N_2O						
IPPU	2G3a Medical application of N2O	N_2O						
IPPU	2G3b N2O as propellant for pressure and aerosol products	N_2O						
IPPU	2G4 Fireworks	N_2O						
IPPU	2G4 Tobacco	N_2O						
IPPU	2G4 Charcoal	N_2O						
IPPU	2F1 Refrigeration and air conditioning	HFCs		19	11		14	3
IPPU	2F2 Foam blowing agents	HFCs				34		33
IPPU	2F4 Aerosols	HFCs						
IPPU	2E Electronics industry	PFCs						
IPPU	2F1 Refrigeration and air conditioning	PFCs						
IPPU	2C4 Magnesium production	SF_6						
IPPU	2G1 Electrical equipment	SF_6						
IPPU	2G2 SF6 and PFCs from other product use	SF_6						43
Agriculture	3A Enteric Fermentation	CH_4	5	4	12	7	6	17
Agriculture	3B Manure Management	CH_4	10	7	13	15	12	16
Agriculture	3F Field Burning of Agricultural Residues	CH_4						
Agriculture	3B Manure Management	N_2O	18	22		6	8	46
Agriculture	3B5 Atmospheric deposition	N_2O				25	26	
Agriculture	3Da1 Inorganic N fertilizer	N_2O	8	14	16	3	5	2
Agriculture	3Da2a Animal manure applied to soils	N_2O	14	12	24	5	2	5
Agriculture	3Da2b Sewage sludge applied to soils	N_2O						
Agriculture	3Da2c Other organic fertilizer applied to soils	N_2O						
Agriculture	3Da3 Urine and dung deposited by grazing animals	N_2O	32	36		20	21	40
Agriculture	3Da4 Crop Residues	N_2O	23	20	25	8	7	6
Agriculture	3Da5 Mineralization	N_2O		38		24	19	49
Agriculture	3Da6 Cultivation of organic soils	N_2O	27	29		11	13	41
Agriculture	3Db1 Atmospheric deposition	N_2O	30	39		18	23	22

IPCC Source Categories (LULUCF included)		GHG	Key categories with number according to ranking in analysis Identification criteria					
			Level Approach 1 1990	Level Approach 1 2013	Trend Approach 1 1990-2013	Level Approach 2 1990	Level Approach 2 2013	Trend Approach 2 1990-2013
Agriculture	3Db2 Leaching	N_2O	25	31		10	15	21
Agriculture	3F Field Burning of Agricultural Residues	N_2O						
Agriculture	3G Liming	CO_2	24	34	29	9	18	9
Agriculture	3H Urea applicaton	CO_2						
Agriculture	3I Other carbon-containing fertilizers	CO_2						
LULUCF	4.A.1 Forest land remaining forest land, Living biomass	CO_2		5	5		22	10
LULUCF	4.A.1 Forest land remaining forest land, Dead organic matter	CO_2		24	15			51
LULUCF	4.A.1 Forest land remaining forest land, Mineral soils	CO_2						
LULUCF	4.A.1 Forest land remaining forest land, Organic soils	CO_2		32		28	32	47
LULUCF	4.A.2 Land converted to forest land	CO_2						
LULUCF	4.B.1 Cropland remaining cropland, Living biomass	CO_2						
LULUCF	4.B.1 Cropland remaining cropland, Mineral soils	CO_2	11	9	28	4	4	13
LULUCF	4.B.1 Cropland remaining cropland, Organic soils	CO_2	4	6	20	2	1	12
LULUCF	4.B .2 Forest land converted to cropland	CO_2						
LULUCF	4.B .2 Other land uses converted to cropland	CO_2						
LULUCF	4.C.1 Grassland remaining grassland, Living biomass	CO_2						
LULUCF	4.C.1 Grassland remaining grassland, Organic soils	CO_2	20	25		14	17	
LULUCF	4.C.2 Forest land converted to grassland	CO_2						
LULUCF	4.C.2 Other land uses converted to grassland	CO_2						
LULUCF	4.D.1.1 Peat extraction remaining peat extraction	CO_2						
LULUCF	4.D.1.2 Flooded land remaining flooded land	CO_2						
LULUCF	4.E.2 Forest land converted to settlements	CO_2						
LULUCF	4.E.2 Other land uses converted to settlements	CO_2						39
LULUCF	4.G Harvested wood products	CO_2					41	27
LULUCF	4.D.2 Land converted to wetland	CO_2						
LULUCF	4(V) Biomass Burning	CH_4						
LULUCF	4(II) Grassland on organic soils	CH_4						
LULUCF	4(II) Land converted to wetlands	CH_4						
LULUCF	4(II) Peat extraction remaining peat extraction	CH_4						
LULUCF	4(III) Mineralization/immobilization	N_2O						44
LULUCF	4(V) Biomass burning	N_2O						
LULUCF	4(II) Drainage and rewetting, Forest soils	N_2O						
LULUCF	4(II) Peat extraction remaining peat extraction	N_2O						
Waste	5.E Accidental fires	CO_2						
Waste	5.A Solid waste disposal	CH_4	9	17	17	1	3	1
Waste	5.B.1 Composting	CH_4					27	19
Waste	5.C.1 Incineration of corpses	CH_4						
Waste	5.C.2 Incineration of carcasses	CH_4						
Waste	5.D Wastewater treatment and discharge	CH_4						
Waste	5.E Accidental fires	CH_4						
Waste	5.B.1 Composting	N_2O					29	18
Waste	5.C.1 Incineration of corpses	N_2O						
Waste	5.C.2 Incineration of carcasses	N_2O						
Waste	5.D Wastewater treatment and discharge	N_2O						

Table A1-3 Summary of KCA for Denmark, number of key source categories in each of the KCA.

	Level Approach 1	Level Approach 1	Trend Approach 1	Level Approach 2	Level Approach 2	Trend Approach 2
	1990	2013	1990-2013	1990	2013	1990-2013
Excluding LULUCF	31	36	25	35	41	42
Including LULUCF	36	42	31	37	45	52

Table A1-4 KCA for Denmark, level assessment, base year excl. LULUCF, approach 1.
This table is available at:
http://envs.au.dk/videnudveksling/luft/emissioner/supporting-documentation/air-pollution-iir/

Table A1-5 KCA for Denmark, level assessment base year incl. LULUCF, approach 1.
This table is available at:
http://envs.au.dk/videnudveksling/luft/emissioner/supporting-documentation/air-pollution-iir/

Table A1-6 KCA for Denmark, level assessment 2013 excl. LULUCF, approach 1.
This table is available at:
http://envs.au.dk/videnudveksling/luft/emissioner/supporting-documentation/air-pollution-iir/

Table A1-7 KCA for Denmark, level assessment 2013 incl. LULUCF, approach 1.
This table is available at:
http://envs.au.dk/videnudveksling/luft/emissioner/supporting-documentation/air-pollution-iir/

Table A1-8 KCA for Denmark, trend assessment 1990-2013 excl. LULUCF, approach 1.
This table is available at:
http://envs.au.dk/videnudveksling/luft/emissioner/supporting-documentation/air-pollution-iir/

Table A1-9 KCA for Denmark, trend assessment 1990-2013 incl. LULUCF, approach 1.
This table is available at:
http://envs.au.dk/videnudveksling/luft/emissioner/supporting-documentation/air-pollution-iir/

Table A1-10 KCA for Denmark, level assessment base year excl. LULUCF, approach 2.
This table is available at:
http://envs.au.dk/videnudveksling/luft/emissioner/supporting-documentation/air-pollution-iir/

Table A1-11 KCA for Denmark, level assessment base year incl. LULUCF, approach 2.
This table is available at:
http://envs.au.dk/videnudveksling/luft/emissioner/supporting-documentation/air-pollution-iir/

Table A1-12 KCA for Denmark, level assessment 2013 excl. LULUCF, approach 2.
This table is available at:
http://envs.au.dk/videnudveksling/luft/emissioner/supporting-documentation/air-pollution-iir/

Table A1-13 KCA for Denmark, level assessment 2013 incl. LULUCF, approach 2.
This table is available at:
http://envs.au.dk/videnudveksling/luft/emissioner/supporting-documentation/air-pollution-iir/

Table A1-14 KCA for Denmark, trend assessment 1990-2013 excl. LULUCF, approach 2.
This table is available at:
http://envs.au.dk/videnudveksling/luft/emissioner/supporting-documentation/air-pollution-iir/

Table A1-15 KCA for Denmark, trend assessment 1990-2013 incl. LULUCF, approach 2.
This table is available at:
http://envs.au.dk/videnudveksling/luft/emissioner/supporting-documentation/air-pollution-iir/

Annex 2 - Assessment of uncertainty

Description of methodology used for identifying uncertainties

For the inventory of Denmark the uncertainties are estimated using two approaches. One of the approaches is the Approach 1 of the 2006 IPCC Guidelines. The result of which can be seen in this chapter.

The other approach is in line with Approach 2 as suggested by the 2006 IPCC Guidelines, i.e. Monte Carlo Analysis.

More information on the methodologies used including a detailed description of the Danish Tier 2 calculation of uncertainties is provided in Chapter 1.7. Chapter 1.7 also provides the result of the two approaches.

Table 3.3 of volume 1 of the 2006 IPCC Guidelines

IPCC Source category	Gas	Base year emission	Latest year emission	Activity data uncertainty	Emission factor uncertainty	Combined uncertainty	Combined uncertainty as % of total national emissions in year t	Type A sensitivity	Type B sensitivity	Uncertainty in trend in national emissions introduced by emis-sion factor uncertainty	Uncertainty in trend in national emissions introduced by activity data uncertainty	Uncertainty introduced into the trend in total national emissions
		Input data	Input data	Input data	Input data							
		Gg CO_2 eqv	Gg CO_2 eqv	%	%	%	%	%	%	%	%	%
1A Stationary combustion, Coal, ETS data	CO_2	0.0	12294.4	0.5	0.3	0.583	0.016	0.161	0.161	0.048	0.114	0.015
1A Stationary combustion, Coal, no ETS data	CO_2	23833.9	386.7	1.0	1.0	1.422	0.000	0.227	0.005	0.227	0.007	0.052
1A Stationary combustion, BKB	CO_2	11.3	1.8	3.0	5.0	5.831	0.000	0.000	0.000	0.000	0.000	0.000
1A Stationary combustion, Coke oven coke	CO_2	136.5	69.9	1.7	5.0	5.283	0.000	0.000	0.001	0.002	0.002	0.000
1A Stationary combustion, Fossil waste, ETS data	CO_2	0.0	964.0	2.0	5.0	5.385	0.008	0.013	0.013	0.063	0.036	0.005
1A Stationary combustion, Fossil waste, no ETS data	CO_2	573.5	638.7	5.0	10.0	11.180	0.016	0.003	0.008	0.028	0.059	0.004
1A Stationary combustion, Petroleum coke, ETS data	CO_2	0.0	559.3	0.5	0.5	0.707	0.000	0.007	0.007	0.004	0.005	0.000
1A Stationary combustion, Petroleum coke, no ETS data	CO_2	414.7	4.8	2.0	5.0	5.385	0.000	0.004	0.000	0.020	0.000	0.000
1A Stationary combustion, Residual oil, ETS data	CO_2	0.0	338.9	0.5	0.5	0.707	0.000	0.004	0.004	0.002	0.003	0.000
1A Stationary combustion, Residual oil, no ETS data	CO_2	2496.0	107.7	1.4	2.0	2.441	0.000	0.023	0.001	0.046	0.003	0.002
1A Stationary combustion, Gas oil	CO_2	4542.5	786.7	2.4	1.5	2.798	0.001	0.034	0.010	0.051	0.034	0.004
1A Stationary combustion, Kerosene	CO_2	367.6	2.1	2.8	3.0	4.111	0.000	0.004	0.000	0.011	0.000	0.000
1A Stationary combustion, LPG	CO_2	186.7	79.3	2.5	4.0	4.695	0.000	0.001	0.001	0.003	0.004	0.000
1A1b Stationary combustion, Petroleum refining, Refinery gas	CO_2	816.1	897.1	1.0	2.0	2.236	0.001	0.004	0.012	0.008	0.017	0.000
1A Stationary combustion, Natural gas, onshore	CO_2	3790.5	6514.9	1.2	0.4	1.294	0.022	0.048	0.085	0.019	0.149	0.022
1A1c_ii Stationary combustion, Oil and gas extraction, Off shore gas turbines, Natural gas	CO_2	544.9	1333.7	0.5	0.5	0.707	0.000	0.012	0.017	0.006	0.012	0.000
1A1 Stationary Combustion, Solid fuels	CH_4	5.3	2.9	1	100	100.005	0.000	0.000	0.000	0.001	0.000	0.000
1A1 Stationary Combustion, Liquid fuels	CH_4	0.7	0.6	1	100	100.005	0.000	0.000	0.000	0.000	0.000	0.000
1A1 Stationary Combustion, not engines, gase-ous fuels	CH_4	0.8	2.1	1	100	100.005	0.000	0.000	0.000	0.002	0.000	0.000
1A1 Stationary Combustion, Waste	CH_4	0.2	0.3	3	100	100.045	0.000	0.000	0.000	0.000	0.000	0.000
1A1 Stationary Combustion, not engines, Bio-mass	CH_4	3.6	9.8	3	100	100.045	0.000	0.000	0.000	0.009	0.001	0.000
1A2 Stationary Combustion, solid fuels	CH_4	3.8	1.0	2	100	100.020	0.000	0.000	0.000	0.002	0.000	0.000

IPCC Source category	Gas	Base year emission	Latest year emission	Activity data uncertainty	Emission factor uncertainty	Combined uncertainty	Combined uncertainty as % of total national emissions in year t	Type A sensitivity	Type B sensitivity	Uncertainty in trend in national emissions introduced by emission factor uncertainty	Uncertainty in trend in national emissions introduced by activity data uncertainty	Uncertainty introduced into the trend in total national emissions
		Input data	Input data	Input data	Input data							
		Gg CO_2 eqv	Gg CO_2 eqv	%	%	%	%	%	%	%	%	%
1A2 Stationary Combustion,Liquid fuels	CH_4	0.9	0.6	2	100	100.020	0.000	0.000	0.000	0.000	0.000	0.000
1A2 Stationary Combustion, not engines, gaseous fuels	CH_4	0.6	0.8	2	100	100.020	0.000	0.000	0.000	0.001	0.000	0.000
1A2 Stationary Combustion, Waste	CH_4	0.0	1.3	3	100	100.045	0.000	0.000	0.000	0.002	0.000	0.000
1A2 Stationary Combustion, not engines, Biomass	CH_4	1.6	2.1	10	100	100.499	0.000	0.000	0.000	0.001	0.000	0.000
1A4 Stationary Combustion, Solid fuels	CH_4	6.2	0.5	3	100	100.045	0.000	0.000	0.000	0.005	0.000	0.000
1A4 Stationary Combustion, Liquid fuels	CH_4	2.9	0.3	3	100	100.045	0.000	0.000	0.000	0.003	0.000	0.000
1A4 Stationary Combustion, not engines, gaseous fuels	CH_4	0.6	1.0	3	100	100.045	0.000	0.000	0.000	0.001	0.000	0.000
1A4 Stationary Combustion, Waste	CH_4	0.7	0.3	3	100	100.045	0.000	0.000	0.000	0.000	0.000	0.000
1A4 Stationary Combustion, not engines, not residential wood and not residential/agricultural straw, Biomass	CH_4	0.1	0.4	10	100	100.499	0.000	0.000	0.000	0.000	0.000	0.000
1A4b_i Stationary combustion, Residential wood combustion	CH_4	70.7	88.0	20	150	151.327	0.055	0.000	0.001	0.069	0.033	0.006
1A4b_i/1A4c_i Stationary Combustion, Residential and agricultural straw combustion	CH_4	63.6	36.2	15	150	150.748	0.009	0.000	0.000	0.022	0.010	0.001
1A Stationary combustion, Natural gas fuelled engines, gaseous fuels	CH_4	5.5	115.2	1	2	2.236	0.000	0.001	0.002	0.003	0.002	0.000
1A Stationary combustion, Biogas fuelled engines, Biomass	CH_4	1.8	38.8	3	10	10.440	0.000	0.000	0.001	0.005	0.002	0.000
1A1 Stationary Combustion, Solid fuels	N_2O	57.4	31.1	1	400	400.001	0.048	0.000	0.000	0.062	0.001	0.004
1A1 Stationary Combustion, Liquid fuels	N_2O	2.8	2.0	1	1000	1000.000	0.001	0.000	0.000	0.002	0.000	0.000
1A1 Stationary Combustion, Gaseous fuels	N_2O	12.2	19.0	1	750	750.001	0.062	0.000	0.000	0.097	0.000	0.009
1A1 Stationary Combustion, Waste	N_2O	5.2	13.1	3	400	400.011	0.009	0.000	0.000	0.049	0.001	0.002
1A1 Stationary Combustion, Biomass	N_2O	8.4	32.6	3	400	400.011	0.052	0.000	0.000	0.138	0.002	0.019
1A2 Stationary Combustion, Solid fuels	N_2O	6.7	9.6	2	400	400.005	0.005	0.000	0.000	0.024	0.000	0.001
1A2 Stationary Combustion, Liquid fuels	N_2O	28.6	7.8	2	1000	1000.002	0.019	0.000	0.000	0.176	0.000	0.031
1A2 Stationary Combustion, Gaseous fuels	N_2O	7.2	9.3	2	750	750.003	0.015	0.000	0.000	0.039	0.000	0.002
1A2 Stationary Combustion, Waste	N_2O	0.0	2.1	3	400	400.011	0.000	0.000	0.000	0.011	0.000	0.000
1A2 Stationary Combustion, Biomass	N_2O	6.9	9.2	10	400	400.125	0.004	0.000	0.000	0.021	0.002	0.000
1A4 Stationary Combustion, Solid fuels	N_2O	1.5	0.7	3	400	400.011	0.000	0.000	0.000	0.002	0.000	0.000

IPCC Source category	Gas	Base year emission	Latest year emission	Activity data uncertainty	Emission factor uncertainty	Combined uncertainty	Combined uncertainty as % of total national emissions in year t	Type A sensitivity	Type B sensitivity	Uncertainty in trend in national emissions introduced by emission factor uncertainty	Uncertainty in trend in national emissions introduced by activity data uncertainty	Uncertainty introduced into the trend in total national emissions
		Input data	Input data	Input data	Input data							
		Gg CO_2 eqv	Gg CO_2 eqv	%	%	%	%	%	%	%	%	%
1A4 Stationary Combustion, Liquid fuels	N_2O	11.2	1.4	3	1000	1000.004	0.001	0.000	0.000	0.091	0.000	0.008
1A4 Stationary Combustion, Gaseous fuels	N_2O	7.7	11.6	3	750	750.006	0.023	0.000	0.000	0.058	0.001	0.003
1A4 Stationary Combustion, Waste	N_2O	1.1	0.4	3	400	400.011	0.000	0.000	0.000	0.002	0.000	0.000
1A4 Stationary Combustion, not residential wood and not residential/agricultural straw, Biomass	N_2O	0.4	1.9	10	400	400.125	0.000	0.000	0.000	0.008	0.000	0.000
1A4b_i Stationary Combustion, Residential wood combustion	N_2O	10.7	37.2	20	500	500.400	0.107	0.000	0.000	0.191	0.014	0.037
1A4b_i/1A4c_i Stationary Combustion, Residential and agricultural straw combustion	N_2O	10.1	5.8	15	500	500.225	0.003	0.000	0.000	0.012	0.002	0.000
1.A.2.g Industry (mobile)	CO_2	843.7	1024.6	41	5	41.304	0.552	0.005	0.013	0.026	0.778	0.606
1.A.3.a Civil aviation	CO_2	257.6	140.2	10	5	11.180	0.001	0.001	0.002	0.003	0.026	0.001
1.A.3.b Road Transport	CO_2	9283.5	11020.8	2	5	5.385	1.085	0.054	0.144	0.268	0.408	0.238
1.A.3.c Railways	CO_2	296.7	247.8	2	5	5.385	0.001	0.000	0.003	0.002	0.009	0.000
1.A.3.d Navigation (large vessels)	CO_2	747.7	393.2	11	5	12.083	0.007	0.002	0.005	0.011	0.080	0.007
1.A.4.a Commercial/Institutional (mobile)	CO_2	73.7	171.4	35	5	35.355	0.011	0.002	0.002	0.008	0.111	0.012
1.A.4.b Residential (mobile)	CO_2	39.1	62.3	35	5	35.355	0.001	0.000	0.001	0.002	0.040	0.002
1.A.4.c ii Agriculture (mobile)	CO_2	1272.3	1126.6	24	5	24.515	0.235	0.002	0.015	0.012	0.501	0.251
1.A.4.c ii Forestry (mobile)	CO_2	35.7	16.8	30	5	30.414	0.000	0.000	0.000	0.001	0.009	0.000
1.A.4.c iii Fisheries	CO_2	586.1	511.0	2	5	5.385	0.002	0.001	0.007	0.005	0.019	0.000
1.A.5.b Other (military)	CO_2	47.9	98.4	41	5	41.304	0.005	0.001	0.001	0.004	0.075	0.006
1.A.5.b Other (small boats)	CO_2	119.0	140.7	2	5	5.385	0.000	0.001	0.002	0.003	0.005	0.000
1.A.2.g Industry (mobile)	CH_4	1.6	0.8	41	100	108.079	0.000	0.000	0.000	0.000	0.001	0.000
1.A.3.a Civil aviation	CH_4	0.1	0.1	10	100	100.499	0.000	0.000	0.000	0.000	0.000	0.000
1.A.3.b Road Transport	CH_4	55.8	12.0	2	40	40.050	0.000	0.000	0.000	0.016	0.000	0.000
1.A.3.c Railways	CH_4	0.3	0.2	2	100	100.020	0.000	0.000	0.000	0.000	0.000	0.000
1.A.3.d Navigation (large vessels)	CH_4	0.4	0.2	11	100	100.603	0.000	0.000	0.000	0.000	0.000	0.000
1.A.4.a Commercial/Institutional (mobile)	CH_4	2.9	4.3	35	100	105.948	0.000	0.000	0.000	0.003	0.003	0.000
1.A.4.b Residential (mobile)	CH_4	1.3	1.1	35	100	105.948	0.000	0.000	0.000	0.000	0.001	0.000
1.A.4.c ii Agriculture (mobile)	CH_4	2.3	2.3	24	100	102.840	0.000	0.000	0.000	0.001	0.001	0.000
1.A.4.c ii Forestry (mobile)	CH_4	4.0	0.4	30	100	104.403	0.000	0.000	0.000	0.003	0.000	0.000

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		Input data Gg CO_2 eqv	Input data Gg CO_2 eqv	Input data %	Input data %	%	%	%	%	%	%	%
1.A.4.c iii Fisheries	CH_4	0.3	0.3	2	100	100.020	0.000	0.000	0.000	0.000	0.000	0.000
1.A.5.b Other (military)	CH_4	1.9	0.3	41	100	108.079	0.000	0.000	0.000	0.002	0.000	0.000
1.A.5.b Other (small boats)	CH_4	0.1	0.1	2	100	100.020	0.000	0.000	0.000	0.000	0.000	0.000
1.A.2.g Industry (mobile)	N_2O	10.2	13.0	41	1000	1000.840	0.052	0.000	0.000	0.070	0.010	0.005
1.A.3.a Civil aviation	N_2O	3.0	2.1	10	1000	1000.050	0.001	0.000	0.000	0.002	0.000	0.000
1.A.3.b Road Transport	N_2O	87.1	113.0	2	50	50.040	0.010	0.001	0.001	0.031	0.004	0.001
1.A.3.c Railways	N_2O	2.4	2.0	2	1000	1000.002	0.001	0.000	0.000	0.003	0.000	0.000
1.A.3.d Navigation (large vessels)	N_2O	14.0	7.4	11	1000	1000.060	0.017	0.000	0.000	0.041	0.002	0.002
1.A.4.a Commercial/Institutional (mobile)	N_2O	0.3	0.8	35	1000	1000.612	0.000	0.000	0.000	0.007	0.001	0.000
1.A.4.b Residential (mobile)	N_2O	0.2	0.3	35	1000	1000.612	0.000	0.000	0.000	0.002	0.000	0.000
1.A.4.c ii Agriculture (mobile)	N_2O	14.7	14.3	24	1000	1000.288	0.063	0.000	0.000	0.044	0.006	0.002
1.A.4.c ii Forestry (mobile)	N_2O	0.2	0.2	30	1000	1000.450	0.000	0.000	0.000	0.000	0.000	0.000
1.A.4.c iii Fisheries	N_2O	11.1	9.6	2	1000	1000.002	0.029	0.000	0.000	0.018	0.000	0.000
1.A.5.b Other (military)	N_2O	0.4	1.0	41	1000	1000.840	0.000	0.000	0.000	0.010	0.001	0.000
1.A.5.b Other (small boats)	N_2O	1.1	1.5	2	1000	1000.002	0.001	0.000	0.000	0.009	0.000	0.000
1.B.2.a.1 Exploration, oil	CO_2	4.7	3.0	2	10	10.198	0.000	0.000	0.000	0.000	0.000	0.000
1.B.2.a.2 Production, oil	CO_2	0.0	0.0	2	100	100.020	0.000	0.000	0.000	0.000	0.000	0.000
1.B.2.a.3 Transport, oil	CO_2	0.0	0.0	2	40	40.050	0.000	0.000	0.000	0.000	0.000	0.000
1.B.2.b.1 Exploration, gas	CO_2	8.3	0.0	2	10	10.198	0.000	0.000	0.000	0.001	0.000	0.000
1.B.2.b.2 Production, gas	CO_2	0.1	0.1	2	100	100.020	0.000	0.000	0.000	0.000	0.000	0.000
1.B.2.b.4 Transmission and storage, gas	CO_2	0.0	0.0	15	2	15.133	0.000	0.000	0.000	0.000	0.000	0.000
1.B.2.b.5 Distribution, gas	CO_2	0.0	0.0	25	10	26.926	0.000	0.000	0.000	0.000	0.000	0.000
1.B.2.c.1.ii Venting, gas	CO_2	0.0	0.0	15	2	15.133	0.000	0.000	0.000	0.000	0.000	0.000
1.B.2.c.2.i Flaring, oil	CO_2	22.9	14.7	11	2	11.180	0.000	0.000	0.000	0.000	0.003	0.000
1.B.2.c.2.ii Flaring, gas	CO_2	304.7	220.5	7.5	2	7.762	0.001	0.000	0.003	0.000	0.031	0.001
1.B.2.a.1 Exploration, oil	CH_4	0.0	0.0	2	125	125.016	0.000	0.000	0.000	0.000	0.000	0.000
1.B.2.a.2 Production, oil	CH_4	0.1	0.2	2	100	100.020	0.000	0.000	0.000	0.000	0.000	0.000
1.B.2.a.3 Transport, oil	CH_4	20.4	19.2	2	40	40.050	0.000	0.000	0.000	0.002	0.001	0.000
1.B.2.a.4 Refining/storage	CH_4	10.9	15.5	1	125	125.004	0.001	0.000	0.000	0.012	0.000	0.000

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		Input data Gg CO_2 eqv	Input data Gg CO_2 eqv	Input data %	Input data %	%	%	%	%	%	%	%
1.B.2.b.1 Exploration, gas	CH_4	0.8	0.0	2	125	125.016	0.000	0.000	0.000	0.001	0.000	0.000
1.B.2.b.2 Production, gas	CH_4	48.8	44.7	2	100	100.020	0.006	0.000	0.001	0.011	0.002	0.000
1.B.2.b.4 Transmission and storage, gas	CH_4	4.8	0.4	15	2	15.133	0.000	0.000	0.000	0.000	0.000	0.000
1.B.2.b.5 Distribution, gas	CH_4	6.4	3.1	25	10	26.926	0.000	0.000	0.000	0.000	0.001	0.000
1.B.2.c.1.ii Venting, gas	CH_4	1.5	1.3	15	2	15.133	0.000	0.000	0.000	0.000	0.000	0.000
1.B.2.c.2.i Flaring, oil	CH_4	0.2	0.1	11	15	18.601	0.000	0.000	0.000	0.000	0.000	0.000
1.B.2.c.2.ii Flaring, gas	CH_4	28.8	22.9	7.5	125	125.225	0.003	0.000	0.000	0.002	0.003	0.000
1.B.2.a.1 Exploration, oil	N_2O	0.0	0.0	2	1000	1000.002	0.000	0.000	0.000	0.000	0.000	0.000
1.B.2.b.1 Exploration, gas	N_2O	1.4	0.0	2	1000	1000.002	0.000	0.000	0.000	0.013	0.000	0.000
1.B.2.c.2.i Flaring, oil	N_2O	0.1	0.0	11	1000	1000.060	0.000	0.000	0.000	0.000	0.000	0.000
1.B.2.c.2.ii Flaring, gas	N_2O	51.2	41.1	7.5	1000	1000.028	0.520	0.000	0.001	0.037	0.006	0.001
2A1 Cement production	CO_2	882.4	867.1	1	2	2.236	0.001	0.003	0.011	0.005	0.016	0.000
2A2 Lime production	CO_2	105.1	54.2	5	4	6.403	0.000	0.000	0.001	0.001	0.005	0.000
2A3 Glass production	CO_2	20.2	7.0	1	2	2.236	0.000	0.000	0.000	0.000	0.000	0.000
2A4a Ceramics	CO_2	41.3	26.6	5	2	5.385	0.000	0.000	0.000	0.000	0.002	0.000
2A4b Other uses of soda ash	CO_2	11.8	9.1	5	2	5.385	0.000	0.000	0.000	0.000	0.001	0.000
2A4d Other process uses of carbonates	CO_2	17.5	31.5	30	2	30.067	0.000	0.000	0.000	0.000	0.018	0.000
2B10 Production of catalysts	CO_2	0.9	1.3	5	5	7.071	0.000	0.000	0.000	0.000	0.000	0.000
2C1a Steel	CO_2	30.3	0.0	5	10	11.180	0.000	0.000	0.000	0.003	0.000	0.000
2C5 Lead production	CO_2	0.2	0.2	10	50	50.990	0.000	0.000	0.000	0.000	0.000	0.000
2D1 Lubricant use	CO_2	49.7	31.7	10	20	22.361	0.000	0.000	0.000	0.001	0.006	0.000
2D2 Paraffin wax use	CO_2	21.7	84.7	15	60	61.847	0.008	0.001	0.001	0.054	0.024	0.003
2D3 Paint Application	CO_2	13.2	7.8	10	15	18.028	0.000	0.000	0.000	0.000	0.001	0.000
2D3 Degreasing, dry cleaning and electronics	CO_2	0.0	0.0	10	15	18.028	0.000	0.000	0.000	0.000	0.000	0.000
2D3 Chemical products manufacturing or processing	CO_2	19.4	11.6	10	15	18.028	0.000	0.000	0.000	0.001	0.002	0.000
2D3 Other use of solvents and related activities	CO_2	60.6	48.3	10	20	22.361	0.000	0.000	0.001	0.001	0.009	0.000
2D3 Road paving with asphalt	CO_2	0.1	0.1	20	75	77.621	0.000	0.000	0.000	0.000	0.000	0.000
2D3 Asphalt roofing	CO_2	0.0	0.0	20	75	77.621	0.000	0.000	0.000	0.000	0.000	0.000
2D3 Urea based catalysts	CO_2	0.0	6.0	5	10	11.180	0.000	0.000	0.000	0.001	0.001	0.000

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		Input data Gg CO_2 eqv	Input data Gg CO_2 eqv	Input data %	Input data %	%	%	%	%	%	%	%
2G4 Fireworks	CO_2	0.1	0.2	15	60	61.847	0.000	0.000	0.000	0.000	0.000	0.000
2D2 Paraffin wax use	CH_4	0.0	0.1	15	60	61.847	0.000	0.000	0.000	0.000	0.000	0.000
2D3 Road paving with asphalt	CH_4	0.3	0.4	20	75	77.621	0.000	0.000	0.000	0.000	0.000	0.000
2G4 Fireworks	CH_4	0.0	0.1	15	60	61.847	0.000	0.000	0.000	0.000	0.000	0.000
2G4 Tobacco	CH_4	1.0	0.7	15	60	61.847	0.000	0.000	0.000	0.000	0.000	0.000
2G4 Charcoal	CH_4	1.1	2.1	15	60	61.847	0.000	0.000	0.000	0.001	0.001	0.000
2B2 Nitric acid production	N_2O	1002.5	0.0	2	25	25.080	0.000	0.010	0.000	0.245	0.000	0.060
2D2 Paraffin wax use	N_2O	0.1	0.2	15	60	61.847	0.000	0.000	0.000	0.000	0.000	0.000
2G3a Medical application of N2O	N_2O	11.9	11.0	25	20	32.016	0.000	0.000	0.000	0.001	0.005	0.000
2G3b N_2O as propellant for pressure and aerosol products	N_2O	5.6	4.8	100	150	180.278	0.000	0.000	0.000	0.001	0.009	0.000
2G4 Fireworks	N_2O	0.7	2.6	15	60	61.847	0.000	0.000	0.000	0.002	0.001	0.000
2G4 Tobacco	N_2O	0.2	0.2	15	60	61.847	0.000	0.000	0.000	0.000	0.000	0.000
2G4 Charcoal	N_2O	0.1	0.1	15	60	61.847	0.000	0.000	0.000	0.000	0.000	0.000
2F1 Refrigeration and air conditioning	HFCs	42.6	703.8	10	50	50.990	0.397	0.009	0.009	0.440	0.130	0.211
2F2 Foam blowing agents	HFCs	199.5	60.7	10	50	50.990	0.003	0.001	0.001	0.058	0.011	0.003
2F4 Aerosols	HFCs	0.0	17.7	10	50	50.990	0.000	0.000	0.000	0.012	0.003	0.000
2E Electronics industry	PFCs	0.0	3.7	10	50	50.990	0.000	0.000	0.000	0.002	0.001	0.000
2F1 Refrigeration and air conditioning	PFCs	0.6	7.1	10	50	50.990	0.000	0.000	0.000	0.004	0.001	0.000
2C4 Magnesium production	SF_6	34.2	0.0	10	30	31.623	0.000	0.000	0.000	0.010	0.000	0.000
2G1 Electrical equipment	SF_6	3.7	13.1	10	50	50.990	0.000	0.000	0.000	0.007	0.002	0.000
2G2 SF_6 and PFCs from other product use	SF_6	64.5	117.4	10	50	50.990	0.011	0.001	0.002	0.045	0.022	0.003
3A Enteric Fermentation	CH_4	3798.9	3466.5	2	20	20.100	1.496	0.008	0.045	0.165	0.128	0.044
3B Manure Management	CH_4	1728.9	1917.6	5	20	20.616	0.481	0.008	0.025	0.164	0.178	0.059
3F Field Burning of Agricultural Residues	CH_4	2.2	3.2	25	50	55.902	0.000	0.000	0.000	0.001	0.001	0.000
3B Manure Management	N_2O	780.6	614.9	25	100	103.078	1.238	0.000	0.008	0.042	0.285	0.083
3B5 Atmospheric deposition	N_2O	197.2	140.4	16	100	101.272	0.062	0.000	0.002	0.009	0.042	0.002
3Da1 Inorganic N fertilizer	N_2O	1875.0	906.4	3	100	100.045	2.533	0.006	0.012	0.646	0.050	0.419
3Da2a Animal manure applied to soils	N_2O	1002.3	976.0	25	100	103.078	3.118	0.003	0.013	0.299	0.452	0.294

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		Input data Gg CO_2 eqv	Input data Gg CO_2 eqv	Input data %	Input data %	%	%	%	%	%	%	%
3Da2b Sewage sludge applied to soils	N_2O	14.6	11.5	15	100	101.119	0.000	0.000	0.000	0.001	0.003	0.000
3Da2c Other organic fertilizer applied to soils	N_2O	7.2	21.5	20	100	101.980	0.001	0.000	0.000	0.021	0.008	0.001
3Da3 Urine and dung deposited by grazing animals	N_2O	299.0	184.7	10	100	100.499	0.106	0.001	0.002	0.050	0.034	0.004
3Da4 Crop Residues	N_2O	569.3	640.5	25	100	103.078	1.343	0.003	0.008	0.282	0.297	0.168
3Da5 Mineralization	N_2O	189.9	168.8	50	100	111.803	0.110	0.000	0.002	0.035	0.156	0.026
3Da6 Cultivation of organic soils	N_2O	542.7	367.5	20	100	101.980	0.433	0.000	0.005	0.049	0.136	0.021
3Db1 Atmospheric deposition	N_2O	312.5	152.0	16	100	101.272	0.073	0.001	0.002	0.106	0.045	0.013
3Db2 Leaching	N_2O	549.3	329.1	20	100	101.980	0.347	0.001	0.004	0.106	0.122	0.026
3F Field Burning of Agricultural Residues	N_2O	0.7	1.0	25	50	55.902	0.000	0.000	0.000	0.000	0.000	0.000
3G Liming	CO_2	565.5	243.9	5	100	100.125	0.184	0.002	0.003	0.233	0.023	0.055
3H Urea application	CO_2	14.7	0.7	3	100	100.045	0.000	0.000	0.000	0.013	0.000	0.000
3I Other carbon-containing fertilizers	CO_2	38.4	1.9	3	100	100.045	0.000	0.000	0.000	0.035	0.000	0.001
4.A.1 Forest land remaining forest land, Living biomass	CO_2	0.0	-3169.1	5	2	5.385	0.090	0.042	0.042	0.083	0.294	0.093
4.A.1 Forest land remaining forest land, Dead organic matter	CO_2	0.0	534.5	5	2	5.385	0.003	0.007	0.007	0.014	0.050	0.003
4.A.1 Forest land remaining forest land, Mineral soils	CO_2	0.0	0.0	5	2	5.385	0.000	0.000	0.000	0.000	0.000	0.000
4.A.1 Forest land remaining forest land, Organic soils	CO_2	252.9	250.2	10	50	50.990	0.050	0.001	0.003	0.040	0.046	0.004
4.A.2 Land converted to forest land	CO_2	79.0	40.0	10	9	13.280	0.000	0.000	0.001	0.002	0.007	0.000
4.B.1 Cropland remaining cropland, Living bio-mass	CO_2	-81.0	69.3	3	15	15.207	0.000	0.002	0.001	0.025	0.003	0.001
4.B.1 Cropland remaining cropland, Mineral soils	CO_2	1415.3	1253.1	3	75	75.042	2.724	0.003	0.016	0.193	0.058	0.041
4.B.1 Cropland remaining cropland, Organic soils	CO2	4115.8	2750.0	3	50	50.109	5.850	0.004	0.036	0.211	0.168	0.073
4.B .2 Forest land converted to cropland	CO_2	15.5	10.0	10	50	50.990	0.000	0.000	0.000	0.001	0.002	0.000
4.B .2 Other land uses converted to cropland	CO_2	-5.2	-11.5	10	50	50.990	0.000	0.000	0.000	0.005	0.002	0.000
4.C.1 Grassland remaining grassland, Living biomass	CO_2	83.2	45.4	3	7	7.433	0.000	0.000	0.001	0.002	0.002	0.000
4.C.1 Grassland remaining grassland, Organic soils	CO_2	716.2	517.7	3	50	50.109	0.207	0.000	0.007	0.011	0.032	0.001
4.C.2 Forest land converted to grassland	CO_2	8.9	2.3	9	50	50.758	0.000	0.000	0.000	0.003	0.000	0.000

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		Input data Gg CO_2 eqv	Input data Gg CO_2 eqv	Input data %	Input data %	%	%	%	%	%	%	%
4.C.2 Other land uses converted to grassland	CO_2	12.4	13.5	9	50	50.758	0.000	0.000	0.000	0.003	0.002	0.000
4.D.1.1 Peat extraction remaining peat extraction	CO_2	99.5	20.3	10	75	75.664	0.001	0.001	0.000	0.053	0.004	0.003
4.D.1.2 Flooded land remaining flooded land	CO_2	0.0	0.0	10	75	75.664	0.000	0.000	0.000	0.000	0.000	0.000
4.E.2 Forest land converted to settlements	CO_2	3.1	13.5	10	75	75.664	0.000	0.000	0.000	0.011	0.002	0.000
4.E.2 Other land uses converted to settlements	CO_2	9.8	60.4	10	75	75.664	0.006	0.001	0.001	0.052	0.011	0.003
4.G Harvested wood products	CO_2	-2.1	-88.9	25	75	79.057	0.015	0.001	0.001	0.086	0.041	0.009
4.D.2 Land converted to wetland	CO_2	2.4	0.0	25	50	55.902	0.000	0.000	0.000	0.001	0.000	0.000
4(V) Biomass Burning	CH_4	0.7	0.0	10	30	31.623	0.000	0.000	0.000	0.000	0.000	0.000
4(II) Grassland on organic soils	CH_4	9.3	6.7	10	90	90.554	0.000	0.000	0.000	0.000	0.001	0.000
4(II) Land converted to wetlands	CH_4	0.0	0.1	10	90	90.554	0.000	0.000	0.000	0.000	0.000	0.000
4(II) Peat extraction remaining peat extraction	CH_4	0.2	0.1	10	90	90.554	0.000	0.000	0.000	0.000	0.000	0.000
4(III) Mineralization/immobilization	N_2O	0.3	38.1	10	90	90.554	0.004	0.000	0.000	0.045	0.007	0.002
4(V) Biomass burning	N_2O	0.4	0.0	10	30	31.623	0.000	0.000	0.000	0.000	0.000	0.000
4(II) Drainage and rewetting, Forest soils	N_2O	34.8	34.4	10	50	50.990	0.001	0.000	0.000	0.006	0.006	0.000
4(II) Peat extraction remaining peat extraction	N_2O	0.2	0.1	10	50	50.990	0.000	0.000	0.000	0.000	0.000	0.000
5.E Accidental fires	CO_2	17.5	16.0	10	300	300.167	0.007	0.000	0.000	0.011	0.003	0.000
5.A Solid waste disposal	CH_4	1774.1	844.0	10	118	118.323	3.072	0.006	0.011	0.741	0.156	0.574
5.B.1 Composting	CH_4	34.7	125.7	40	100	107.703	0.056	0.001	0.002	0.131	0.093	0.026
5.C.1 Incineration of corpses	CH_4	0.0	0.0	1	150	150.003	0.000	0.000	0.000	0.000	0.000	0.000
5.C.2 Incineration of carcasses	CH_4	0.0	0.0	40	150	155.242	0.000	0.000	0.000	0.000	0.000	0.000
5.D Wastewater treatment and discharge	CH_4	99.5	112.7	24	32	39.678	0.006	0.001	0.001	0.016	0.050	0.003
5.E Accidental fires	CH_4	1.9	1.8	10	500	500.100	0.000	0.000	0.000	0.002	0.000	0.000
5.B.1 Composting	N_2O	12.4	123.3	40	100	107.703	0.054	0.001	0.002	0.149	0.091	0.031
5.C.1 Incineration of corpses	N_2O	0.2	0.2	1	150	150.003	0.000	0.000	0.000	0.000	0.000	0.000
5.C.2 Incineration of carcasses	N_2O	0.0	0.1	40	150	155.242	0.000	0.000	0.000	0.000	0.000	0.000
5.D Wastewater treatment and discharge	N_2O	100.9	73.9	22	50	54.145	0.005	0.000	0.001	0.001	0.030	0.001
Total		76342	56974									
Total uncertainties			Overall uncertainty in the year (%):			5.214				Trend uncertainty (%):		1.931

Annex 3 - Other detailed methodological descriptions for individual source or sink categories (where relevant)

Annex 3A – Stationary Combustion

Annex 3B – Transport

Annex 3C – Industrial Processes

Annex 3D – Agriculture

Annex 3E – LULUCF

Annex 3F – Waste

Annex 3A - Stationary combustion

Annex 3A-1 Correspondence list between SNAP and CRF source categories

Table 3A-1.1 Correspondence list between SNAP and CRF source categories for stationary combustion.

snap_id	snap_name	CRF id	CRF name
010100	Public power	1A1a	Public electricity and heat production
010101	Combustion plants >= 300 MW (boilers)	1A1a	Public electricity and heat production
010102	Combustion plants >= 50 and < 300 MW (boilers)	1A1a	Public electricity and heat production
010103	Combustion plants < 50 MW (boilers)	1A1a	Public electricity and heat production
010104	Gas turbines	1A1a	Public electricity and heat production
010105	Stationary engines	1A1a	Public electricity and heat production
010200	District heating plants	1A1a	Public electricity and heat production
010201	Combustion plants >= 300 MW (boilers)	1A1a	Public electricity and heat production
010202	Combustion plants >= 50 and < 300 MW (boilers)	1A1a	Public electricity and heat production
010203	Combustion plants < 50 MW (boilers)	1A1a	Public electricity and heat production
010204	Gas turbines	1A1a	Public electricity and heat production
010205	Stationary engines	1A1a	Public electricity and heat production
010300	Petroleum refining plants	1A1b	Petroleum refining
010301	Combustion plants >= 300 MW (boilers)	1A1b	Petroleum refining
010302	Combustion plants >= 50 and < 300 MW (boilers)	1A1b	Petroleum refining
010303	Combustion plants < 50 MW (boilers)	1A1b	Petroleum refining
010304	Gas turbines	1A1b	Petroleum refining
010305	Stationary engines	1A1b	Petroleum refining
010306	Process furnaces	1A1b	Petroleum refining
010400	Solid fuel transformation plants	1A1c	Oil and gas extraction
010401	Combustion plants >= 300 MW (boilers)	1A1c	Oil and gas extraction
010402	Combustion plants >= 50 and < 300 MW (boilers)	1A1c	Oil and gas extraction
010403	Combustion plants < 50 MW (boilers)	1A1c	Oil and gas extraction
010404	Gas turbines	1A1c	Oil and gas extraction
010405	Stationary engines	1A1c	Oil and gas extraction
010406	Coke oven furnaces	1A1c	Oil and gas extraction
010407	Other (coal gasification, liquefaction)	1A1c	Oil and gas extraction
010500	Coal mining, oil / gas extraction, pipeline compressors	1A1c	Oil and gas extraction
010501	Combustion plants >= 300 MW (boilers)	1A1c	Oil and gas extraction
010502	Combustion plants >= 50 and < 300 MW (boilers)	1A1c	Oil and gas extraction
010503	Combustion plants < 50 MW (boilers)	1A1c	Oil and gas extraction
010504	Gas turbines	1A1c	Oil and gas extraction
010505	Stationary engines	1A1c	Oil and gas extraction
010506	Pipeline compressors	1A3e i	Pipeline transport
020100	Commercial and institutional plants	1A4a i	Commercial/institutional: Stationary
020101	Combustion plants >= 300 MW (boilers)	1A4a i	Commercial/institutional: Stationary
020102	Combustion plants >= 50 and < 300 MW (boilers)	1A4a i	Commercial/institutional: Stationary
020103	Combustion plants < 50 MW (boilers)	1A4a i	Commercial/institutional: Stationary
020104	Stationary gas turbines	1A4a i	Commercial/institutional: Stationary
020105	Stationary engines	1A4a i	Commercial/institutional: Stationary
020106	Other stationary equipments	1A4a i	Commercial/institutional: Stationary
020200	Residential plants	1A4b i	Residential: Stationary
020201	Combustion plants >= 50 MW (boilers)	1A4b i	Residential: Stationary
020202	Combustion plants < 50 MW (boilers)	1A4b i	Residential: Stationary
020203	Gas turbines	1A4b i	Residential: Stationary
020204	Stationary engines	1A4b i	Residential: Stationary
020205	Other equipments (stoves, fireplaces, cooking)	1A4b i	Residential: Stationary
020300	Plants in agriculture, forestry and aquaculture	1A4c i	Agriculture/Forestry/Fishing: Stationary
020301	Combustion plants >= 50 MW (boilers)	1A4c i	Agriculture/Forestry/Fishing: Stationary
020302	Combustion plants < 50 MW (boilers)	1A4c i	Agriculture/Forestry/Fishing: Stationary
020303	Stationary gas turbines	1A4c i	Agriculture/Forestry/Fishing: Stationary
020304	Stationary engines	1A4c i	Agriculture/Forestry/Fishing: Stationary
020305	Other stationary equipments	1A4c i	Agriculture/Forestry/Fishing: Stationary
030100	Comb. in boilers, gas turbines and stationary	1A2g viii	Other manufacturing industry
030101	Combustion plants >= 300 MW (boilers)	1A2g viii	Other manufacturing industry
030102	Combustion plants >= 50 and < 300 MW (boilers)	1A2g viii	Other manufacturing industry
030103	Combustion plants < 50 MW (boilers)	1A2g viii	Other manufacturing industry
030104	Gas turbines	1A2g viii	Other manufacturing industry
030105	Stationary engines	1A2g viii	Other manufacturing industry
030106	Other stationary equipments	1A2g viii	Other manufacturing industry
030200	Process furnaces without contact (a)	1A2g viii	Other manufacturing industry
030203	Blast furnace cowpers	1A2a	Iron and steel
030204	Plaster furnaces	1A2g viii	Other manufacturing industry
030205	Other furnaces	1A2g viii	Other manufacturing industry

snap_id	snap_name	CRF id	CRF name
030400	Iron and Steel	1A2a	Iron and steel
030401	Combustion plants >= 300 MW (boilers)	1A2a	Iron and steel
030402	Combustion plants >= 50 and < 300 MW (boilers)	1A2a	Iron and steel
030403	Combustion plants < 50 MW (boilers)	1A2a	Iron and steel
030404	Gas turbines	1A2a	Iron and steel
030405	Stationary engines	1A2a	Iron and steel
030406	Other stationary equipments	1A2a	Iron and steel
030500	Non-Ferrous Metals	1A2b	Non-ferrous metals
030501	Combustion plants >= 300 MW (boilers)	1A2b	Non-ferrous metals
030502	Combustion plants >= 50 and < 300 MW (boilers)	1A2b	Non-ferrous metals
030503	Combustion plants < 50 MW (boilers)	1A2b	Non-ferrous metals
030504	Gas turbines	1A2b	Non-ferrous metals
030505	Stationary engines	1A2b	Non-ferrous metals
030506	Other stationary equipments	1A2b	Non-ferrous metals
030600	Chemical and Petrochemical	1A2c	Chemicals
030601	Combustion plants >= 300 MW (boilers)	1A2c	Chemicals
030602	Combustion plants >= 50 and < 300 MW (boilers)	1A2c	Chemicals
030603	Combustion plants < 50 MW (boilers)	1A2c	Chemicals
030604	Gas turbines	1A2c	Chemicals
030605	Stationary engines	1A2c	Chemicals
030606	Other stationary equipments	1A2c	Chemicals
030700	Non-Metallic Minerals	1A2f	Non-metallic minerals
030701	Combustion plants >= 300 MW (boilers)	1A2f	Non-metallic minerals
030702	Combustion plants >= 50 and < 300 MW (boilers)	1A2f	Non-metallic minerals
030703	Combustion plants < 50 MW (boilers)	1A2f	Non-metallic minerals
030704	Gas turbines	1A2f	Non-metallic minerals
030705	Stationary engines	1A2f	Non-metallic minerals
030706	Other stationary equipments	1A2f	Non-metallic minerals
030800	Mining and Quarrying	1A2g viii	Other manufacturing industry
030801	Combustion plants >= 300 MW (boilers)	1A2g viii	Other manufacturing industry
030802	Combustion plants >= 50 and < 300 MW (boilers)	1A2g viii	Other manufacturing industry
030803	Combustion plants < 50 MW (boilers)	1A2g viii	Other manufacturing industry
030804	Gas turbines	1A2g viii	Other manufacturing industry
030805	Stationary engines	1A2g viii	Other manufacturing industry
030806	Other stationary equipments	1A2g viii	Other manufacturing industry
030900	Food and Tobacco	1A2e	Food processing, beverages and tobacco
030901	Combustion plants >= 300 MW (boilers)	1A2e	Food processing, beverages and tobacco
030902	Combustion plants >= 50 and < 300 MW (boilers)	1A2e	Food processing, beverages and tobacco
030903	Combustion plants < 50 MW (boilers)	1A2e	Food processing, beverages and tobacco
030904	Gas turbines	1A2e	Food processing, beverages and tobacco
030905	Stationary engines	1A2e	Food processing, beverages and tobacco
030906	Other stationary equipments	1A2e	Food processing, beverages and tobacco
031000	Textile and Leather	1A2g viii	Other manufacturing industry
031001	Combustion plants >= 300 MW (boilers)	1A2g viii	Other manufacturing industry
031002	Combustion plants >= 50 and < 300 MW (boilers)	1A2g viii	Other manufacturing industry
031003	Combustion plants < 50 MW (boilers)	1A2g viii	Other manufacturing industry
031004	Gas turbines	1A2g viii	Other manufacturing industry
031005	Stationary engines	1A2g viii	Other manufacturing industry
031006	Other stationary equipments	1A2g viii	Other manufacturing industry
031100	Paper, Pulp and Print	1A2d	Pulp, Paper and Print
031101	Combustion plants >= 300 MW (boilers)	1A2d	Pulp, Paper and Print
031102	Combustion plants >= 50 and < 300 MW (boilers)	1A2d	Pulp, Paper and Print
031103	Combustion plants < 50 MW (boilers)	1A2d	Pulp, Paper and Print
031104	Gas turbines	1A2d	Pulp, Paper and Print
031105	Stationary engines	1A2d	Pulp, Paper and Print
031106	Other stationary equipments	1A2d	Pulp, Paper and Print
031200	Transport Equipment	1A2g viii	Other manufacturing industry
031201	Combustion plants >= 300 MW (boilers)	1A2g viii	Other manufacturing industry
031202	Combustion plants >= 50 and < 300 MW (boilers)	1A2g viii	Other manufacturing industry
031203	Combustion plants < 50 MW (boilers)	1A2g viii	Other manufacturing industry
031204	Gas turbines	1A2g viii	Other manufacturing industry
031205	Stationary engines	1A2g viii	Other manufacturing industry
031206	Other stationary equipments	1A2g viii	Other manufacturing industry
031300	Machinery	1A2g viii	Other manufacturing industry
031301	Combustion plants >= 300 MW (boilers)	1A2g viii	Other manufacturing industry
031302	Combustion plants >= 50 and < 300 MW (boilers)	1A2g viii	Other manufacturing industry
031303	Combustion plants < 50 MW (boilers)	1A2g viii	Other manufacturing industry
031304	Gas turbines	1A2g viii	Other manufacturing industry

snap_id	snap_name	CRF id	CRF name
031306	Other stationary equipments	1A2g viii	Other manufacturing industry
031400	Wood and Wood Products	1A2g viii	Other manufacturing industry
031401	Combustion plants >= 300 MW (boilers)	1A2g viii	Other manufacturing industry
031402	Combustion plants >= 50 and < 300 MW (boilers)	1A2g viii	Other manufacturing industry
031403	Combustion plants < 50 MW (boilers)	1A2g viii	Other manufacturing industry
031404	Gas turbines	1A2g viii	Other manufacturing industry
031405	Stationary engines	1A2g viii	Other manufacturing industry
031406	Other stationary equipments	1A2g viii	Other manufacturing industry
031500	Construction	1A2g viii	Other manufacturing industry
031501	Combustion plants >= 300 MW (boilers)	1A2g viii	Other manufacturing industry
031502	Combustion plants >= 50 and < 300 MW (boilers)	1A2g viii	Other manufacturing industry
031503	Combustion plants < 50 MW (boilers)	1A2g viii	Other manufacturing industry
031504	Gas turbines	1A2g viii	Other manufacturing industry
031505	Stationary engines	1A2g viii	Other manufacturing industry
031506	Other stationary equipments	1A2g viii	Other manufacturing industry
031600	Cement production	1A2f	Non-metallic minerals
031601	Combustion plants >= 300 MW (boilers)	1A2f	Non-metallic minerals
031602	Combustion plants >= 50 and < 300 MW (boilers)	1A2f	Non-metallic minerals
031603	Combustion plants < 50 MW (boilers)	1A2f	Non-metallic minerals
031604	Gas turbines	1A2f	Non-metallic minerals
031605	Stationary engines	1A2f	Non-metallic minerals
031606	Other stationary equipments	1A2f	Non-metallic minerals
032000	Non-specified (Industry)	1A2g viii	Other manufacturing industry
032001	Combustion plants >= 300 MW (boilers)	1A2g viii	Other manufacturing industry
032002	Combustion plants >= 50 and < 300 MW (boilers)	1A2g viii	Other manufacturing industry
032003	Combustion plants < 50 MW (boilers)	1A2g viii	Other manufacturing industry
032004	Gas turbines	1A2g viii	Other manufacturing industry
032005	Stationary engines	1A2g viii	Other manufacturing industry
032006	Other stationary equipments	1A2g viii	Other manufacturing industry

Annex 3A-2 Fuel rate

Table 3A-2.1 Fuel consumption rate for stationary combustion plants 1990-2013, PJ.

Sum of Fuel_rate_PJ			Year									
fuel_type	fuel_id	fuel_gr_abbr	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
SOLID	101A	ANODIC CARBON										
	102A	COAL	253.4	344.3	286.8	300.8	323.4	270.3	371.9	276.3	234.3	196.5
	103A	FLY ASH (COAL)										
	106A	BROWN COAL BRI.	0.1	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0
	107A	COKE OVEN COKE	1.3	1.4	1.2	1.2	1.2	1.3	1.2	1.3	1.3	1.4
LIQUID	110A	PETROLEUM COKE	4.5	4.4	4.3	5.7	7.5	5.3	5.9	6.0	5.3	6.8
	203A	RESIDUAL OIL	32.1	38.3	38.5	32.8	46.2	33.0	37.8	26.6	30.0	23.7
	204A	GAS OIL	61.4	64.9	56.0	62.0	53.9	53.6	58.0	51.0	48.4	47.4
	206A	KEROSENE	5.1	1.0	0.8	0.8	0.7	0.6	0.5	0.4	0.4	0.3
	225A	ORIMULSION						19.9	36.8	40.5	32.6	34.2
	303A	LPG	3.0	2.7	2.4	2.5	2.6	2.7	3.0	2.6	2.8	2.5
	308A	REFINERY GAS	14.2	14.5	14.9	15.4	16.4	20.8	21.4	16.9	15.2	15.7
GAS	301A	NATURAL GAS	76.1	86.1	90.5	102.5	114.6	132.7	156.3	164.5	178.7	187.9
WASTE	114A	WASTE	15.5	16.7	17.8	19.4	20.3	22.9	25.0	26.8	26.6	29.1
	115A	INDUSTR. WASTES										
BIOMASS	111A	WOOD	18.2	20.0	21.0	22.2	21.9	21.8	23.4	23.4	22.9	24.4
	117A	STRAW	12.5	13.3	13.9	13.4	12.7	13.1	13.5	13.9	13.9	13.7
	215A	LIQUID BIOFUELS	0.7	0.7	0.7	0.8	0.2	0.3	0.1	0.0	0.0	0.0
	309A	BIOGAS	0.8	0.9	0.9	1.1	1.3	1.8	2.1	2.4	2.7	2.6
	310A	BIO GASIF GAS					0.1	0.0	0.0	0.0	0.0	0.0
Grand Total			498.9	609.6	549.9	580.6	623.0	600.2	756.8	652.7	615.2	586.4

Sum of Fuel_rate_PJ			Year									
fuel_type	fuel_id	fuel_gr_abbr	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
SOLID	101A	ANODIC CARBON										0.0
	102A	COAL	164.7	174.3	174.7	239.0	182.5	154.0	232.0	194.1	170.5	167.7
	103A	FLY ASH (COAL)										
	106A	BROWN COAL BRI.	0.0	0.0	0.0	0.0					0.0	0.0
	107A	COKE OVEN COKE	1.2	1.1	1.1	1.0	1.1	1.0	1.0	1.1	1.0	0.8
LIQUID	110A	PETROLEUM COKE	6.8	7.8	7.8	8.0	8.4	8.1	8.5	9.2	6.9	5.9
	203A	RESIDUAL OIL	18.8	21.1	26.2	28.6	24.5	21.9	26.1	19.8	15.8	14.7
	204A	GAS OIL	41.2	43.6	38.6	38.8	35.7	31.5	26.4	21.6	21.2	24.5
	206A	KEROSENE	0.2	0.3	0.3	0.3	0.2	0.3	0.2	0.1	0.1	0.1
	225A	ORIMULSION	34.1	30.2	23.8	1.9	0.0					
	303A	LPG	2.4	2.2	2.0	2.1	2.2	2.2	2.3	1.9	1.7	1.5
	308A	REFINERY GAS	15.6	15.8	15.2	16.6	15.9	15.3	16.1	15.9	14.8	15.4
GAS	301A	NATURAL GAS	186.1	193.8	193.6	195.9	195.1	187.4	191.1	171.0	171.9	164.9
WASTE	114A	WASTE	29.8	31.3	33.3	35.1	35.3	35.8	36.9	38.1	39.6	37.6
	115A	INDUSTR. WASTES	0.5	1.4	1.9	1.5	2.0	2.0	1.5	1.6	2.0	1.7
BIOMASS	111A	WOOD	27.5	30.8	31.6	38.9	43.9	49.7	52.1	60.3	63.6	66.0
	117A	STRAW	12.2	13.7	15.7	16.9	17.9	18.5	18.5	18.8	15.9	17.4
	215A	LIQUID BIOFUELS	0.0	0.2	0.1	0.4	0.6	0.8	1.1	1.2	1.8	1.7
	309A	BIOGAS	3.0	3.1	3.5	3.7	3.9	4.0	4.1	4.1	4.2	4.4
	310A	BIO GASIF GAS	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.3
Grand Total			544.4	570.8	569.2	628.8	569.3	532.6	618.1	558.9	531.1	524.6

Sum of Fuel_rate_PJ			Year			
fuel_type	fuel_id	fuel_gr_abbr	2010	2011	2012	2013
SOLID	101A	ANODIC CARBON	0.0	0.0	0.0	0.0
	102A	COAL	163.0	135.5	106.2	135.0
	103A	FLY ASH (COAL)		0.0	0.1	0.1
	106A	BROWN COAL BRI.	0.0	0.0	0.0	0.0
	107A	COKE OVEN COKE	0.7	0.7	0.6	0.6
LIQUID	110A	PETROLEUM COKE	5.1	6.5	6.7	6.1
	203A	RESIDUAL OIL	13.0	8.0	7.3	5.7
	204A	GAS OIL	23.2	16.9	13.0	10.6
	206A	KEROSENE	0.1	0.0	0.0	0.0
	225A	ORIMULSION				
	303A	LPG	1.5	1.4	1.5	1.3
	308A	REFINERY GAS	14.3	15.0	15.6	15.4
GAS	301A	NATURAL GAS	184.9	156.5	146.4	138.0
WASTE	114A	WASTE	36.4	36.7	35.8	37.1
	115A	INDUSTR. WASTES	1.4	1.7	1.5	1.8
BIOMASS	111A	WOOD	81.3	78.8	83.6	82.5
	117A	STRAW	23.3	20.2	18.3	20.6
	215A	LIQUID BIOFUELS	2.0	0.8	1.1	0.9
	309A	BIOGAS	4.6	4.3	4.7	4.9
	310A	BIO GASIF GAS	0.2	0.3	0.4	0.4
Grand Total			555.0	483.4	442.7	460.9

Table 3A-2.2 Detailed fuel consumption data for stationary combustion plants, 1990-2013, PJ.

This table is available at: http://envs.au.dk/videnudveksling/luft/emissioner/supporting-documentation/greenhouse-gases-nir/

Annex 3A-3 Default Lower Calorific Value (LCV) of fuels and fuel correspondence list

Table 3A-3.1 Time-series for calorific values of fuels (DEA 2014a).

		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Crude Oil, Average	GJ per tonne	42.40	42.40	42.40	42.70	42.70	42.70	42.70	43.00	43.00	42.40
Crude Oil, Golf	GJ per tonne	41.80	41.80	41.80	41.80	41.80	41.80	41.80	41.80	41.80	41.80
Crude Oil, North Sea	GJ per tonne	42.70	42.70	42.70	42.70	42.70	42.70	42.70	43.00	43.00	42.70
Refinery Feedstocks	GJ per tonne	41.60	41.60	41.60	41.60	41.60	41.60	41.60	42.70	42.70	41.60
Refinery Gas	GJ per tonne	52.00	52.00	52.00	52.00	52.00	52.00	52.00	52.00	52.00	52.00
LPG	GJ per tonne	46.00	46.00	46.00	46.00	46.00	46.00	46.00	46.00	46.00	46.00
Naphtha (LVN)	GJ per tonne	44.50	44.50	44.50	44.50	44.50	44.50	44.50	44.50	44.50	44.50
Motor Gasoline	GJ per tonne	43.80	43.80	43.80	43.80	43.80	43.80	43.80	43.80	43.80	43.80
Aviation Gasoline	GJ per tonne	43.80	43.80	43.80	43.80	43.80	43.80	43.80	43.80	43.80	43.80
JP4	GJ per tonne	43.80	43.80	43.80	43.80	43.80	43.80	43.80	43.80	43.80	43.80
Other Kerosene	GJ per tonne	43.50	43.50	43.50	43.50	43.50	43.50	43.50	43.50	43.50	43.50
JP1	GJ per tonne	43.50	43.50	43.50	43.50	43.50	43.50	43.50	43.50	43.50	43.50
Gas/Diesel Oil	GJ per tonne	42.70	42.70	42.70	42.70	42.70	42.70	42.70	42.70	42.70	42.70
Fuel Oil	GJ per tonne	40.40	40.40	40.40	40.40	40.40	40.40	40.70	40.65	40.65	40.40
Orimulsion	GJ per tonne	27.60	27.60	27.60	27.60	27.60	28.13	28.02	27.72	27.84	27.60
Petroleum Coke	GJ per tonne	31.40	31.40	31.40	31.40	31.40	31.40	31.40	31.40	31.40	31.40
Waste Oil	GJ per tonne	41.90	41.90	41.90	41.90	41.90	41.90	41.90	41.90	41.90	41.90
White Spirit	GJ per tonne	43.50	43.50	43.50	43.50	43.50	43.50	43.50	43.50	43.50	43.50
Bitumen	GJ per tonne	39.80	39.80	39.80	39.80	39.80	39.80	39.80	39.80	39.80	39.80
Lubricants	GJ per tonne	41.90	41.90	41.90	41.90	41.90	41.90	41.90	41.90	41.90	41.90
Natural Gas	GJ per 1000 Nm^3	39.00	39.00	39.00	39.30	39.30	39.30	39.30	39.60	39.90	40.00
Town Gas	GJ per 1000 m^3							17.00	17.00	17.00	17.00
Electricity Plant Coal	GJ per tonne	25.30	25.40	25.80	25.20	24.50	24.50	24.70	24.96	25.00	25.00
Other Hard Coal	GJ per tonne	26.10	26.50	26.50	26.50	26.50	26.50	26.50	26.50	26.50	26.50
Coke	GJ per tonne	31.80	29.30	29.30	29.30	29.30	29.30	29.30	29.30	29.30	29.30
Brown Coal Briquettes	GJ per tonne	18.30	18.30	18.30	18.30	18.30	18.30	18.30	18.30	18.30	18.30
Straw	GJ per tonne	14.50	14.50	14.50	14.50	14.50	14.50	14.50	14.50	14.50	14.50
Wood Chips	GJ per cubic metre	2.80	2.80	2.80	2.80	2.80	2.80	2.80	2.80	2.80	2.80
Wood Chips	GJ per tonne	9.30	9.30	9.30	9.30	9.30	9.30	9.30	9.30	9.30	9.30
Firewood, Hardwood	GJ per m^3	10.40	10.40	10.40	10.40	10.40	10.40	10.40	10.40	10.40	10.40
Firewood, Conifer	GJ per m^3	7.60	7.60	7.60	7.60	7.60	7.60	7.60	7.60	7.60	7.60
Wood Pellets	GJ per tonne	17.50	17.50	17.50	17.50	17.50	17.50	17.50	17.50	17.50	17.50
Wood Waste	GJ per tonne	14.70	14.70	14.70	14.70	14.70	14.70	14.70	14.70	14.70	14.70
Wood Waste	GJ per cubic metre	3.20	3.20	3.20	3.20	3.20	3.20	3.20	3.20	3.20	3.20
Biogas	GJ per 1000 m^3								23.00	23.00	23.00
Wastes	GJ per tonne	8.20	8.20	9.00	9.40	9.40	10.00	10.50	10.50	10.50	10.50
Bioethanol	GJ per tonne	26.70	26.70	26.70	26.70	26.70	26.70	26.70	26.70	26.70	26.70
Liquid Biofuels	GJ per tonne	37.60	37.60	37.60	37.60	37.60	37.60	37.60	37.60	37.60	37.60
Bio Oil	GJ per tonne	37.20	37.20	37.20	37.20	37.20	37.20	37.20	37.20	37.20	37.20

Continued		2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Crude Oil, Average	GJ per tonne	43.00	43.00	43.00	43.00	43.00	43.00	43.00	43.00	43.00	43.00
Crude Oil, Golf	GJ per tonne	41.80	41.80	41.80	41.80	41.80	41.80	41.80	41.80	41.80	41.80
Crude Oil, North Sea	GJ per tonne	43.00	43.00	43.00	43.00	43.00	43.00	43.00	43.00	43.00	43.00
Refinery Feedstocks	GJ per tonne	42.70	42.70	42.70	42.70	42.70	42.70	42.70	42.70	42.70	42.70
Refinery Gas	GJ per tonne	52.00	52.00	52.00	52.00	52.00	52.00	52.00	52.00	52.00	52.00
LPG	GJ per tonne	46.00	46.00	46.00	46.00	46.00	46.00	46.00	46.00	46.00	46.00
Naphtha (LVN)	GJ per tonne	44.50	44.50	44.50	44.50	44.50	44.50	44.50	44.50	44.50	44.50
Motor Gasoline	GJ per tonne	43.80	43.80	43.80	43.80	43.80	43.80	43.80	43.80	43.80	43.80
Aviation Gasoline	GJ per tonne	43.80	43.80	43.80	43.80	43.80	43.80	43.80	43.80	43.80	43.80
JP4	GJ per tonne	43.80	43.80	43.80	43.80	43.80	43.80	43.80	43.80	43.80	43.80
Other Kerosene	GJ per tonne	43.50	43.50	43.50	43.50	43.50	43.50	43.50	43.50	43.50	43.50
JP1	GJ per tonne	43.50	43.50	43.50	43.50	43.50	43.50	43.50	43.50	43.50	43.50
Gas/Diesel Oil	GJ per tonne	42.70	42.70	42.70	42.70	42.70	42.70	42.70	42.70	42.70	42.70
Fuel Oil	GJ per tonne	40.65	40.65	40.65	40.65	40.65	40.65	40.65	40.65	40.65	40.65
Orimulsion	GJ per tonne	27.62	27.64	27.71	27.65	27.65	27.65	27.65	27.65	27.65	27.65
Petroleum Coke	GJ per tonne	31.40	31.40	31.40	31.40	31.40	31.40	31.40	31.40	31.40	31.40
Waste Oil	GJ per tonne	41.90	41.90	41.90	41.90	41.90	41.90	41.90	41.90	41.90	41.90
White Spirit	GJ per tonne	43.50	43.50	43.50	43.50	43.50	43.50	43.50	43.50	43.50	43.50
Bitumen	GJ per tonne	39.80	39.80	39.80	39.80	39.80	39.80	39.80	39.80	39.80	39.80
Lubricants	GJ per tonne	41.90	41.90	41.90	41.90	41.90	41.90	41.90	41.90	41.90	41.90
Natural Gas	GJ per 1000 Nm^3	40.15	39.99	40.06	39.94	39.77	39.67	39.54	39.59	39.48	39.46
Town Gas	GJ per 1000 m^3	17.01	16.88	17.39	16.88	17.58	17.51	17.20	17.14	15.50	21.29
Electricity Plant Coal	GJ per tonne	24.80	24.90	25.15	24.73	24.60	24.40	24.80	24.40	24.30	24.60
Other Hard Coal	GJ per tonne	26.50	26.50	26.50	26.50	26.50	26.50	26.50	26.50	25.81	25.13
Coke	GJ per tonne	29.30	29.30	29.30	29.30	29.30	29.30	29.30	29.30	29.30	29.30
Brown Coal Briquettes	GJ per tonne	18.30	18.30	18.30	18.30	18.30	18.30	18.30	18.30	18.30	18.30
Straw	GJ per tonne	14.50	14.50	14.50	14.50	14.50	14.50	14.50	14.50	14.50	14.50
Wood Chips	GJ per cubic metre	2.80	2.80	2.80	2.80	2.80	2.80	2.80	2.80	2.80	2.80
Wood Chips	GJ per tonne	9.30	9.30	9.30	9.30	9.30	9.30	9.30	9.30	9.30	9.30
Firewood, Hardwood	GJ per m^3	10.40	10.40	10.40	10.40	10.40	10.40	10.40	10.40	10.40	10.40
Firewood, Conifer	GJ per m^3	7.60	7.60	7.60	7.60	7.60	7.60	7.60	7.60	7.60	7.60
Wood Pellets	GJ per tonne	17.50	17.50	17.50	17.50	17.50	17.50	17.50	17.50	17.50	17.50
Wood Waste	GJ per tonne	14.70	14.70	14.70	14.70	14.70	14.70	14.70	14.70	14.70	14.70
Wood Waste	GJ per cubic metre	3.20	3.20	3.20	3.20	3.20	3.20	3.20	3.20	3.20	3.20
Biogas	GJ per 1000 m^3	23.00	23.00	23.00	23.00	23.00	23.00	23.00	23.00	23.00	23.00
Wastes	GJ per tonne	10.50	10.50	10.50	10.50	10.50	10.50	10.50	10.50	10.50	10.50
Bioethanol	GJ per tonne	26.70	26.70	26.70	26.70	26.70	26.70	26.70	26.70	26.70	26.70
Liquid Biofuels	GJ per tonne	37.60	37.60	37.60	37.60	37.60	37.60	37.60	37.60	37.50	37.50
Bio Oil	GJ per tonne	37.20	37.20	37.20	37.20	37.20	37.20	37.20	37.20	37.20	37.20

Continued		2010	2011	2012	2013
Crude Oil, Average	GJ per tonne	43.00	43.00	43.00	43.00
Crude Oil, Golf	GJ per tonne	41.80	41.80	41.80	41.80
Crude Oil, North Sea	GJ per tonne	43.00	43.00	43.00	43.00
Refinery Feedstocks	GJ per tonne	42.70	42.70	42.70	42.70
Refinery Gas	GJ per tonne	52.00	52.00	52.00	52.00
LPG	GJ per tonne	46.00	46.00	46.00	46.00
Naphtha (LVN)	GJ per tonne	44.50	44.50	44.50	44.50
Motor Gasoline	GJ per tonne	43.80	43.80	43.80	43.80
Aviation Gasoline	GJ per tonne	43.80	43.80	43.80	43.80
JP4	GJ per tonne	43.80	43.80	43.80	43.80
Other Kerosene	GJ per tonne	43.50	43.50	43.50	43.50
JP1	GJ per tonne	43.50	43.50	43.50	43.50
Gas/Diesel Oil	GJ per tonne	42.70	42.70	42.70	42.70
Fuel Oil	GJ per tonne	40.65	40.65	40.65	40.65
Orimulsion	GJ per tonne	27.65	27.65	27.65	27.65
Petroleum Coke	GJ per tonne	31.40	31.40	31.40	31.40
Waste Oil	GJ per tonne	41.90	41.90	41.90	41.90
White Spirit	GJ per tonne	43.50	43.50	43.50	43.50
Bitumen	GJ per tonne	39.80	39.80	39.80	39.80
Lubricants	GJ per tonne	41.90	41.90	41.90	41.90
Natural Gas	GJ per 1000 Nm^3	39.46	39.51	39.55	38.99
Town Gas	GJ per 1000 m^3	21.35	21.37	19.30	18.72
Electricity Plant Coal	GJ per tonne	24.44	24.38	24.23	24.49
Other Hard Coal	GJ per tonne	24.44	24.38	24.23	24.49
Coke	GJ per tonne	29.30	29.30	29.30	29.30
Brown Coal Briquettes	GJ per tonne	18.30	18.30	18.30	18.30
Straw	GJ per tonne	14.50	14.50	14.50	14.50
Wood Chips	GJ per cubic metre	2.80	2.80	2.80	2.80
Wood Chips	GJ per tonne	9.30	9.30	9.30	9.30
Firewood, Hardwood	GJ per m^3	10.40	10.40	10.40	10.40
Firewood, Conifer	GJ per m^3	7.60	7.60	7.60	7.60
Wood Pellets	GJ per tonne	17.50	17.50	17.50	17.50
Wood Waste	GJ per tonne	14.70	14.70	14.70	14.70
Wood Waste	GJ per cubic metre	3.20	3.20	3.20	3.20
Biogas	GJ per 1000 m^3	23.00	23.00	23.00	23.00
Wastes	GJ per tonne	10.50	10.50	10.50	10.60
Bioethanol	GJ per tonne	26.70	26.70	26.70	26.70
Liquid Biofuels	GJ per tonne	37.50	37.50	37.50	37.50
Bio Oil	GJ per tonne	37.20	37.20	37.20	37.20

Table 3A-3.2 Fuel category correspondence list, DEA, DCE and Climate Convention reporting (CRF).

Danish Energy Agency	**DCE Emission database**	**IPCC fuel category**
Other Hard Coal	Coal	Solid
Coke	Coke oven coke	Solid
Electricity Plant Coal	Coal	Solid
Brown Coal Briquettes	Brown coal briq.	Solid
-	Anode carbon	Solid
-	Fly ash	Solid
Orimulsion	Orimulsion	Liquid
Petroleum Coke	Petroleum coke	Liquid
Fuel Oil	Residual oil	Liquid
Waste Oil	Residual oil	Liquid
Gas/Diesel Oil	Gas oil	Liquid
Other Kerosene	Kerosene	Liquid
LPG	LPG	Liquid
Refinery Gas	Refinery gas	Liquid
Town Gas	Natural gas	Gas
Natural Gas	Natural gas	Gas
Straw	Straw	Biomass
Wood Waste	Wood and similar	Biomass
Wood Pellets	Wood and similar	Biomass
Wood Chips	Wood and similar	Biomass
Firewood, Hardwood & Conifer	Wood and similar	Biomass
Waste Combustion (biomass)	Municipal wastes	Biomass
Bio fuels	Liquid biofuels	Biomass
Biogas	Biogas	Biomass
Biogas, other	Biogas	Biomass
Biogas, landfill	Biogas	Biomass
Biogas, sewage sludge	Biogas	Biomass
(Wood applied in gas engines)	Biomass producer gas	Biomass
Waste Combustion (fossil)	Fossil waste	Other fuel

Annex 3A-4 Emission factors

Table 3A-4.1 CO_2 emission factors, 2013.

Fuel	Emission factor kg per GJ Bio-mass	Emission factor kg per GJ Fossil fuel	Reference type	IPCC fuel category
Coal, source category 1A1a Public electricity and heat production		93.95 [1)]	Country specific	Solid
Coal, Other source categories		94.6[3)]	IPCC (2006)	Solid
Brown coal briquettes		**r** 97.5	IPCC (2006)	Solid
Coke oven coke		**r** 107 [3)]	IPCC (2006)	Solid
Other solid fossil fuels [6)]		**r** 118[1)]	Country specific	Solid
Fly ash fossil (from coal)		95.4	Country specific	Solid
Petroleum coke		93 [3)]	Country-specific	Liquid
Residual oil, source category 1A1a Public electricity and heat production		79.28 [1)]	Country-specific	Liquid
Residual oil, other source categories		77.4[3)]	IPCC (2006)	Liquid
Gas oil		74 [1)]	EEA (2007)	Liquid
Kerosene		71.9	IPCC (2006)	Liquid
Orimulsion		80 [2)]	Country-specific	Liquid
LPG		63.1	IPCC (2006)	Liquid
Refinery gas		58.274	Country-specific	Liquid
Natural gas, off shore gas turbines		57.295	Country-specific	Gas
Natural gas, other		56.79	Country-specific	Gas
Waste	75.1 [3)4)]	+ 37[3)4)]	Country-specific	Biomass and Other fuels
Straw	**r** 100		IPCC (2006)	Biomass
Wood	**r** 112		IPCC (2006)	Biomass
Bio oil	70.8		IPCC (2006)	Biomass
Biogas	84.1		Country-specific	Biomass
Biomass gasification gas	142.9[5)]		Country-specific	Biomass

1) Plant specific data from EU ETS incorporated for individual plants.

2) Not applied in 2013. Orimulsion was applied in Denmark in 1995 – 2004.

3) Plant specific data from EU ETS incorporated for cement industry and sugar, lime and mineral wool production.

4) The emission factor for waste is (37+75.1) kg CO_2 per GJ waste. The fuel consumption and the CO_2 emission have been disaggregated to the two IPCC fuel categories *Biomass* and *Other fossil fuels* in CRF. The IEF[1] for CO_2, Other fuels is 82.22 kg CO_2 per GJ fossil waste.

5) Includes a high content of CO_2 in the gas.

6) Anodic carbon

Time series have been estimated for:

- Coal applied for production of electricity and district heating
- Residual oil applied for production of electricity and district heating
- Refinery gas
- Natural gas combusted in off shore gas turbines
- Natural gas, other
- Industrial waste, biomass part

For all other fuels the same emission factor has been applied for 1990-2013.

[1] Not including cement production.

Table 3A-4.2 CO_2 emission factors, time-series.

Year	Coal, sector 1A1a, kg per GJ	Residual oil, sector 1A1a, kg per GJ	Refinery gas, kg per GJ	Natural gas, off shore gas turbines, kg per GJ	Natural gas, other, kg per GJ	Industrial waste, biomass part
1990	94	78.4	57.6	57.469	56.9	86.7
1991	94	78.4	57.6	57.469	56.9	86.7
1992	94	78.4	57.6	57.469	56.9	84.2
1993	94	78.4	57.6	57.469	56.9	83
1994	94	78.4	57.6	57.469	56.9	83
1995	94	78.4	57.6	57.469	56.9	81.1
1996	94	78.4	57.6	57.469	56.9	79.6
1997	94	78.4	57.6	57.469	56.9	79.6
1998	94	78.4	57.6	57.469	56.9	79.6
1999	94	78.4	57.6	57.469	56.9	79.6
2000	94	78.4	57.6	57.469	57.1	79.6
2001	94	78.4	57.6	57.469	57.25	79.6
2002	94	78.4	57.6	57.469	57.28	79.6
2003	94	78.4	57.6	57.469	57.19	79.6
2004	94	78.4	57.6	57.469	57.12	79.6
2005	94	78.4	57.6	57.469	56.96	79.6
2006	94.4	78.2	57.812	57.879	56.78	79.6
2007	94.3	78.1	57.848	57.784	56.78	79.6
2008	94	78.5	57.948	56.959	56.77	79.6
2009	93.6	78.9	56.817	57.254	56.69	79.6
2010	93.6	79.2	57.134	57.314	56.74	79.6
2011	94.73	79.25	57.861	57.379	56.97	79.6
2012	94.25	79.21	58.108	57.423	57.03	79.6
2013	93.95	79.28	58.274	57.295	56.79	79.6

Table 3A-4.3 CH_4 emission factors and references, 2013.

Fuel group	Fuel	CRF source category	CRF source category	SNAP	Emission factor, g per GJ	Reference
SOLID	COAL	1A1a	Public electricity and heat production	0101 0102	0.9	IPCC (2006), Tier 3, Table 2-6, Utility Boiler, Pulverised bituminous coal combustion, Wet bottom.
		1A2 a-f	Industry	03	10	IPCC (2006), Tier 1, Table 2-3, Manufacturing industries.
		1A4b i	Residential	0202	300	IPCC (2006), Tier 1, Table 2.5, Residential, Bituminous coal.
		1A4c i	Agriculture/ Forestry	0203	10	IPCC (2006), Tier 1, Table 2-4, Commercial, coal.[1)]
	BROWN COAL BRI.	1A4b i	Residential	0202	300	IPCC (2006), Tier 1, Table 2-5, Residential, brown coal briquettes
	COKE OVEN COKE	1A2 A-f	Industry	03	10	IPCC (2006), Tier 1, Table 2-4, Commercial, coke oven coke.
		1A4b i	Residential	0202	300	IPCC (2006), Tier 1, Table 2-5, Residential, coke oven coke.
	ANODIC CARBON	1A2a-f	Industry	03	10	IPCC (2006), Tier 1, Table 2-3, Manufacturing industries.
	FOSSIL FLY ASH	1A1a	Public electricity and heat production	0101	0.9	IPCC (2006), Tier 3, Table 2-6, Utility Boiler, Pulverised bituminous coal combustion, Wet bottom.
LIQUID	PETROLEUM COKE	1A2a-f	Industry	03	**r** 3	IPCC (2006), Tier 1, Table 2-3, Industry, petroleum coke.
	RESIDUAL OIL	1A1a	Public electricity and heat production	010101	**r** 0.8	IPCC (2006), Tier 3, Table 2-6, Utility Boiler, Residual fuel oil.
				010102 010103	1.3	Nielsen et al. (2010)
				010104	3	IPCC (2006), Tier 1, Table 2-2, Energy industries, residual oil.
				010203	**r** 0.8	IPCC (2006), Tier 3, Table 2-6, Utility Boiler, Residual fuel oil.
		1A1b	Petroleum refining	010306	3	IPCC (2006), Tier 1, Table 2-2, Energy industries, residual fuel oil.
		1A2 a-f	Industry	03	1.3	Nielsen et al. (2010)
				Engines	4	IPCC (2006), Tier 3, Table 2-6, Utility, Large diesel engines
		1A4a	Commercial/ Institutional	0201	1.4	IPCC (2006), Tier 3, Table 2-10, Commercial, residual fuel oil boilers.
		1A4b	Residential	0202	1.4	IPCC (2006), Tier 3, Table 2-9, Residential, residual fuel oil.
		1A4c	Agriculture/ Forestry	0203	1.4	IPCC (2006), Tier 3, Table 2-10, Commercial, residual fuel oil boilers.[1)].
	GAS OIL	1A1a	Public electricity and heat production	010101 010102 010103	0.9	IPCC (2006), Tier 3, Table 2-6, Utility, gas oil, boilers.
				010104	3	IPCC (2006), Tier 1, Table 2-2, Energy industries, gas oil.
				010105	24	Nielsen et al. (2010)
				010202 010203	0.9	IPCC (2006), Tier 3, Table 2-6, Utility, gas oil, boilers.
		1A1b	Petroleum refining	010306	3	IPCC (2006), Tier 1, Table 2-2, Energy industries, gas oil.
		1A1c	Oil and gas extraction	010504	3	IPCC (2006), Tier 1, Table 2-2, Energy industries, gas oil.
		1A2 a-f	Industry	03	0.2	IPCC (2006), Tier 3, Table 2-7, Industry, gas oil, boilers.
				Turbines	**r** 3	IPCC (2006), Tier 1, Table 2-3, Industry, gas oil.
				Engines	24	Nielsen et al. (2010)
		1A4a	Commercial/ Institutional	0201	0.7	IPCC (2006), Tier 3, Table 2-10, Commercial, gas oil.
				020105	24	Nielsen et al. (2010)
		1A4b i	Residential	0202	0.7	IPCC (2006), Tier 3, Table 2.9, Residential, gas oil.
		1A4c	Agriculture/ Forestry	0203	0.7	IPCC (2006), Tier 3, Table 2-10, Commercial, gas oil[1)].
	KEROSENE	1A2 a-f	Industry	all	**r** 3	IPCC (2006), Tier 1, Table 2-3, Industry, other kerosene.

Fuel group	Fuel	CRF source category	CRF source category	SNAP	Emission factor, g per GJ	Reference
		1A4a	Commercial/ Institutional	0201	**r** 10	IPCC (2006), Tier 1, Table 2-4, Commercial, other kerosene.
		1A4b i	Residential	0202	**r** 10	IPCC (2006), Tier 1, Table 2-5, Residential/agricultural, other kerosene.
		1A4c i	Agriculture/ Forestry	0203	**r** 10	IPCC (2006), Tier 1, Table 2-5, Residential/agricultural, other kerosene.
	LPG	1A1a	Public electricity and heat production	0101 0102	**r** 1	IPCC (2006), Tier 1, Table 2-2, Energy Industries, LPG.
		1A1b	Petroleum refining	0103	**r** 1	IPCC (2006), Tier 1, Table 2-2, Energy Industries, LPG.
		1A2 a-f	Industry	03	**r** 1	IPCC (2006), Tier 1, Table 2-3, Industry, LPG
		1A4a	Commercial/ Institutional	0201	**r** 5	IPCC (2006), Tier 1, Table 2-4, Commercial, LPG.
		1A4b i	Residential	0202	**r** 5	IPCC (2006), Tier 1, Table 2-5, Residential / agricultural, LPG.
		1A4c i	Agriculture/ Forestry	0203	**r** 5	IPCC (2006), Tier 1, Table 2-5, Residential / agricultural, LPG.
	REFINERY GAS	1A1b	Petroleum refining	010304	1.7	Assumed equal to natural gas fuelled gas turbines. Nielsen et al. (2010)
				010306	1	IPCC (2006), Tier 1, Table 2-2, refinery gas.
GAS	NATURAL GAS	1A1a	Public electricity and heat production	010101 010102 010103	**r** 1	IPCC (2006), Tier 3, Table 2-6, Utility, natural gas, boilers.
				010104	1.7	Nielsen et al. (2010)
				010105	481	Nielsen et al. (2010)
				010202 010203	**r** 1	IPCC (2006), Tier 3, Table 2-6, Utility, natural gas, boilers.
		1A1c	Oil and gas extraction	010504	1.7	Nielsen et al. (2010)
		1A2 a-f	Industry	Other	**r** 1	IPCC (2006), Tier 3, Table 2-7, Industry, natural gas boilers.
				Gas turbines	1.7	Nielsen et al. (2010)
				Engines	481	Nielsen et al. (2010)
		1A4a	Commercial/ Institutional	0201	**r** 1	IPCC (2006), Tier 3, Table 2-10, Commercial, natural gas boilers.
				020105	481	Nielsen et al. (2010)
		1A4b i	Residential	0202	**r** 1	IPCC (2006), Tier 3, Table 2-9. Residential, natural gas boilers.
				020204	481	Nielsen et al. (2010)
		1A4c i	Agriculture/ Forestry	0203	**r** 1	IPCC (2006), Tier 3, Table 2-10, Commercial, natural gas boilers[1)].
				020304	481	Nielsen et al. (2010)
WASTE	WASTE	1A1a	Public electricity and heat production	0101 0102	0.34	Nielsen et al. (2010)
		1A2a-f	Industry	03	30	IPCC (2006), Tier 1, Table 2-3, Industry, municipal wastes.
		1A4a	Commercial/ Institutional	0201	30	IPCC (2006), Tier 1, Table 2-3, Industry, municipal wastes [2)].
	INDUSTRIAL WASTE	1A2f	Industry	0316	30	IPCC (2006), Tier 1, Table 2-3, Industry, industrial wastes.
BIO-MASS	WOOD	1A1a	Public electricity and heat production	0101	3.1	Nielsen et al. (2010)
				0102	**r** 11	IPCC (2006), Tier 3, Table 2-6, Utility boilers, wood
		1A2 a-f	Industry	03	**r** 11	IPCC (2006), Tier 3, Table 2-7, Industry, wood, boilers.
		1A4a	Commercial/ Institutional	0201	**r** 11	IPCC (2006), Tier 3, Table 2-10, Commercial, wood.
		1A4b i	Residential	0202	129.3	DCE estimate based on technology distribution [3)]
		1A4c i	Agriculture/ Forestry	0203	**r** 11	IPCC (2006), Tier 3, Table 2-10, Commercial, wood.[1)].
	STRAW	1A1a	Public electricity and heat production	0101	0.47	Nielsen et al. (2010)
				0102	30	IPCC (2006), Tier 1, Table 2-2, Energy industries, other primary solid biomass

Fuel group	Fuel	CRF source category	CRF source category	SNAP	Emission factor, g per GJ	Reference
		1A4b i	Residential	0202	300	IPCC (2006), Tier 1, Table 2-5, Residential, other primary solid biomass.
		1A4c i	Agriculture/ Forestry	020300	300	IPCC (2006), Tier 1, Table 2-5, Agriculture, other primary solid biomass.
				020302	30	IPCC (2006), Tier 1, Table 2-2, Energy industries, other primary solid biomass (large agricultural plants considered equal to this plant category)
	BIO OIL	1A1a	Public electricity and heat production	010102	**r** 3	IPCC (2006), Tier 1, Table 2-2, Energy industries, biodiesels.
				010105	24	Nielsen et al. (2010) assumed same emission factor as for gas oil fuelled engines.
				0102	**r** 3	IPCC (2006), Tier 1, Table 2-2, Energy industries, biodiesels.
		1A2 a-f	Industry	03	**r** 3	IPCC (2006), Tier 1, Table 2-3, Industry, biodiesels.
		1A4b i	Residential	0202	**r** 10	IPCC (2006), Tier 1, Table 2-5, Residential, biodiesels.
	BIOGAS	1A1a	Public electricity and heat production	0101	1	IPCC (2006), Tier 1, Table 2-2, Energy industries, other biogas.
				010105	434	Nielsen et al. (2010)
				0102	1	IPCC (2006), Tier 1, Table 2-2, Energy industries, other biogas.
		1A2 a-f	Industry	03	1	IPCC (2006), Tier 1, Table 2-3, Industry, other biogas.
				Engines	434	Nielsen et al. (2010)
		1A4a	Commercial/ Institutional	0201	5	IPCC (2006), Tier 1, Table 2-4, Commercial, other biogas.
				020105	434	Nielsen et al. (2010)
		1A4c i	Agriculture/ Forestry	0203	5	IPCC (2006), Tier 1, Table 2-5, Agriculture, other biogas.
				020304	434	Nielsen et al. (2010)
	BIO PROD GAS	1A1a	Public electricity and heat production	010105	13	Nielsen et al. (2010)
		1A4a	Commercial/Institutional	020105	13	Nielsen et al. (2010)

1) Assumed same emission factors as for commercial plants. Plant capacity and technology are similar for Danish plants.

2) Assumed same emission factor as for industrial plants. Plant capacity and technology is similar to industrial plants rather than to residential plants.

3) Aggregated emission factor based on the technology distribution in the sector (DEPA, 2013) and technology specific emission factors that refer to: Paulrud et al. (2005), Johansson et al. (2004) and Olsson & Kjällstrand (2005). The emission factor is within the IPCC (2006) interval for residential wood combustion (100-900 g/GJ).

In general, the same emission factors have been applied for 1990-2013. However, time series have been estimated for both natural gas fuelled engines and biogas fuelled engines, residential wood combustion, natural gas fuelled gas turbines[2] and waste incineration plants[2].

[2] A minor emission source.

Table 3A-4.4 CH_4 emission factors, time-series.

Year	Natural gas fuelled engines Emission factor, g per GJ	Biogas fuelled engines Emission factor, g per GJ	Residential wood combustion, g per GJ	Waste incineration g per GJ	Natural gas fuelled gas turbines, g per GJ
1990	266	239	316	0.59	1.5
1991	309	251	310	0.59	1.5
1992	359	264	304	0.59	1.5
1993	562	276	298	0.59	1.5
1994	623	289	291	0.59	1.5
1995	632	301	284	0.59	1.5
1996	616	305	274	0.59	1.5
1997	551	310	266	0.59	1.5
1998	542	314	256	0.59	1.5
1999	541	318	235	0.59	1.5
2000	537	323	222	0.59	1.5
2001	522	342	198	0.59	1.5
2002	508	360	189	0.59	1.6
2003	494	379	187	0.59	1.6
2004	479	397	184	0.51	1.7
2005	465	416	175	0.42	1.7
2006	473	434	165	0.34	1.7
2007	481	434	166	0.34	1.7
2008	481	434	157	0.34	1.7
2009	481	434	144	0.34	1.7
2010	481	434	137	0.34	1.7
2011	481	434	129	0.34	1.7
2012	481	434	123	0.34	1.7
2013	481	434	113	0.34	1.7

Table 3A-4.5 N_2O emission factors and references 2013.

Fuel group	Fuel	CRF source category	CRF source category	SNAP	Emission factor, g per GJ	Reference
SOLID	COAL	1A1a	Public electricity and heat production	0101	0.8	Elsam (2005)
				0102	1.4	IPCC (2006), Tier 3, Table 2.6, Utility source, pulverised bituminous coal, wet bottom boiler.
		1A2 a-f	Industry	03	1.5	IPCC (2006), Tier 1, Table 2-3, Manufacturing industries, coal
		1A4b i	Residential	0202	1.5	IPCC (2006), Tier 1, Table 2-5, Residential, coal
		1A4c i	Agriculture/ Forestry	0203	1.5	IPCC (2006), Tier 1, Table 2-4, Commercial, coal[1)]
	BROWN COAL BRI.	1A4b i	Residential	0202	1.5	IPCC (2006), Tier 1, Table 2-5, Residential, brown coal briquettes
	COKE OVEN COKE	1A2 a-f	Industry	03	1.5	IPCC (2006), Tier 1, Table 2-3, Industry, coke oven coke
		1A4b i	Residential	020200	1.5	IPCC (2006), Tier 1, Table 2-5, Residential, coke oven coke
	ANODIC CARBON	1A2 a-f	Industry	03	1.5	IPCC (2006), Tier 1, Table 2-3, manufacturing industries, other bituminous coal
LIQ-UID	PETROLEUM COKE	1A2a-f	Industry – other	03	0.6	IPCC (2006), Tier 1, Table 2-3, Industry, petroleum coke
	RESIDUAL OIL	1A1a	Public electricity and heat production	010101	0.3	IPCC (2006), Tier 3, Table 2-6, Utility, residual fuel oil
				010102 010103	5	Nielsen et al. (2010)
				010104	0.6	IPCC (2006), Tier 1, Table 2-2, Energy industries, residual fuel oil
				010203	0.3	IPCC (2006), Tier 3, Table 2-6, Utility, residual fuel oil
		1A1b	Petroleum refining	010306	0.6	IPCC (2006), Tier 1, Table 2-2, Energy industries, residual fuel oil
		1A2 a-f	Industry	03	5	Nielsen et al. (2010)
				Engines	0.6	IPCC (2006), Tier 1, Table 2-3, manufacturing industries and construction, residual fuel oil.
		1A4a	Commercial/ Institutional	0201	0.3	IPCC (2006), Tier 3, Table 2-10, Commercial, fuel oil boilers
		1A4b i	Residential	0202	0.6	IPCC (2006), Tier 1, Table 2-5, Residential, residual fuel oil
		1A4c i	Agriculture/ Forestry	0203	0.3	IPCC (2006), Tier 3, Table 2-10, Commercial, fuel oil boilers[1)]
	GAS OIL	1A1a	Public electricity and heat production	010101 010102 010103	0.4	IPCC (2006), Tier 3, Table 2-6, Utility, gas oil boilers
				010104	0.6	IPCC (2006), Tier 1, Table 2-2, Energy industries, gas oil
				010105	2.1	Nielsen et al. (2010)
				0102	0.4	IPCC (2006), Tier 3, Table 2-6, Utility, gas oil boilers
		1A1b	Petroleum refining	010306	0.6	IPCC (2006), Tier 1, Table 2-2, Energy industries, gas oil
		1A2 a-f	Industry	03	0.4	IPCC (2006), Tier 3, Table 2-7, Industry, gas oil boilers
				Tur-bines	0.6	IPCC (2006), Tier 1, Table 2-3, Industry, gas oil
				Engines	2.1	Nielsen et al. (2010)
		1A4a	Commercial/ Institutional	0201	0.4	IPCC (2006), Tier 3, Table 2-10, Commercial, gas oil boilers
				Engines	2.1	Nielsen et al. (2010)
		1A4b i	Residential	0202	0.6	IPCC (2006), Tier 1, Table 2-5, Residential, gas oil
		1A4c	Agriculture/ Forestry	0203	0.4	IPCC (2006), Tier 3, Table 2-10, Commercial, gas oil boilers[1)]
	KEROSENE	1A2 a-f	Industry	03	**r** 0.6	IPCC (2006), Tier 1, Table 2-3, Industry, other kerosene
		1A4a	Commercial/ Institutional	0201	**r** 0.6	IPCC (2006), Tier 1, Table 2-4,

Fuel group	Fuel	CRF source catego-ry	CRF source category	SNAP	Emission factor, g per GJ	Reference
						Commercial, other kerosene
		1A4b i	Residential	0202	**r** 0.6	IPCC (2006), Tier 1, Table 2-5, Residential, other kerosene
		1A4c i	Agriculture/ Forestry	0203	**r** 0.6	IPCC (2006), Tier 1, Table 2-4, Commercial, other kerosene [1)]
	LPG	1A1a	Public electricity and heat production	0101 0102	**r** 0.1	IPCC (2006), Tier 1, Table 2-2, Energy industries, LPG
		1A1b	Petroleum refining	010306	**r** 0.1	IPCC (2006), Tier 1, Table 2-2, Energy industries, LPG
		1A2 a-f	Industry	03	**r** 0.1	IPCC (2006), Tier 1, Table 2-3, Industry, LPG
		1A4a	Commercial/ Institutional	0201	**r** 0.1	IPCC (2006), Tier 1, Table 2-4, Commercial, LPG
		1A4b i	Residential	0202	**r** 0.1	IPCC (2006), Tier 1, Table 2-5, Residential, LPG
		1A4c i	Agriculture/ Forestry	0203	**r** 0.1	IPCC (2006), Tier 1, Table 2-5, Residential/Agricultural, LPG
	REFINERY GAS	1A1b	Petroleum refining	010304	1	Assumed equal to natural gas fuelled tur-bines. Based on Nielsen et al. (2010).
				010306	0.1	IPCC (2006), Tier 1, Table 2-2, Energy industries, refinery gas
GAS	NATURAL GAS	1A1a	Public electricity and heat production	010101 010102 010103	**r** 1	IPCC (2006), Tier 3, Table 2-6, Natural gas, Utility, boiler
				010104	1	Nielsen et al. (2010)
				010105	0.58	Nielsen et al. (2010)
				0102	**r** 1	IPCC (2006), Tier 3, Table 2-6, Natural gas, Utility, boiler
		1A1c	Oil and gas extraction	010504	1	Nielsen et al. (2010)
		1A2 a-f	Industry	03	**r** 1	IPCC (2006), Tier 3, Table 2-7, Industry, natural gas boilers
				Gas turbines	1	Nielsen et al. (2010)
				Engines	0.58	Nielsen et al. (2010)
		1A4a	Commercial/ Institutional	020100 020103	**r** 1	IPCC (2006), Tier 3, Table 2-10, Commercial, natural gas boilers
				Engines	0.58	Nielsen et al. (2010)
		1A4b i	Residential	0202	**r** 1	IPCC (2006), Tier 3, Table 2-9, Residential, natural gas boilers
				Engines	0.58	Nielsen et al. (2010)
		1A4c i	Agriculture/ Forestry	0203	**r** 1	IPCC (2006), Tier 3, Table 2-10, Commercial, natural gas boilers [1)]
				Engines	0.58	Nielsen et al. (2010)
WASTE	WASTE	1A1a	Public electricity and heat production	0101 0102	1.2	Nielsen et al. (2010)
		1A2 a-f	Industry	03	4	IPCC (2006), Tier 1, Table 2-3, Industry, wastes
		1A4a	Commercial/ Institutional	0201	4	IPCC (2006), Tier 1, Table 2-4, Commercial, municipal wastes
	INDUSTR. WASTE	1A2a-f	Industry	03	4	IPCC (2006), Tier 1, Table 2-3, Industry, industrial wastes
BIO-MASS	WOOD	1A1a	Public electricity and heat production	0101	0.8	Nielsen et al. (2010)
				0102	4	IPCC (2006), Tier 1, Table 2-2, Energy industries, wood
		1A2 a-f	Industry	03	4	IPCC (2006), Tier 1, Table 2-3, Industry, wood
		1A4a	Commercial/ Institutional	0201	4	IPCC (2006), Tier 1, Table 2-4, Commercial, wood
		1A4b i	Residential	0202	4	IPCC (2006), Tier 1, Table 2-5, Residential, wood
		1A4c i	Agriculture/ Forestry	0203	4	IPCC (2006), Tier 1, Table 2-5, Agriculture, wood
	STRAW	1A1a	Public electricity and heat production	0101	1.1	Nielsen et al. (2010)
				0102	4	IPCC (2006), Tier 1, Table 2-2, Energy industries, other primary solid biomass

Fuel group	Fuel	CRF source category	CRF source category	SNAP	Emission factor, g per GJ	Reference
		1A4b i	Residential	0202	4	IPCC (2006), Tier 1, Table 2-5, Residential, other primary solid biomass
		1A4c i	Agriculture/ Forestry	0203	4	IPCC (2006), Tier 1, Table 2-5, Agriculture, other primary solid biomass
	BIO OIL	1A1a	Public electricity and heat production	0101 0102	**r** 0.6	IPCC (2006), Tier 3, Table 2-2, Utility, biodiesels
				Engines	2.1	Assumed equal to gas oil. Based on Nielsen et al. (2010)
		1A2 a-f	Industry	03	**r** 0.6	IPCC (2006), Tier 1, Table 2-3, Industry, biodiesels
		1A4b i	Residential	0202	0.6	IPCC (2006), Tier 1, Table 2-5, Residential, biodiesels
	BIOGAS	1A1a	Public electricity and heat production	0101 0102	0.1	IPCC (2006), Tier 1, Table 2-2, Energy industries, other biogas
				Engines	1.6	Nielsen et al. (2010)
		1A2 a-f	Industry	03	0.1	IPCC (2006), Tier 1, Table 2-3, Industry, other biogas
				Engines	1.6	Nielsen et al. (2010)
		1A4a	Commercial/ Institutional	0201	0.1	IPCC (2006), Tier 1, Table 2,4, Commercial, other biogas
				Engines	1.6	Nielsen et al. (2010)
		1A4c i	Agriculture/ Forestry	0203	0.1	IPCC (2006), Tier 1, Table 2-5, Agriculture, other biogas
				Engines	1.6	Nielsen et al. (2010)
	BIO PROD GAS	1A1a	Public electricity and heat production	010105	2.7	Nielsen et al. (2010)
		1A4a	Commercial/ Institutional	020105	2.7	Nielsen et al. (2010)

1) In Denmark, plants in Agriculture/Forestry are similar to Commercial plants.

Time series have been estimated for natural gas fuelled gas turbines and refinery gas fuelled turbines. All other emission factors have been applied unchanged for 1990-2013.

Table 3A-4.6 N_2O emission factors, time-series.

Year	Natural gas fuelled gas turbines. Emission factor, g per GJ	Refinery gas fuelled gas turbines. Emission factor, g per GJ
1990	2.2	2.2
1991	2.2	2.2
1992	2.2	2.2
1993	2.2	2.2
1994	2.2	2.2
1995	2.2	2.2
1996	2.2	2.2
1997	2.2	2.2
1998	2.2	2.2
1999	2.2	2.2
2000	2.2	2.2
2001	2.0	2.0
2002	1.9	1.9
2003	1.7	1.7
2004	1.5	1.5
2005	1.4	1.4
2006	1.2	1.2
2007	1.0	1.0
2008	1.0	1.0
2009	1.0	1.0
2010	1.0	1.0
2011	1.0	1.0
2012	1.0	1.0
2013	1.0	1.0

Table 3A-4.15 Technology specific CH_4 emission factors for residential wood combustion.

Emission factor (g/GJ)	Pollutant	Emission factor, g/GJ	Reference
Old stove	CH_4	430	Methane emissions from residential biomass combustion, Paulrud et al. (2005) (SMED report, Sweden)
New stove	CH_4	215	Assumed ½ the emission factor for old stoves.
Stove according to resent Danish legislation (2008)	CH_4	125	Estimated based on the emission factor for new stoves and the emission factors for NMVOC.
Eco labelled stove	CH_4	2	Low emissions from wood burning in an ecolabelled residential boiler. Olsson & Kjällstrand (2005).
Other stove	CH_4	430	Assumed equal to old stove.
Old boilers with hot water storage	CH_4	211	Methane emissions from residential biomass combustion, Paulrud et al 2005 (SMED report, Sweden)
Old boilers without hot water storage	CH_4	256	Methane emissions from residential biomass combustion, Paulrud et al 2005 (SMED report, Sweden)
New boilers with hot water storage	CH_4	50	Emission characteristics of modern and old-type residential boilers fired with wood logs and wood pellets. Johansson et al. (2004)
New boilers without hot water storage	CH_4	50	Emission characteristics of modern and old-type residential boilers fired with wood logs and wood pellets. Johansson et al. (2004)
Pellet boilers/stoves	CH_4	3	Methane emissions from residential biomass combustion, Paulrud et al 2005 (SMED report, Sweden)

Annex 3A-5 Large point sources

Table 3A-5.1 Large point sources, 2013 (stationary combustion).

Large point sources
AffaldPlus+, Naestved Forbraendingsanlaeg
AffaldPlus+, Naestved Kraftvarmevaerk
Affaldplus+, Slagelse Forbr. and DONG Slagelse KVV
Affaldscenter aarhus - Forbraendsanlaegget
Affaldsforbraendingsanlaeg I/S REFA
Amagerforbraending
Amagervaerket
Ardagh Glass Holmegaard A/S
Asnaesvaerket
Avedoerevaerket
AVV Forbraendingsanlaeg
Bofa I/S
Centralkommunernes Transmissionsselskab F_berg
Cheminova
Dalum Papir
Danisco Grindsted
DanSteel
DTU
Energi Randers Produktion
Enstedvaerket
Esbjergvaerket
Faxe Kalk
Fjernvarme Fyn, Centrum Varmecentral
Frederikshavn Affaldskraftvarmevaerk
Frederikshavn Kraftvarmevaerk
Fynsvaerket
Grenaa Forbraending
Grenaa Kraftvarmevaerk
H.C.Oerstedsvaerket
Haderslev Kraftvarmevaerk
Haldor Topsoee
Hammel Fjernvarmeselskab
Helsingoer Kraftvarmevaerk
Herningvaerket
Hilleroed Kraftvarmevaerk
Hjoerring Varmeforsyning
Horsens Kraftvarmevaerk
I/S Faelles Forbraending
I/S Kara Affaldsforbraendingsanlaeg
I/S Kraftvarmevaerk Thisted
I/S Nordforbraending
I/S Reno Nord
I/S Reno Syd
I/S Vestforbraending
Koege Kraftvarmevaerk
Kolding Forbraendingsanlaeg TAS
Kommunekemi
Koppers
Kyndbyvaerket
L90 Affaldsforbraending
Maricogen
Masnedoevaerket
Maabjergvaerket
Nordic Sugar Nakskov
Nordic Sugar Nykoebing
Nordjyllandsvaerket
Nybro Gasbehandlingsanlaeg
Odense Kraftvarmevaerk
Oestkraft
Rensningsanlaegget Lynetten
Rockwool A/S Doense
Rockwool A/S Vamdrup
Saint-Gobain Isover A/S
Shell Raffinaderi
Silkeborg Kraftvarmevaerk

Continued
Skaerbaekvaerket
Skagen Forbraending
Soenderborg Kraftvarmevaerk
Special Waste System
Statoil Raffinaderi
Stigsnaesvaerket
Studstrupvaerket
Svanemoellevaerket
Svendborg Kraftvarmevaerk
Viborg Kraftvarme
Vordingborg Kraftvarme
Aalborg Portland
AarhusKarlshamn Denmark A/S

Table 3A-5.2 Large point sources, aggregated fuel consumption in 2013.

Year	**2013**		
nfr_id_EA	**fuel_id**	**fuel_gr_abbr**	**Sum of Fuel_TJ**
1A1a	102A	COAL	130035
	103A	SUB-BITUMINOUS	83
	107A	COKE OVEN COKE	0
	111A	WOOD	30300
	114A	WASTE	34706
	117A	STRAW	9324
	203A	RESIDUAL OIL	1292
	204A	GAS OIL	1328
	215A	BIO OIL	46
	301A	NATURAL GAS	23102
	303A	LPG	22
	309A	BIOGAS	142
1A1a Total			230381
1A1b	203A	RESIDUAL OIL	656
	204A	GAS OIL	1
	303A	LPG	0
	308A	REFINERY GAS	14751
1A1b Total			15408
1A1c	204A	GAS OIL	0
	301A	NATURAL GAS	139
1A1c Total			140
1A2a	204A	GAS OIL	0
	301A	NATURAL GAS	1222
	303A	LPG	4
1A2a Total			1226
1A2c	203A	RESIDUAL OIL	191
	204A	GAS OIL	2
	301A	NATURAL GAS	1499
	303A	LPG	1
1A2c Total			1693
1A2d	111A	WOOD	454
	204A	GAS OIL	0
	301A	NATURAL GAS	2
1A2d Total			455
1A2e	102A	COAL	1166
	107A	COKE OVEN COKE	121
	111A	WOOD	12
	203A	RESIDUAL OIL	2586
	204A	GAS OIL	18
	215A	BIO OIL	51
	301A	NATURAL GAS	55
	309A	BIOGAS	90
1A2e Total			4099
1A2f	102A	COAL	1418
	110A	PETROLEUM COKE	6014
	115A	INDUSTR. WASTES	1781
	203A	RESIDUAL OIL	186
	204A	GAS OIL	4
	215A	BIO OIL	0
	301A	NATURAL GAS	6
1A2f Total			9409
1A2g viii	101A	ANODIC CARBON	22
	102A	COAL	93
	107A	COKE OVEN COKE	400
	204A	GAS OIL	1
	301A	NATURAL GAS	1171
	303A	LPG	0
1A2g viii Total			1687
1A4a i	114A	WASTE	116
	204A	GAS OIL	0
	309A	BIOGAS	0
1A4a i Total			116
Grand Total			264613

Annex 3A-6 Adjustment of CO_2 emission

Table 3A-6.1 Adjustment of CO_2 emission (DEA, 2014a).

		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Actual Degree Days	Degree days	2857	3284	3022	3434	3148	3297	3837	3236	3217	3056
Normal Degree Days	Degree days	3379	3380	3359	3365	3366	3378	3395	3389	3375	3339
Net electricity import	PJ	25.4	-7.1	13.5	4.3	-17.4	-2.9	-55.4	-26.1	-15.6	-8.3
Actual CO_2 emission	1 000 000 tonnes	37.7	47.3	41.5	43.7	47.3	44.0	57.1	47.3	43.4	40.2
Adjusted CO_2 emission	1 000 000 tonnes	43.9	45.8	44.4	44.8	43.5	43.3	44.1	41.4	39.8	38.3
Continued		**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
Actual Degree Days	Degree days	2902	3279	3011	3150	3113	3068	2908	2807	2853	3061
Normal Degree Days	Degree days	3304	3289	3273	3271	3261	3224	3188	3136	3120	3127
Net electricity import	PJ	2.4	-2.1	-7.5	-30.8	-10.3	4.9	-25.0	-3.4	5.2	1.2
Actual CO_2 emission	1 000 000 tonnes	36.3	37.9	37.5	42.2	36.2	32.5	40.1	34.7	31.9	31.1
Adjusted CO_2 emission	1 000 000 tonnes	37.0	37.5	35.9	35.4	34.0	33.6	34.5	33.9	33.0	31.4
Continued		**2010**	**2011**	**2012**	**2013**						
Actual Degree Days	Degree days	3742	2970	3234	3207						
Normal Degree Days	Degree days	3171	3156	3166	3155						
Net electricity import	PJ	-4.1	4.7	18.8	3.9						
Actual CO2 emission	1 000 000 tonnes	31.4	26.7	23.0	25.0						
Adjusted CO2 emission	1 000 000 tonnes	30.5	27.8	27.2	25.9						

Annex 3A-7 Uncertainty estimates

Table 3A-7.1 Uncertainty estimation, approach 1, GHG

This table is available at: http://envs.au.dk/videnudveksling/luft/emissioner/supporting-documentation/greenhouse-gases-nir/

Table 3A-7.2 Uncertainty estimation, approach 1, CO_2

This table is available at: http://envs.au.dk/videnudveksling/luft/emissioner/supporting-documentation/greenhouse-gases-nir/

Table 3A-7.3 Uncertainty estimation, approach 1, CH_4

This table is available at: http://envs.au.dk/videnudveksling/luft/emissioner/supporting-documentation/greenhouse-gases-nir/

Table 3A-7.4 Uncertainty estimation, approach 1, N_2O

This table is available at: http://envs.au.dk/videnudveksling/luft/emissioner/supporting-documentation/greenhouse-gases-nir/

Table 3A-7.5 Uncertainty estimation for GHG 2013, approach 2.

This table is available at: http://envs.au.dk/videnudveksling/luft/emissioner/supporting-documentation/greenhouse-gases-nir/

Annex 3A-8 Emission inventory 2013 based on SNAP sectors

Table 3A-8.1 Emission inventory 2013 based on SNAP sectors.

SNAP	CO_2 [Gg] [1)]	CH_4 [Mg]	N_2O [Mg]
10100	0	0	0
10101	13640.77	144.34	119.47
10102	3954.35	41.52	39.79
10103	1683.1	10.31	17.08
10104	2870.05	67.17	29.91
10105	733.4	4978.83	9.89
10200	0	0	0
10201	0	0	0
10202	16.37	0.23	0.11
10203	2997.36	301.26	84.82
10204	0	0	0
10205	0	0	0
10300	0	0	0
10301	0	0	0
10302	0	0	0
10303	0	0	0
10304	102.1	3.02	1.78
10305	0	0	0
10306	847.51	15.62	1.76
10400	0	0	0
10401	0	0	0
10402	0	0	0
10403	0	0	0
10404	0	0	0
10405	0	0	0
10406	0	0	0
10407	0	0	0
10500	0	0	0
10501	0	0	0
10502	0	0	0
10503	7.91	0.14	0.14
10504	1333.69	39.57	23.28
10505	0	0	0
10506	0	0	0
20100	880.01	31.62	14.71
20101	0	0	0
20102	0	0	0
20103	18.58	3.61	0.52
20104	0	0	0
20105	65.17	382.17	1.07
20106	0	0	0
20200	5839.99	4427.25	167.55
20201	0	0	0
20202	10.39	0.6	0.19
20203	0	0	0
20204	25.14	212.92	0.26
20205	0	0	0
20300	459.92	597.97	12.31
20301	0	0	0
20302	2.4	0.62	0.09
20303	0	0	0
20304	75.31	485.98	1.17
20305	0	0	0
30100	0	0	0
30101	0	0	0
30102	0	0	0
30103	0	0	0
30104	0	0	0
30105	0	0	0
30106	1.15	0.02	0.02
30400	0	0	0
30401	0	0	0
30402	69.64	1.23	1.22
30403	0	0	0
30404	0	0	0

SNAP	CO_2 [Gg] [1)]	CH_4 [Mg]	N_2O [Mg]
30405	0	0	0
30406	0	0	0
30500	0	0	0
30501	0	0	0
30502	0	0	0
30503	0	0	0
30504	0	0	0
30505	0	0	0
30506	0	0	0
30600	0	0	0
30601	0	0	0
30602	38.04	0.67	0.67
30603	16.82	0.28	0.99
30604	45.25	1.35	0.8
30605	0	0	0
30606	0	0	0
30700	0	0	0
30701	0	0	0
30702	0	0	0
30703	23.06	2.44	0.37
30704	0	0	0
30705	0	0	0
30706	0	0	0
30800	0	0	0
30801	0	0	0
30802	0	0	0
30803	0	0	0
30804	0	0	0
30805	0	0	0
30806	0	0	0
30900	0	0	0
30901	0	0	0
30902	217.3	11.79	8.75
30903	125.59	4.71	6.22
30904	1.58	0.05	0.03
30905	0	0	0
30906	0	0	0
31000	0	0	0
31001	0	0	0
31002	0	0	0
31003	0	0	0
31004	0	0	0
31005	0	0	0
31006	0	0	0
31100	0	0	0
31101	0	0	0
31102	50.91	4.99	1.82
31103	0	0	0
31104	0	0	0
31105	0	0	0
31106	0	0	0
31200	0	0	0
31201	0	0	0
31202	0	0	0
31203	0	0	0
31204	0	0	0
31205	0	0	0
31206	0	0	0
31300	0	0	0
31301	0	0	0
31302	0	0	0
31303	0	0	0
31304	0	0	0
31305	0	0	0
31306	0	0	0
31400	0	0	0
31401	0	0	0
31402	0	0	0
31403	0	0	0

SNAP	CO_2 [Gg] [1)]	CH_4 [Mg]	N_2O [Mg]
31404	0	0	0
31405	0	0	0
31406	0	0	0
31500	0	0	0
31501	0	0	0
31502	0	0	0
31503	0	0	0
31504	0	0	0
31505	0	0	0
31506	0	0	0
31600	841.72	83.46	18.84
31601	0	0	0
31602	0	0	0
31603	0	0	0
31604	0	0	0
31605	0	0	0
31606	0	0	0
32000	55.96	0.98	0.98
32001	0	0	0
32002	64.92	5.34	27.17
32003	0	0	0
32004	0	0	0
32005	0	0	0
32006	0	0	0

[1)] Including CO_2 emission from biomass.

Annex 3A-9 EU ETS data for coal

EU ETS data are available for the years 2006-2013. Corresponding values for lower calorific value (LCV) and implied emission factor (IEF) for CO2 for 2006-2009 are shown in Figure 3A-10.1. The IEF factors include the oxidation factors.

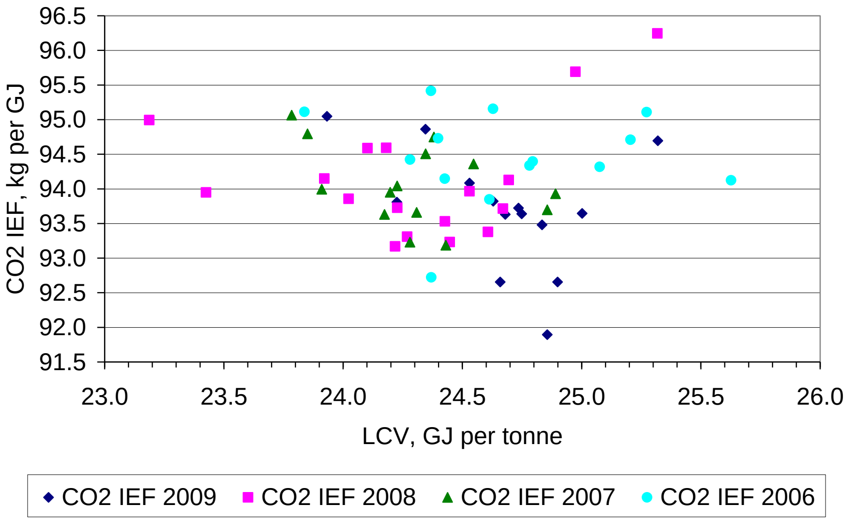

Figure 3A-9.1 EU ETS data for LCV and CO_2 IEF (including oxidation factor) for coal. Data for the years 2006-2009.

Annex 3B - Transport and other mobile sources

Annex 3B-1: Fleet data 1985-2013 for road transport (No. vehicles)

Annex 3B-2: Mileage data 1985-2013 for road transport (km)

Annex 3B-3: EU directive emission limits for road transportation vehicles

Annex 3B-4: Basis emission factors for road transportation vehicles (g/km)

Annex 3B-5: Reduction factors for road transport emission factors

Annex 3B-6: Deterioration factors for road transport emission factors

Annex 3B-7: Final fuel consumption factors (MJ/km) and emission factors (g/km) in 2013

Annex 3B-8: Fuel consumption (GJ) and emissions (tons) per vehicle category and as totals

Annex 3B-9: COPERT IV:DEA statistics fuel use ratios and mileage adjustment factors

Annex 3B-10-1: Correspondence table between actual aircraft type codes and representative aircraft types

Annex 3B-10-2: LTO no. per representative aircraft type for domestic and int. flights (Copenhagen and other airports)

Annex 3B-10-3: No. of flights between Danish airports and airports in Greenland and Faroe Islands

Annex 3B-10-4: LTO fuel consumption and emission factors per representative aircraft type for Copenhagen Airport and other airports

Annex 3B-11-1: Stock data for diesel tractors 1985-2013

Annex 3B-11-2: Stock data for gasoline tractors 1985-2013

Annex 3B-11-3: Stock data for harvesters 1985-2013

Annex 3B-11-4: Stock data for fork lifts 1985-2013

Annex 3B-11-5: Stock data for construction machinery 1985-2013

Annex 3B-11-6: Stock data for machine pools 1985-2013

Annex 3B-11-7: Stock data for household and gardening machinery 1985-2013

Annex 3B-11-8: Stock data and engine size data for recreational craft 1985-2013

Annex 3B-11-9: Basis fuel consumption and emission factors, deterioration factors and transient factors for non road working machinery and equipment and recreational craft. Stock and activity data for certain specific types of machinery

Annex 3B-12-1: Annual traffic data (no. of round trips) for Danish domestic ferries 1990-2013

Annex 3B-12-2: Ferry service, ferry name, engine year, main engine MCR (kW), engine type, specific fuel consumption (sfc), aux. engine (kW)

Annex 3B-12-3: Sailing time (single trip) for Danish domestic ferries

Annex 3B-12-4: Engine load factor (% MCR) for Danish domestic ferries

Annex 3B-12-5: Round trip shares for Danish domestic ferries

Annex 3B-13-1: Specific fuel consumption, NOx, CO, VOC, NMVOC and CH_4 emission factors (g pr kWh) per engine year for diesel ship engines

Annex 3B-13-2: S-%, SO_2 , PM and BC emission factors (g/kg fuel and g/GJ) per fuel type for diesel ship engines

Annex 3B-14: Fuel sales figures from DEA, and further processed fuel consumption data suited for the Danish inventory

Annex 3B-15-1: Emission factors for 1990 in CollectER format

Annex 3B-15-2: Emission factors for 2013 in CollectER format

Annex 3B-15-3: Emissions for 1990 in CollectER format

Annex 3B-15-4: Emissions for 2013 in CollectER format

Annex 3B-15-5: Non-exhaust emission factors, activity data and total non-exhaust emissions of TSP, PM_1, $PM_{2.5}$, BC and heavy metals in 2013

Annex 3B-16-1: Fuel consumption 1985-2013 in CRF format

Annex 3B-16-2: Emissions 1985-2013 in CRF format

Annex 3B-17: Uncertainty estimates

Annex 3B-1: Fleet data 1985-2013 for road transport (No. vehicles)

http://envs.au.dk/videnudveksling/luft/emissioner/supporting-documentation/greenhouse-gases-nir/

Annex 3B-2: Mileage data 1985-2013 for road transport (km)

http://envs.au.dk/videnudveksling/luft/emissioner/supporting-documentation/greenhouse-gases-nir/

Annex 3B-3: EU directive emission limits for road transportation vehicles

Private cars and light duty vehicles I (<1305 kg).

G prkm		EURO 1	EURO 2	EURO 3[1)]	EURO 4	EURO 5	EURO 6
Normal temp.							
CO	Gasoline	2.72	2.2	2.3	1.0	1.0	1.0
	Diesel	2.72	1.0	0.64	0.5	0.5	0.5
HC	Gasoline	-	-	0.20	0.10	0.1	0.1
NMHC	Gasoline	-	-	-	-	0.068	0.068
NO_x	Gasoline	-	-	0.15	0.08	0.06	0.06
	Diesel	-	-	0.5	0.25	0.18	0.08
HC+NO_x	Gasoline	0.97	0.5	-	-		-
	Diesel	0.97	0.7/0.9[2)]	0.56	0.30	0.23	0.17
Particulates	Diesel	0.14	0.08/0.10[2)]	0.05	0.025	0.005	0.005
Particulates (#)		-	-	-	-	-	$6x10^{11}$ [4)]
Low temp.							
CO	Gasoline	-	-	-	15	15	15
HC	Gasoline	-	-	-	1.8	1.8	1.8
Evaporation							
HC[3)]	Gasoline	2.0	2.0	2.0	2.0	2.0	2.0

[1)] Changed test procedure at normal temperatures (40 s warm-up phase omitted) and for evaporation measurements. [2)] Less stringent emission limits for direct injection diesel engines. [3)] Unit: g/test. [4)] Applicable for diesel and gasoline direct injection (GDI). $6x10^{12}$ within first three years of Euro 6 effective dates

Light duty vehicles II (1305-1760 kg)

G pr km		EURO 1	EURO 2	EURO 3[1)]	EURO 4	EURO 5	EURO 6
Normal temp.							
CO	Gasoline	5.17	4.0	4.17	1.81	1.81	1.81
	Diesel	5.17	1.25	0.80	0.63	0.63	0.63
HC	Gasoline	-	-	0.25	0.13	0.13	0.13
NMHC	Gasoline	-	-	-	-	0.9	0.9
NO_x	Gasoline	-	-	0.18	0.10	0.75	0.75
	Diesel	-	-	0.65	0.33	0.235	0.105
HC+NO_x	Gasoline	1.4	0.6	-	-	-	-
	Diesel	1.4	1.0/1.3[2)]	0.72	0.39	0.295	0.195
Particulates	Gasoline					0.005	0.005
	Diesel	0.19	0.12/0.14[2)]	0.07	0.04	0.005	0.005
Particulates (#)		-	-	-	-	-	$6x10^{11}$ [4)]
Low temp.							
CO	Gasoline	-	-	-	24	24	24
HC	Gasoline	-	-		2.7	2.7	2.7
Evaporation							
HC[3)]	Gasoline	2.0	2.0	2.0	2.0	2.0	2.0

[1)] Changed test procedure at normal temperatures (40 s warm-up phase omitted) and for evaporation measurements. [2)] Less stringent emission limits for direct injection diesel engines. [3)] Unit: g/test. [4)] Applicable for diesel and gasoline direct injection (GDI). $6x10^{12}$ within first three years of Euro 6 effective dates

Light duty vehicles III (>1760 kg).

G pr km		EURO 1	EURO 2	EURO 3[1]	EURO 4	EURO 5	EURO 6
Normal temp.							
CO	Gasoline	6.9	5.0	5.22	2.27	2.27	2.27
	Diesel	6.9	1.5	0.95	0.74	0.74	0.74
HC	Gasoline	-	-	0.29	0.16	0.16	0.16
NMHC	Gasoline					0.108	0.108
NO_x	Gasoline	-	-	0.21	0.11	0.082	0.082
	Diesel	-	-	0.78	0.39	0.28	0.125
HC+NO_x	Gasoline	1.7	0.7	-	-	-	-
	Diesel	1.7	1.2/1.6[2]	0.86	0.46	0.35	0.215
Particulates	Gasoline					0.005	0.005
	Diesel	0.25	0.17/0.20[2]	0.10	0.06	0.005	0.005
Particulates (#)		-	-	-	-	-	$6x10^{11}$ [4]
Low temp.							
CO	Gasoline	-	-	-	30	30	30
HC	Gasoline	-	-	-	3.2	3.2	3.2
Evaporation							
HC[3]	Gasoline	2.0	2.0	2.0	2.0	2.0	2.0

[1] Changed test procedure at normal temperatures (40 s warm-up phase omitted) and for evaporation measurements. [2] Less stringent emission limits for direct injection diesel engines. [3] Unit: g/test. [4] Applicable for diesel and gasoline direct injection (GDI). $6x10^{12}$ within first three years of Euro 6 effective dates.

Heavy duty diesel vehicles.

(g pr kWh)	Test[1]	EURO I 1993	EURO II 1996	EURO III 2001	EURO IV 2006	EURO V 2009	EURO VI 2014	EEV[2] 2000
CO	ECE/ESC	4.5	4.0	2.1	1.5	1.5	1.5	1.5
	ETC	-	-	(5.45)	4.0	4.0	4.0	3.0
HC	ECE/ESC	1.1	1.1	0.66	0.46	0.46	0.13	0.25
	ETC	-	-	(0.78)	0.55	0.55	0.16	0.40
NO_x	ECE/ESC	8.0	7.0	5.0	3.5	2.0	0.4	2.0
	ETC	-	-	(5.0)	3.5	2.0	0.4	2.0
Particulates[3]	ECE/ESC	0.36/0.61	0.15/0.25	0.10/0.13	0.02	0.02	0.01	0.02
	ETC	-	-	(0.16/0.21)	0.03	0.03	0.01	0.02
	ELR	-	-	0.8	0.5	0.5		0.15
NH_3	ECE/ESC						10 (ppm)	
	ETC						10 (ppm)	

[1] Test procedure: Euro 1 og Euro 2: ECE (stationary)

Euro 3: ESC (stationary) + ELR (load response)

Euro 4, Euro 5 og EEV: ESC (stationary) + ETC (transient) + ELR (load response)

[2] EEV: Emission limits for extra environmental friendly vehicles, used as a basis for economical incitaments (gas fueled vehicles).

[3] For Euro 1, Euro 2 og Euro 3 less stringent emission limits apply for small engines:

Euro 1: <85 kW
Euro 2: <0,7 l
Euro 3: <0,75 l

Annex 3B-4: Basis emission factors for road transportation vehicles (g/km)

http://envs.au.dk/videnudveksling/luft/emissioner/supporting-documentation/greenhouse-gases-nir/

Annex 3B-5: Reduction factors for road transport emission factors

http://envs.au.dk/videnudveksling/luft/emissioner/supporting-documentation/greenhouse-gases-nir/

Annex 3B-6: Deterioration factors for road transport emission factors

http://envs.au.dk/videnudveksling/luft/emissioner/supporting-documentation/greenhouse-gases-nir/

Annex 3B-7: Final fuel consumption factors (MJ/km) and emission factors (g/km) in 2013

http://envs.au.dk/videnudveksling/luft/emissioner/supporting-documentation/greenhouse-gases-nir/

Annex 3B-8: Fuel consumption (GJ) and emissions (tons) per vehicle category and as totals

http://envs.au.dk/videnudveksling/luft/emissioner/supporting-documentation/greenhouse-gases-nir/

Annex 3B-9: COPERT IV:DEA statistics fuel use ratios and mileage adjustment factors

http://envs.au.dk/videnudveksling/luft/emissioner/supporting-documentation/greenhouse-gases-nir/

Annex 3B-10-1: Correspondence table between actual aircraft type codes and representative aircraft types

http://envs.au.dk/videnudveksling/luft/emissioner/supporting-documentation/greenhouse-gases-nir/

Annex 3B-10-2: LTO no. per representative aircraft type for domestic and int. flights (Copenhagen and other airports)

http://envs.au.dk/videnudveksling/luft/emissioner/supporting-documentation/greenhouse-gases-nir/

Annex 3B-10-3: No. of flights between Danish airports and airports in Greenland and Faroe Islands

http://envs.au.dk/videnudveksling/luft/emissioner/supporting-documentation/greenhouse-gases-nir/

Annex 3B-10-4: LTO fuel consumption and emission factors per representative aircraft type for Copenhagen Airport and other airports

http://envs.au.dk/videnudveksling/luft/emissioner/supporting-documentation/greenhouse-gases-nir/

Annex 3B-11-1: Stock data for diesel tractors 1985-2013

http://envs.au.dk/videnudveksling/luft/emissioner/supporting-documentation/greenhouse-gases-nir/

Annex 3B-11-2: Stock data for gasoline tractors 1985-2013

http://envs.au.dk/videnudveksling/luft/emissioner/supporting-documentation/greenhouse-gases-nir/

Annex 3B-11-3: Stock data for harvesters 1985-2013

http://envs.au.dk/videnudveksling/luft/emissioner/supporting-documentation/greenhouse-gases-nir/

Annex 3B-11-4: Stock data for fork lifts 1985-2013

http://envs.au.dk/videnudveksling/luft/emissioner/supporting-documentation/greenhouse-gases-nir/

Annex 3B-11-5: Stock data for construction machinery 1985-2013

http://envs.au.dk/videnudveksling/luft/emissioner/supporting-documentation/greenhouse-gases-nir/

Annex 3B-11-6: Stock data for machine pools 1985-2013

http://envs.au.dk/videnudveksling/luft/emissioner/supporting-documentation/greenhouse-gases-nir/

Annex 3B-11-7: Stock data for household and gardening machinery 1985-2013

http://envs.au.dk/videnudveksling/luft/emissioner/supporting-documentation/greenhouse-gases-nir/

Annex 3B-11-8: Stock data and engine size data for recreational craft 1985-2013

http://envs.au.dk/videnudveksling/luft/emissioner/supporting-documentation/greenhouse-gases-nir/

Annex 3B-11-9: Basis fuel consumption and emission factors, deterioration factors and transient factors for non road working machinery and equipment and recreational craft. Stock and activity data for certain specific types of machinery

Basis factors for diesel fuelled non road machinery.

Engine size [P=kW]	Emission Level	NO_x	VOC	CO	N_2O [g pr kWh]	NH_3	TSP	Fuel
P<19	<1981	12,00	5,00	7,00	0,035	0,002	2,80	300
P<19	1981-1990	11,50	3,80	6,00	0,035	0,002	2,30	285
P<19	1991-Stage I	11,20	2,50	5,00	0,035	0,002	1,60	270
P<19	Stage I	11,20	2,50	5,00	0,035	0,002	1,60	270
P<19	Stage II	11,20	2,50	5,00	0,035	0,002	1,60	270
P<19	Stage IIIA	11,20	2,50	5,00	0,035	0,002	1,60	270
P<19	Stage IIIB	11,20	2,50	5,00	0,035	0,002	1,60	270
P<19	Stage IV	11,20	2,50	5,00	0,035	0,002	1,60	270
19<=P<37	<1981	18,00	2,50	6,50	0,035	0,002	2,00	300
19<=P<37	1981-1990	18,00	2,20	5,50	0,035	0,002	1,40	281
19<=P<37	1991-Stage I	9,80	1,80	4,50	0,035	0,002	1,40	262
19<=P<37	Stage I	9,80	1,80	4,50	0,035	0,002	1,40	262
19<=P<37	Stage II	6,50	0,60	2,20	0,035	0,002	0,40	262
19<=P<37	Stage IIIA	6,08	0,60	2,20	0,035	0,002	0,40	262
19<=P<37	Stage IIIB	6,08	0,60	2,20	0,035	0,002	0,40	262
19<=P<37	Stage IV	6,08	0,60	2,20	0,035	0,002	0,40	262
37<=P<56	<1981	7,70	2,40	6,00	0,035	0,002	1,80	290
37<=P<56	1981-1990	8,60	2,00	5,30	0,035	0,002	1,20	275
37<=P<56	1991-Stage I	11,50	1,50	4,50	0,035	0,002	0,80	260
37<=P<56	Stage I	7,70	0,60	2,20	0,035	0,002	0,40	260
37<=P<56	Stage II	5,50	0,40	2,20	0,035	0,002	0,20	260
37<=P<56	Stage IIIA	3,81	0,40	2,20	0,035	0,002	0,20	260
37<=P<56	Stage IIIB	3,81	0,28	2,20	0,035	0,002	0,03	260
37<=P<56	Stage IV	3,81	0,28	2,20	0,035	0,002	0,03	260
56<=P<75	<1981	7,70	2,40	6,00	0,035	0,002	1,80	290
56<=P<75	1981-1990	8,60	2,00	5,30	0,035	0,002	1,20	275
56<=P<75	1991-Stage I	11,50	1,50	4,50	0,035	0,002	0,80	260
56<=P<75	Stage I	7,70	0,60	2,20	0,035	0,002	0,40	260
56<=P<75	Stage II	5,50	0,40	2,20	0,035	0,002	0,20	260
56<=P<75	Stage IIIA	3,81	0,40	2,20	0,035	0,002	0,20	260
56<=P<75	Stage IIIB	2,97	0,28	2,20	0,035	0,002	0,03	260
56<=P<75	Stage IV	0,40	0,28	2,20	0,035	0,002	0,03	260
75<=P<130	<1981	10,50	2,00	5,00	0,035	0,002	1,40	280
75<=P<130	1981-1990	11,80	1,60	4,30	0,035	0,002	1,00	268
75<=P<130	1991-Stage I	13,30	1,20	3,50	0,035	0,002	0,40	255
75<=P<130	Stage I	8,10	0,40	1,50	0,035	0,002	0,20	255
75<=P<130	Stage II	5,20	0,30	1,50	0,035	0,002	0,20	255
75<=P<130	Stage IIIA	3,24	0,30	1,50	0,035	0,002	0,20	255
75<=P<130	Stage IIIB	2,97	0,13	1,50	0,035	0,002	0,03	255
75<=P<130	Stage IV	0,40	0,13	1,50	0,035	0,002	0,03	255
130<=P<560	<1981	17,80	1,50	2,50	0,035	0,002	0,90	270
130<=P<560	1981-1990	12,40	1,00	2,50	0,035	0,002	0,80	260
130<=P<560	1991-Stage I	11,20	0,50	2,50	0,035	0,002	0,40	250
130<=P<560	Stage I	7,60	0,30	1,50	0,035	0,002	0,20	250
130<=P<560	Stage II	5,20	0,30	1,50	0,035	0,002	0,10	250
130<=P<560	Stage IIIA	3,24	0,30	1,50	0,035	0,002	0,10	250
130<=P<560	Stage IIIB	1,80	0,13	1,50	0,035	0,002	0,03	250
130<=P<560	Stage IV	0,40	0,13	1,50	0,035	0,002	0,03	250

Basis factors for 4-stroke gasoline non road machinery.

Engine	Size code	Size classe	Emission Level	NO_x	VOC	CO	N_2O	NH_3	TSP	Fuel
		[S=ccm]					[g pr kWh]			
4-stroke	SH2	20<=S<50	<1981	2.4	33	198	0.002	0.03	0.09	496
4-stroke	SH2	20<=S<50	1981-1990	3.5	27.5	165	0.002	0.03	0.08	474
4-stroke	SH2	20<=S<50	1991-Stage I	4.7	22	132	0.002	0.03	0.06	451
4-stroke	SH2	20<=S<50	Stage I	4.7	22	132	0.002	0.03	0.06	406
4-stroke	SH2	20<=S<50	Stage II	4.7	22	132	0.002	0.03	0.06	406
4-stroke	SH3	S>=50	<1981	2.4	33	198	0.002	0.03	0.09	496
4-stroke	SH3	S>=50	1981-1990	3.5	27.5	165	0.002	0.03	0.08	474
4-stroke	SH3	S>=50	1991-Stage I	4.7	22	132	0.002	0.03	0.06	451
4-stroke	SH3	S>=50	Stage I	4.7	22	132	0.002	0.03	0.06	406
4-stroke	SH3	S>=50	Stage II	4.7	22	132	0.002	0.03	0.06	406
4-stroke	SN1	S<66	<1981	1.2	26.9	822	0.002	0.03	0.09	603
4-stroke	SN1	S<66	1981-1990	1.8	22.5	685	0.002	0.03	0.08	603
4-stroke	SN1	S<66	1991-Stage I	2.4	18	548	0.002	0.03	0.06	603
4-stroke	SN1	S<66	Stage I	4.3	16.1	411	0.002	0.03	0.06	475
4-stroke	SN1	S<66	Stage II	4.3	16.1	411	0.002	0.03	0.06	475
4-stroke	SN2	66<=S<100	<1981	2.3	10.5	822	0.002	0.03	0.09	627
4-stroke	SN2	66<=S<100	1981-1990	3.5	8.7	685	0.002	0.03	0.08	599
4-stroke	SN2	66<=S<100	1991-Stage I	4.7	7	548	0.002	0.03	0.06	570
4-stroke	SN2	66<=S<100	Stage I	4.7	7	467	0.002	0.03	0.06	450
4-stroke	SN2	66<=S<100	Stage II	4.7	7	467	0.002	0.03	0.06	450
4-stroke	SN3	100<=S<225	<1981	2.6	19.1	525	0.002	0.03	0.09	601
4-stroke	SN3	100<=S<225	1981-1990	3.8	15.9	438	0.002	0.03	0.08	573
4-stroke	SN3	100<=S<225	1991-Stage I	5.1	12.7	350	0.002	0.03	0.06	546
4-stroke	SN3	100<=S<225	Stage I	5.1	11.6	350	0.002	0.03	0.06	546
4-stroke	SN3	100<=S<225	Stage II	5.1	9.4	350	0.002	0.03	0.06	546
4-stroke	SN4	S>=225	<1981	1.3	11.1	657	0.002	0.03	0.09	539
4-stroke	SN4	S>=225	1981-1990	2	9.3	548	0.002	0.03	0.08	514
4-stroke	SN4	S>=225	1991-Stage I	2.6	7.4	438	0.002	0.03	0.06	490
4-stroke	SN4	S>=225	Stage I	2.6	7.4	438	0.002	0.03	0.06	490
4-stroke	SN4	S>=225	Stage II	2.6	7.4	438	0.002	0.03	0.06	490

Basis factors for 2-stroke gasoline non road machinery.

Engine	Size code	Size classe	Emission Level	NO_x	VOC	CO	N_2O	NH_3	TSP	Fuel
		[ccm]					[g pr kWh]			
2-stroke	SH2	20<=S<50	<1981	1	305	695	0.002	0.01	7	882
2-stroke	SH2	20<=S<50	1981-1990	1	300	579	0.002	0.01	5.3	809
2-stroke	SH2	20<=S<50	1991-Stage I	1.1	203	463	0.002	0.01	3.5	735
2-stroke	SH2	20<=S<50	Stage I	1.5	188	379	0.002	0.01	3.5	720
2-stroke	SH2	20<=S<50	Stage II	1.5	44	379	0.002	0.01	3.5	500
2-stroke	SH3	S>=50	<1981	1.1	189	510	0.002	0.01	3.6	665
2-stroke	SH3	S>=50	1981-1990	1.1	158	425	0.002	0.01	2.7	609
2-stroke	SH3	S>=50	1991-Stage I	1.2	126	340	0.002	0.01	1.8	554
2-stroke	SH3	S>=50	Stage I	2	126	340	0.002	0.01	1.8	529
2-stroke	SH3	S>=50	Stage II	1.2	64	340	0.002	0.01	1.8	500
2-stroke	SN1	S<66	<1981	0.5	155	418	0.002	0.01	2.6	652
2-stroke	SN1	S<66	1981-1990	0.5	155	418	0.002	0.01	2.6	652
2-stroke	SN1	S<66	1991-Stage I	0.5	155	418	0.002	0.01	2.6	652
2-stroke	SN1	S<66	Stage I	0.5	155	418	0.002	0.01	2.6	652
2-stroke	SN1	S<66	Stage II	0.5	155	418	0.002	0.01	2.6	652
2-stroke	SN2	66<=S<100	<1981	0.5	155	418	0.002	0.01	2.6	652
2-stroke	SN2	66<=S<100	1981-1990	0.5	155	418	0.002	0.01	2.6	652
2-stroke	SN2	66<=S<100	1991-Stage I	0.5	155	418	0.002	0.01	2.6	652
2-stroke	SN2	66<=S<100	Stage I	0.5	155	418	0.002	0.01	2.6	652
2-stroke	SN2	66<=S<100	Stage II	0.5	155	418	0.002	0.01	2.6	652
2-stroke	SN3	100<=S<225	<1981	0.5	155	418	0.002	0.01	2.6	652
2-stroke	SN3	100<=S<225	1981-1990	0.5	155	418	0.002	0.01	2.6	652
2-stroke	SN3	100<=S<225	1991-Stage I	0.5	155	418	0.002	0.01	2.6	652
2-stroke	SN3	100<=S<225	Stage I	0.5	155	418	0.002	0.01	2.6	652
2-stroke	SN3	100<=S<225	Stage II	0.5	155	418	0.002	0.01	2.6	652
2-stroke	SN4	S>=225	<1981	0.5	155	418	0.002	0.01	2.6	652
2-stroke	SN4	S>=225	1981-1990	0.5	155	418	0.002	0.01	2.6	652
2-stroke	SN4	S>=225	1991-Stage I	0.5	155	418	0.002	0.01	2.6	652
2-stroke	SN4	S>=225	Stage I	0.5	155	418	0.002	0.01	2.6	652
2-stroke	SN4	S>=225	Stage II	0.5	155	418	0.002	0.01	2.6	652

Fuel consumption and emission factors for LPG fork lifts.

NO_x	VOC	CO	NH_3	N_2O	TSP	FC
[g pr kWh]	[g pr kWh]	[g pr kWh]	[g pr kWh]	[g pr kWh]	[g pr kWh]	[g pr kWh]
19	2.2	1.5	0.003	0.05	0.07	311

Fuel consumption and emission factors for All Terrain Vehicles (ATV's).

ATV type	NO_x	VOC	CO	NH_3	N_2O	TSP	Fuel
	[g pr GJ]	[g pr GJ]	[g pr GJ]	[g pr GJ]	[g pr GJ]	[g pr GJ]	[kg pr hour]
Professional	108	1077	16306	2	2	32	1.125
Private	128	1527	22043	2	2	39	0.75

Fuel consumption and emission factors for recreational craft.

Fuel type	Vessel type	Engine	Engine type	Direktiv	Engine size	CO	VOC	N_2O	NH_3	NO_x	TSP	Fuel
					[kW]	[g pr kWh]						
Gasoline	Other boats (< 20 ft)	Out board	2-stroke	2003/44	8	202.5	45.9	0.01	0.002	2.0	10.00	791
Gasoline	Other boats (< 20 ft)	Out board	2-stroke	Konv.	8	427.0	257.0	0.01	0.002	2.0	10.00	791
Gasoline	Other boats (< 20 ft)	Out board	4-stroke	2003/44	8	202.5	24.0	0.03	0.002	7.0	0.08	426
Gasoline	Other boats (< 20 ft)	Out board	4-stroke	Konv.	8	520.0	24.0	0.03	0.002	7.0	0.08	426
Gasoline	Yawls and cabin boats	Out board	2-stroke	2003/44	20	162.0	36.5	0.01	0.002	3.0	10.00	791
Gasoline	Yawls and cabin boats	Out board	2-stroke	Konv.	20	374.0	172.0	0.01	0.002	3.0	10.00	791
Gasoline	Yawls and cabin boats	Out board	4-stroke	2003/44	20	162.0	14.0	0.03	0.002	10.0	0.08	426
Gasoline	Yawls and cabin boats	Out board	4-stroke	Konv.	20	390.0	14.0	0.03	0.002	10.0	0.08	426
Gasoline	Sailing boats (< 26 ft)	Out board	2-stroke	2003/44	10	189.0	43.0	0.01	0.002	2.0	10.00	791
Gasoline	Sailing boats (< 26 ft)	Out board	2-stroke	Konv.	10	427.0	257.0	0.01	0.002	2.0	10.00	791
Gasoline	Sailing boats (< 26 ft)	Out board	4-stroke	2003/44	10	189.0	24.0	0.03	0.002	7.0	0.08	426
Gasoline	Sailing boats (< 26 ft)	Out board	4-stroke	Konv.	10	520.0	24.0	0.03	0.002	7.0	0.08	426
Gasoline	Speed boats	In board	4-stroke	2003/44	90	141.0	10.0	0.03	0.002	12.0	0.08	426
Gasoline	Speed boats	In board	4-stroke	Konv.	90	346.0	10.0	0.03	0.002	12.0	0.08	426
Gasoline	Speed boats	Out board	2-stroke	2003/44	50	145.8	31.8	0.01	0.002	3.0	10.00	791
Gasoline	Speed boats	Out board	2-stroke	Konv.	50	374.0	172.0	0.01	0.002	3.0	10.00	791
Gasoline	Speed boats	Out board	4-stroke	2003/44	50	145.8	14.0	0.03	0.002	10.0	0.08	426
Gasoline	Speed boats	Out board	4-stroke	Konv.	50	390.0	14.0	0.03	0.002	10.0	0.08	426
Gasoline	Water scooters	Built in	2-stroke	2003/44	45	147.0	32.2	0.01	0.002	3.0	10.00	791
Gasoline	Water scooters	Built in	2-stroke	Konv.	45	374.0	172.0	0.01	0.002	3.0	10.00	791
Gasoline	Water scooters	Built in	4-stroke	2003/44	45	147.0	14.0	0.03	0.002	10.0	0.08	426
Gasoline	Water scooters	Built in	4-stroke	Konv.	45	390.0	14.0	0.03	0.002	10.0	0.08	426
Diesel	Motor boats (27-34 ft)	In board		2003/44	150	5.0	1.7	0.035	0.002	8.6	1.00	275
Diesel	Motor boats (27-34 ft)	In board		Konv.	150	5.3	2.0	0.035	0.002	8.6	1.20	275
Diesel	Motor boats (> 34 ft)	In board		2003/44	250	5.0	1.6	0.035	0.002	8.6	1.00	275
Diesel	Motor boats (> 34 ft)	In board		Konv.	250	5.3	2.0	0.035	0.002	8.6	1.20	275
Diesel	Motor boats (< 27 ft)	In board		2003/44	40	5.0	1.8	0.035	0.002	9.8	1.00	281
Diesel	Motor boats (< 27 ft)	In board		Konv.	40	5.5	2.2	0.035	0.002	18.0	1.40	281
Diesel	Motor sailors	In board		2003/44	30	5.0	1.9	0.035	0.002	9.8	1.00	281
Diesel	Motor sailors	In board		Konv.	30	5.5	2.2	0.035	0.002	18.0	1.40	281
Diesel	Sailing boats (> 26 ft)	In board		2003/44	30	5.0	1.9	0.035	0.002	9.8	1.00	281
Diesel	Sailing boats (> 26 ft)	In board		Konv.	30	5.5	2.2	0.035	0.002	18.0	1.40	281

CH_4 shares of VOC for diesel, gasoline and LPG.

Fuel type	CH_4 share of VOC
Diesel	0.024
Gasoline 4-stroke	0.034
Gasoline 2-stroke	0.07
LPG	0.05

Deterioration factors for diesel machinery.

Emission Level	NO_x	VOC	CO	TSP
<1981	0.024	0.047	0.185	0.473
1981-1990	0.024	0.047	0.185	0.473
1991-Stage I	0.024	0.047	0.185	0.473
Stage I	0.024	0.036	0.101	0.473
Stage II	0.009	0.034	0.101	0.473
Stage IIIA	0.008	0.027	0.151	0.473
Stage IIIB	0.008	0.027	0.151	0.473
Stage IV	0.008	0.027	0.151	0.473

Deterioration factors for gasoline 2-stroke machinery.

Engine	Size code	Size classe	Emission Level	NO_x	VOC	CO	TSP
2-stroke	SH2	20<=S<50	<1981	0	0.2	0.2	0
2-stroke	SH2	20<=S<50	1981-1990	0	0.2	0.2	0
2-stroke	SH2	20<=S<50	1991-Stage I	0	0.2	0.2	0
2-stroke	SH2	20<=S<50	Stage I	0	0.29	0.24	0
2-stroke	SH2	20<=S<50	Stage II	0	0.29	0.24	0
2-stroke	SH3	S>=50	<1981	-0.031	0.2	0.2	0
2-stroke	SH3	S>=50	1981-1990	-0.031	0.2	0.2	0
2-stroke	SH3	S>=50	1991-Stage I	-0.031	0.2	0.2	0
2-stroke	SH3	S>=50	Stage I	0	0.266	0.231	0
2-stroke	SH3	S>=50	Stage II	0	0.266	0.231	0
2-stroke	SN1	S<66	<1981	-0.6	0.201	0.9	1.1
2-stroke	SN1	S<66	1981-1990	-0.6	0.201	0.9	1.1
2-stroke	SN1	S<66	1991-Stage I	-0.6	0.201	0.9	1.1
2-stroke	SN1	S<66	Stage I	-0.33	0.266	1.109	5.103
2-stroke	SN1	S<66	Stage II	-0.33	0	1.109	5.103
2-stroke	SN2	66<=S<100	<1981	-0.6	0.201	0.9	1.1
2-stroke	SN2	66<=S<100	1981-1990	-0.6	0.201	0.9	1.1
2-stroke	SN2	66<=S<100	1991-Stage I	-0.6	0.201	0.9	1.1
2-stroke	SN2	66<=S<100	Stage I	-0.33	0.266	1.109	5.103
2-stroke	SN2	66<=S<100	Stage II	-0.33	0	1.109	5.103
2-stroke	SN3	100<=S<225	<1981	-0.6	0.201	0.9	1.1
2-stroke	SN3	100<=S<225	1981-1990	-0.6	0.201	0.9	1.1
2-stroke	SN3	100<=S<225	1991-Stage I	-0.6	0.201	0.9	1.1
2-stroke	SN3	100<=S<225	Stage I	-0.33	0.266	1.109	5.103
2-stroke	SN3	100<=S<225	Stage II	-0.33	0	1.109	5.103
2-stroke	SN4	S>=225	<1981	-0.6	0.201	0.9	1.1
2-stroke	SN4	S>=225	1981-1990	-0.6	0.201	0.9	1.1
2-stroke	SN4	S>=225	1991-Stage I	-0.6	0.201	0.9	1.1
2-stroke	SN4	S>=225	Stage I	-0.274	0	0.887	1.935
2-stroke	SN4	S>=225	Stage II	-0.274	0	0.887	1.935

Deterioration factors for gasoline 4-stroke machinery.

Engine	Size code	Size classe	Emission Level	NO_x	VOC	CO	TSP
4-stroke	SN1	S<66	<1981	-0.6	1.1	0.9	1.1
4-stroke	SN1	S<66	1981-1990	-0.6	1.1	0.9	1.1
4-stroke	SN1	S<66	1991-Stage I	-0.6	1.1	0.9	1.1
4-stroke	SN1	S<66	Stage I	-0.3	1.753	1.051	1.753
4-stroke	SN1	S<66	Stage II	-0.3	1.753	1.051	1.753
4-stroke	SN2	66<=S<100	<1981	-0.6	1.1	0.9	1.1
4-stroke	SN2	66<=S<100	1981-1990	-0.6	1.1	0.9	1.1
4-stroke	SN2	66<=S<100	1991-Stage I	-0.6	1.1	0.9	1.1
4-stroke	SN2	66<=S<100	Stage I	-0.3	1.753	1.051	1.753
4-stroke	SN2	66<=S<100	Stage II	-0.3	1.753	1.051	1.753
4-stroke	SN3	100<=S<225	<1981	-0.6	1.1	0.9	1.1
4-stroke	SN3	100<=S<225	1981-1990	-0.6	1.1	0.9	1.1
4-stroke	SN3	100<=S<225	1991-Stage I	-0.6	1.1	0.9	1.1
4-stroke	SN3	100<=S<225	Stage I	-0.3	1.753	1.051	1.753
4-stroke	SN3	100<=S<225	Stage II	-0.3	1.753	1.051	1.753
4-stroke	SN4	S>=225	<1981	-0.6	1.1	0.9	1.1
4-stroke	SN4	S>=225	1981-1990	-0.6	1.1	0.9	1.1
4-stroke	SN4	S>=225	1991-Stage I	-0.6	1.1	0.9	1.1
4-stroke	SN4	S>=225	Stage I	-0.599	1.095	1.307	1.095
4-stroke	SN4	S>=225	Stage II	-0.599	1.095	1.307	1.095
4-stroke	SH2	20<=S<50	<1981	0	0	0	0
4-stroke	SH2	20<=S<50	1981-1990	0	0	0	0
4-stroke	SH2	20<=S<50	1991-Stage I	0	0	0	0
4-stroke	SH2	20<=S<50	Stage I	0	0	0	0
4-stroke	SH2	20<=S<50	Stage II	0	0	0	0
4-stroke	SH3	S>=50	<1981	0	0	0	0
4-stroke	SH3	S>=50	1981-1990	0	0	0	0
4-stroke	SH3	S>=50	1991-Stage I	0	0	0	0
4-stroke	SH3	S>=50	Stage I	0	0	0	0
4-stroke	SH3	S>=50	Stage II	0	0	0	0

Transient factors for diesel machinery.

Emission Level	Load	Load factor	NO_x	VOC	CO	TSP	Fuel
<1981	High	> 0.45	0.95	1.05	1.53	1.23	1.01
1981-1990	High	> 0.45	0.95	1.05	1.53	1.23	1.01
1991-Stage I	High	> 0.45	0.95	1.05	1.53	1.23	1.01
Stage I	High	> 0.45	0.95	1.05	1.53	1.23	1.01
Stage II	High	> 0.45	0.95	1.05	1.53	1.23	1.01
Stage IIIA	High	> 0.45	1.04	1.05	1.53	1.47	1.01
Stage IIIB	High	> 0.45	1	1	1	1	1
Stage IV	High	> 0.45	1	1	1	1	1
<1981	Middle	0.25>= LF <= 0.45	1.025	1.67	2.05	1.6	1.095
1981-1990	Middle	0.25>= LF <= 0.45	1.025	1.67	2.05	1.6	1.095
1991-Stage I	Middle	0.25>= LF <= 0.45	1.025	1.67	2.05	1.6	1.095
Stage I	Middle	0.25>= LF <= 0.45	1.025	1.67	2.05	1.6	1.095
Stage II	Middle	0.25>= LF <= 0.45	1.025	1.67	2.05	1.6	1.095
Stage IIIA	Middle	0.25>= LF <= 0.45	1.125	1.67	2.05	1.92	1.095
Stage IIIB	Middle	0.25>= LF <= 0.45	1	1	1	1	1
Stage IV	Middle	0.25>= LF <= 0.45	1	1	1	1	1
<1981	Low	<0.25	1.1	2.29	2.57	1.97	1.18
1981-1990	Low	<0.25	1.1	2.29	2.57	1.97	1.18
1991-Stage I	Low	<0.25	1.1	2.29	2.57	1.97	1.18
Stage I	Low	<0.25	1.1	2.29	2.57	1.97	1.18
Stage II	Low	<0.25	1.1	2.29	2.57	1.97	1.18
Stage IIIA	Low	<0.25	1.21	2.29	2.57	2.37	1.18
Stage IIIB	Low	<0.25	1	1	1	1	1
Stage IV	Low	<0.25	1	1	1	1	1

Annual working hours, load factors and lifetimes for agricultural tractors.

Tractor type	Annual working hours	Load factor	Lifetime (yrs)
Diesel	500 (0-7 years) 500-100 (7-16 years) 100 (>16 years)	0.5	30
Gasoline (certified)	100	0.4	37
Gasoline (non certified)	50	0.4	37

Annual working hours, load factors and lifetimes for harvesters.

Annual working hours	Load factor	Lifetime (yrs)
250-100 (linear decrease 0-24 years)	0.8	25

Annual working hours, load factors and lifetime for machine pool machinery.

Tractor type	Hours pr yr	Load factor	Lifetime (yrs)
Tractors	750	0.5	7
Harvesters	100	0.8	11
Self-propelled vehicles	500	0.75	6

Operational data for other machinery types in agriculture.

Machinery type	Fuel type	Load factor	Lifetime (yrs)	Hours	Size (kW)
ATV private	Gasoline	-	6	250	-
ATV professional	Gasoline	-	8	400	-
Bedding machines	Gasoline	0.3	10	50	3
Fodder trucks	Gasoline	0.4	10	200	8
Other (gasoline)	Gasoline	0.4	10	50	5
Scrapers	Gasoline	0.3	10	50	3
Self-propelled vehicles	Diesel	0.75	15	150	60
Sweepers	Gasoline	0.3	10	50	3

Annual working hours, load factors and lifetimes for forestry machinery.

Machinery type	Hours	Load factors	Lifetime
Chippers	1200	0.5	6
Tractors (other)	100 (1990) 400 (2004)	0.5	15
Tractors (silvicultural)	800	0.5	6
Harvesters	1200	0.5	8
Forwarders	1200	0.5	8
Chain saws (forestry)	800	0.4	3

Annual working hours, load factors and lifetime for fork lifts.

Hours pr yr	Load factor	Lifetime (yrs)
1200 (>=50 kW and <=10 years old) 650 (>=50 kW and >10 years old) 650 (<50 kW)	0.27	20

Operational data for construction machinery.

Machinery type	Load factor	Lifetime	Hours	Size
Track type dozers	0.5	10	1100	140
Track type loaders	0.5	10	1100	100 (1990) 150 (2004)
Wheel loaders (0-5 tonnes)	0.5	10	1200	20
Wheel loaders (> 5,1 tonnes)	0.5	10	1200	120
Wheel type excavators	0.6	10	1200	100
Track type excavators (0-5 tonnes)	0.6	10	1100	20
Track type excavators (>5,1 tonnes)	0.6	10	1100	120
Excavators/Loaders	0.45	10	700	50
Dump trucks	0.4	10	900 (1990) 1200 (2004)	60 (1990) 180 (2004)
Mini loaders	0.5	14	700	30
Telescopic loaders	0.5	14	1000	35

Stock and operational data for other machinery types in industry.

Sector	Fuel type	Machinery type	Size (kW)	No	Load Factor	Hours
Construction machinery	Diesel	Tampers/Land rollers	30	2800	0.45	600
Construction machinery	Diesel	Generators (diesel)	45	5000	0.5	200
Construction machinery	Diesel	Kompressors (diesel)	45	5000	0.5	500
Construction machinery	Diesel	Pumps (diesel)	75	1000	0.5	5
Construction machinery	Diesel	Asphalt pavers	80	300	0.35	700
Construction machinery	Diesel	Motor graders	100	100	0.4	700
Construction machinery	Diesel	Refuse compressors	160	100	0.25	1300
Construction machinery	Gasoline	Generators (gasoline)	2.5	11000	0.4	80
Construction machinery	Gasoline	Pumps (gasoline)	4	10000	0.4	300
Construction machinery	Gasoline	Kompressors (gasoline)	4	500	0.35	15
Industry	Diesel	Refrigerating units (distribution)	8	3000	0.5	1250
Industry	Diesel	Refrigerating units (long distance)	15	3500	0.5	200
Industry	Diesel	Tractors (transport, industry)	50	3000	0.4	500
Airport GSE and other	Diesel	Airport GSE and other (light duty)	100	500	0.5	400
Airport GSE and other	Diesel	Airport GSE and other (medium duty)	125	350	0.5	300
Airport GSE and other	Diesel	Airport GSE and other (Heavy duty)	175	650	0.5	200
Building and construction	Diesel	Vibratory plates	6	3500	0.6	300
Building and construction	Diesel	Aereal lifts (diesel)	30	150	0.4	400
Building and construction	Diesel	Sweepers (diesel)	30	200	0.4	300
Building and construction	Diesel	High pressure cleaners (diesel)	30	50	0.8	500
Building and construction	Gasoline	Rammers	2.5	3000	0.4	80
Building and construction	Gasoline	Drills	3	100	0.4	10
Building and construction	Gasoline	Vibratory plates (gasoline)	4	2500	0.5	200
Building and construction	Gasoline	Cutters	4	800	0.5	50
Building and construction	Gasoline	Other (gasoline)	5	1000	0.5	40
Building and construction	Gasoline	High pressure cleaners (gasoline)	5	500	0.6	200
Building and construction	Gasoline	Sweepers (gasoline)	10	500	0.4	150
Building and construction	Gasoline	Slicers	10	100	0.7	150
Building and construction	Gasoline	Aereal lifts (gasoline)	20	50	0.4	400

Operational data for the most important types of household and gardening machinery.

Machinery type	Engine	Size (kW)	Hours	Load factor	Lifetime (yrs)
Chain saws (private)	2-stroke	2	5	0.3	10
Chain saws (professional)	2-stroke	3	270	0.4	3
Cultivators (private-large)	4-stroke	3.7	5	0.6	5
Cultivators (private-small)	4-stroke	1	5	0.6	15
Cultivators (professional)	4-stroke	7	360	0.6	8
Hedge cutters (private)	2-stroke	0.9	10	0.5	10
Hedge cutters (professional)	2-stroke	2	300	0.5	4
Lawn movers (private)	4-stroke	2.5 (2000) 3.5 (2004)	25	0.4	8
Lawn movers (professional)	4-stroke	2.5 (2000) 3.5 (2004)	250	0.4	4
Riders (private)	4-stroke	11	50	0.5	12
Riders (professional)	4-stroke	13	330	0.5	5
Shrub clearers (private)	2-stroke	1	15	0.6	10
Shrub clearers (professional)	2-stroke	2	300	0.6	4
Trimmers (private)	2-stroke	0.9	20	0.5	10
Trimmers (professional)	2-stroke	0.9	200	0.5	4

Stock and operational data for other machines in household and gardening.

Machinery type	Engine	No.	Size (kW)	Hours	Load factor	Lifetime (yrs)
Chippers	2-stroke	200	10	100	0.7	10
Garden shredders	2-stroke	500	3	20	0.7	10
Other (gasoline)	2-stroke	200	2	20	0.5	10
Suction machines	2-stroke	300	4	80	0.5	10
Wood cutters	4-stroke	100	4	15	0.5	10

Operational data for recreational craft.

Fuel type	Vessel type	Engine type	Stroke	Hours	Lifetime	Load factor
Gasoline	Other boats (<20 ft)	Out board engine	2-stroke	30	10	0.5
Gasoline	Other boats (<20 ft)	Out board engine	4-stroke	30	10	0.5
Gasoline	Yawls and cabin boats	Out board engine	2-stroke	50	10	0.5
Gasoline	Yawls and cabin boats	Out board engine	4-stroke	50	10	0.5
Gasoline	Sailing boats (<26ft)	Out board engine	2-stroke	5	10	0.5
Gasoline	Sailing boats (<26ft)	Out board engine	4-stroke	5	10	0.5
Gasoline	Speed boats	In board engine	4-stroke	75	10	0.5
Gasoline	Speed boats	Out board engine	2-stroke	50	10	0.5
Gasoline	Speed boats	Out board engine	4-stroke	50	10	0.5
Gasoline	Water scooters	Built in	2-stroke	10	10	0.5
Gasoline	Water scooters	Built in	4-stroke	10	10	0.5
Diesel	Motor boats (27-34 ft)	In board engine		150	15	0.5
Diesel	Motor boats (>34 ft)	In board engine		100	15	0.5
Diesel	Motor boats (<27 ft)	In board engine		75	15	0.5
Diesel	Motor sailors	In board engine		75	15	0.5
Diesel	Sailing boats (<26ft)	In board engine		25	15	0.5

Annex 3B-12-1: Annual traffic data (no. of round trips) for Danish domestic ferries 1990-2013

http://envs.au.dk/videnudveksling/luft/emissioner/supporting-documentation/greenhouse-gases-nir/

Annex 3B-12-2: Ferry service, ferry name, engine year, main engine MCR (kW), engine type, specific fuel consumption (sfc), aux. engine (kW)

http://envs.au.dk/videnudveksling/luft/emissioner/supporting-documentation/greenhouse-gases-nir/

Annex 3B-12-3: Sailing time (single trip) for Danish domestic ferries

http://envs.au.dk/videnudveksling/luft/emissioner/supporting-documentation/greenhouse-gases-nir/

Annex 3B-12-4: Engine load factor (% MCR) for Danish domestic ferries

http://envs.au.dk/videnudveksling/luft/emissioner/supporting-documentation/greenhouse-gases-nir/

Annex 3B-12-5: Round trip shares for Danish domestic ferries

http://envs.au.dk/videnudveksling/luft/emissioner/supporting-documentation/greenhouse-gases-nir/

Annex 3B-13-1: Specific fuel consumption, NOx, CO, VOC, NMVOC and CH_4 emission factors (g pr kWh) per engine year for diesel ship engines

http://envs.au.dk/videnudveksling/luft/emissioner/supporting-documentation/greenhouse-gases-nir/

Annex 3B-13-2: S-%, SO_2 , PM and BC emission factors (g/kg fuel and g/GJ) per fuel type for diesel ship engines

http://envs.au.dk/videnudveksling/luft/emissioner/supporting-documentation/greenhouse-gases-nir/

Annex 3B-14: Fuel sales figures from DEA, and further processed fuel consumption data suited for the Danish inventory

http://envs.au.dk/videnudveksling/luft/emissioner/supporting-documentation/greenhouse-gases-nir/

Annex 3B-15-1: Emission factors for 1990 in CollectER format

http://envs.au.dk/videnudveksling/luft/emissioner/supporting-documentation/greenhouse-gases-nir/

Annex 3B-15-2: Emission factors for 2013 in CollectER format

http://envs.au.dk/videnudveksling/luft/emissioner/supporting-documentation/greenhouse-gases-nir/

Annex 3B-15-3: Emissions for 1990 in CollectER format

http://envs.au.dk/videnudveksling/luft/emissioner/supporting-documentation/greenhouse-gases-nir/

Annex 3B-15-4: Emissions for 2013 in CollectER format

http://envs.au.dk/videnudveksling/luft/emissioner/supporting-documentation/greenhouse-gases-nir/

Annex 3B-15-5: Non-exhaust emission factors, activity data and total non-exhaust emissions of TSP, PM_1, $PM_{2.5}$, BC and heavy metals in 2013

http://envs.au.dk/videnudveksling/luft/emissioner/supporting-documentation/greenhouse-gases-nir/

Annex 3B-16-1: Fuel consumption 1985-2013 in NFR format

http://envs.au.dk/videnudveksling/luft/emissioner/supporting-documentation/greenhouse-gases-nir/

Annex 3B-16-2: Emissions 1985-2013 in NFR format

http://envs.au.dk/videnudveksling/luft/emissioner/supporting-documentation/greenhouse-gases-nir/

Annex 3B-17: Uncertainty estimates

http://envs.au.dk/videnudveksling/luft/emissioner/supporting-documentation/greenhouse-gases-nir/

Annex 3C - Industrial processes and product use

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All annexes are available online at:
http://envs.au.dk/videnudveksling/luft/emissioner/supporting-documentation/air-pollution-iir/

Annex 3D - Agriculture

List of tables and figures

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http://envs.au.dk/videnudveksling/luft/emissioner/supporting-documentation/greenhouse-gases-nir/

Table 3D-2 Number of animals allocated on subcategories for 1990-2013, 1 000 head.
http://envs.au.dk/videnudveksling/luft/emissioner/supporting-documentation/greenhouse-gases-nir/

Table 3D-3 (a-d) NH_3 emission factors for housing units, 2013.

a) **Cattle**

		Urine	Slurry	Solid manure	Deep litter manure
		TAN	TAN	Total N	Total N
Housing type		pct. loss of TAN ex animal		pct. loss of N ex animal	
Tethered	urine and solid manure	10	-	5	-
	slurry manure	-	6	-	-
Loose-housing with beds	slatted floor	-	16	-	-
	slatted floor and scrape	-	12	-	-
	solid floor	-	20	-	-
	drained floor	-	8	-	-
	solid floor with tilt and scrape	-	8	-	-
	solid floor with tilt	-	12	-	-
Deep litter	All	-	-	-	6
	solid floor	-	-	-	6
	slatted floor	-	16	-	6
	slatted floor and scrape	-	12	-	6
	solid floor and scrape	-	20	-	6
Boxes	sloping bedded floor	-	16	-	-
	slatted floor	-	16	-	-

b) **Swine**

			Urine TAN	Slurry TAN	Solid manure Total N	Deep litter Total N
	Housing type	Floor or manure type	Pct. loss of TAN ex animal		pct. loss of N ex animal	
Sows	Individual, mating and gestation	Partly slatted floor	-	13	-	-
		Full slatted floor	-	19	-	-
		Solid floor	21	-	16	-
	Group, mating and gestation	Deep litter	-	-	-	15
		Deep litter + slatted floor	-	16	-	15
		Deep litter + solid floor	-	19	-	15
		Partly slatted floor	-	16	-	-
	Farrowing crate	Full slatted floor	-	13	-	-
		Partly slatted floor	-	26	-	-
	Farrowing pen	Solid floor	20	-	15	-
		Partly slatted floor	-	22	15	-
Weaners		Full slatted floor	-	24	-	-
		Drained + partly slatted floor	-	21	-	-
		Deep litter (to-climate housings)	-	10	-	15
		Solid floor	37	-	25	-
		Deep litter	-	-	-	15
Fattening pigs		Partly slatted floor (50-75 % solid)	-	13	-	-
		Partly slatted floor (25-49% solid)	-	17	-	-
		Drained + partly slatted floor	-	21	-	-
		Full slatted floor	-	24	-	-
		Solid floor	27	-	18	-
		Deep litter, divided	-	18	-	15
		Deep litter	-	-	-	15

c) **Poultry**

			Solid manure Total N	Deep litter Total N
	Housing type	Floor or manure type	pct. loss of N ex animal	
Hens and pullets	Free-range, organic and barn	Deep pit	40	25
		Deep litter	-	28
		Manure belt	10	25
	Battery	Deep pit	12	-
		Manure belt	10	-
Broilers	Conventional	Deep litter	-	7
	Organic and barn	Deep litter	-	9
Turkeys, ducks and geese		Deep litter	-	20

d) **Other**

	Slurry TAN	Deep litter Total N
	Pct. loss of TAN ex animal	pct. loss of N ex animal
Fur animals	30-67	40
Horses, sheep and goats	-	15

Table 3D-4 NH_3 emission factors for storage units, 2013.

			Urine	Slurry	Solid manure	Deep litter	Pct. of solid manure stored in heap on field
Cattle		Total N	2	2.1	4	1	35
		TAN	2.2	3.5	-	-	-
Pigs	Sows	Total N	2	2.4	19	6.5	50
		TAN	2.2	2.9	-	-	-
	Weaners	Total N	2	2.4	19	9.8	-
		TAN	2.2	2.9	-	-	-
	Fattening pigs	Total N	2	2.4	19	9,8	75
		TAN	2.2	2.9	-	-	-
Poultry	Hens and pullets	Total N	-	2	7.5	4.8	95
	Broilers	Total N	-	-	11.5	6.8	85
	Turkeys, ducks, and geese	Total N	-	-	-	6.8, 8(Turkeys)	-
Fur animals		Total N	0	3.1	11.5	-	-
		TAN	0	3.1	-	-	-
Sheep and goats		Total N	-	-	-	4	-
Horses		Total N	-	-	-	4	-

Table 3D-5 EF for poultry for CH_4 from enteric fermentation, kg CH_4 per 100 or 1000 heads

	Number of heads	CH_4 EF
Hens	100	0.021
Pullets (consumption), 112 days	100	0.285
Pullets (hatching), 119 days	100	0.303
Broilers:		
30 days	1 000	0.011
32 days	1 000	0.012
35 days	1 000	0.013
40 days	1 000	0.015
45 days	1 000	0.017
56 days	1 000	0.021
81 days (organic)	1 000	0.075
Other poultry		
Turkeys, male	100	0.014
Turkeys, hen	100	0.007
Ducks	100	0.003
Geese	100	0.005
Pheasant, chicken	1 000	0.003
Pheasant, hen	100	0.472
Ostrich, chicken	1	0.001
Ostrich, hen	1	0.660

Table 3D-6   Parameters for winter feeding plans.

		Feeding code*	% dm*	% Crude protein*	% Raw fat*	% Raw ashes*	% Carbo-hydrates	FU/kg dm*	kg dm/day**	MJ/day	GE_{FU}
		PDIR (2002)									
Heifers:	Straw	781	85.0	4.0	1.9	4.5	89.6	0.2	33.4	571.8	
	Maize silage	593	31.0	8.7	2.2	4.2	84.9	0.9	57.5	1 009.0	
	Toasted soya	155	87.5	49.1	3.2	7.4	40.3	1.4	8.1	161.7	
	Total	-	-	-	-	-	-	-	99.0	1 742.4	25.8
Suckling cows:	Straw	781	85.0	4.0	1.9	4.5	89.6	0.2	1.6	119.1	
Period 1 (2 mth)	Toasted soya	155	87.5	49.1	3.2	7.4	40.3	1.4	3.4	49.6	
	Barley	201	85.0	11.2	2.9	2.2	83.7	1.1	1.8	29.2	
Period 2 (4 mth)	Straw	781	85.0	4.0	1.9	4.5	89.6	0.2	3.2	238.2	
	Toasted soya	155	87.5	49.1	3.2	7.4	40.3	1.4	3.0	29.1	
	Barley	202	85.0	11.2	2.9	2.2	83.7	1.1	3.2	52.0	
	Total	-	-	-	-	-	-	-	15.2	517.1	34.0
Horses:	Straw	781	85.0	4.0	1.9	4.5	89.6	0.2	4.0	58.2	
	Hay	665	85.0	12.1	2.6	7.7	77.6	0.6	3.0	44.0	
	Oat	202	86.0	12.1	5.7	2.7	79.5	0.9	2.5	40.1	
	Supplemental		86.4	15.4	4.3	6.6	73.7	1.0	1.0	15.5	
	Total	-	-	-	-	-	-	-	-	157.7	29.8
Sheep and Goats:	Straw	781	85.0	4.0	1.9	4.5	89.6	0.2	1.0	14.6	
	Toasted soya	155	87.5	49.1	3.2	7.4	40.3	1.4	0.1	1.8	
	Barley	202	85.0	11.2	2.9	2.2	83.7	1.1	0.4	6.2	
	Grass pills (dried)	707	92.0	17.0	3.1	11.0	68.9	0.6	1.0	15.7	
	Total	-	-	-	-	-	-	-	-	38.2	30.0
Summer grazing											
Grazing	Clover grass, 2 weeks old	422	18.0	22.0	4.1	9.4	64.5	1.0	1.0	18.8	
	Total	-	-	-	-	-	-	-	1.0	18.8	18.8
Swine:	Full feeding										
	Sows	-	87.1	16.1	5.2	5.5	73.2	1.2	-	64.2	17.5
	Weaners	-	87.4	18.8	5.7	5.5	70.0	1.3	-	2.1	16.5
	Fattening pigs	-	86.9	17.0	4.7	5.1	73.3	1.2	-	9.6	17.3

Table 3D-7 Energy factors used for GE.

	MJ per kg dm
$E_{Crude\ protein}$	24.237
$E_{Raw\ fat}$	34.116
$E_{Carbonhydrates}$	17.3

Table 3D-8 Feed intake 1990-2013, FU per animal per year. http://envs.au.dk/videnudveksling/luft/emissioner/supporting-documentation/greenhouse-gases-nir/

Table 3D-9 Grazing animals 1990 – 2013, number of days on grass per year. http://envs.au.dk/videnudveksling/luft/emissioner/supporting-documentation/greenhouse-gases-nir/

Table 3D-10 Average gross energy intake (GE) 1990 – 2013, MJ per head per day. http://envs.au.dk/videnudveksling/luft/emissioner/supporting-documentation/greenhouse-gases-nir/

Table 3D-11 VS daily excretion 1990 – 2013, kg dm per head per day. http://envs.au.dk/videnudveksling/luft/emissioner/supporting-documentation/greenhouse-gases-nir/

Table 3D-12 National manure management system and MCF vs. IPCC manure management system and MCF. http://envs.au.dk/videnudveksling/luft/emissioner/supporting-documentation/greenhouse-gases-nir/

Table 3D-13 Area of agricultural land, 1990 – 2013, ha. http://envs.au.dk/videnudveksling/luft/emissioner/supporting-documentation/greenhouse-gases-nir/

Table 3D-14 Above-ground residue dry matter AGDM(T) 1990-2013, kg DM per ha. http://envs.au.dk/videnudveksling/luft/emissioner/supporting-documentation/greenhouse-gases-nir/

Nitrogen leaching and Run-off

Calculations of nitrogen lost by leaching from groundwater are based on two models described in Børgesen and Grant (2003) (in Danish). The model SKEP/DAISY is a dynamic model, N-LES is an empirical model and SKEP is an up scaling model. The SKEP/DAISY calculations were done for 10 scenarios (the years 1984, 1989 and 1995-2002) and the N-LES calculations were done for an 11 year period (1990-2000). Both calculations were up scaled nationwide. The key parameters for the models were land use, nitrogen from synthetic fertilizer and manure, application practice for manure and NH_3 evaporation at application of manure (SKEP/DAISY only). The calculations were normalised to an average climate. A schematic overview of the models is seen below.

Figure 3D-1 Model calculation of nitrogen leaching from groundwater nationwide by SKEP/DAISY and N-LES.

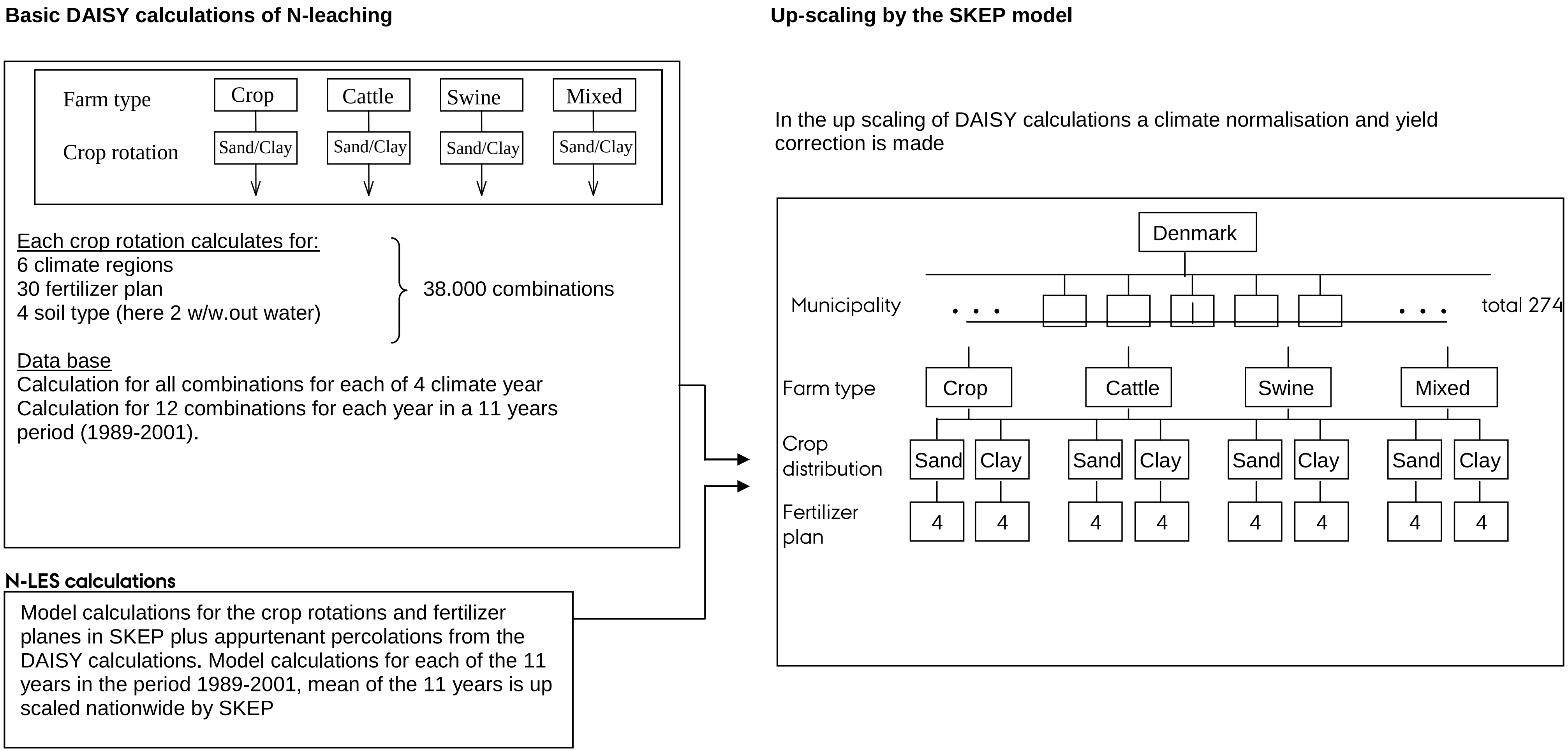

Table 3D-15 QA/QC procedure, stage I – III.

Stage I: Check of input data	Variable	Reference
Livestock production	- number of animal - slaughter data	DSt
Normative figures	- N-excretion - use of straw - amount of manure - feed intake - milk yield	DCA
Housing types	- distribution	DAAS + DAFA
Grazing days		DAAS
Crops	- land use - crop yield - crop production	DSt
Synthetic fertiliser	- N-content - fertiliser types	DAFA
N-leaching	- amount of nitrogen leached	DCE
Atmospheric deposition	- all NH_3 emission sources	DCE – NH_3 inventory
Sewage sludge and industrial waste	- Amount of sludge applied to soils	EPA + DAFA
Stage II: Check of IDA data – overall	**Emission source**	**Variable**
Recalculation	- CO_2 eqv. total emission - CH_4, N_2O, NMVOC - emission from field burning	- compared with latest submission
Time series	- CO_2 eqv. total emission - CH_4, N_2O, NMVOC - emission from field burning	- trends - jumps and dips
Stage III: Check of IDA data – specific	**Emission source**	**Variable**
CH_4	- enteric fermentation	- IEF (jumps and dips) - Ym (dairy cattle + heifer) - GE
CH_4	- manure management	- IEF (jumps and dips) - VS - biogas
N_2O	- manure management	- trends (jumps and dips) - IEF - biogas
N_2O	- synthetic fertiliser	- trends (jumps and dips) - IEF
N_2O	- animal waste applied to soil	- trends (jumps and dips) - IEF
N_2O	- N-fixing crops	- trends (jumps and dips) - IEF
N_2O	- crop residue	- trends (jumps and dips) - IEF
N_2O	- pasture, range and paddock	- trends (jumps and dips) - IEF
N_2O	- atmospheric deposition	- trends (jumps and dips) - IEF
N_2O	- N-leaching and run-off	- trends (jumps and dips) - IEF
N_2O	- sewage sludge + industrial waste	- trends (jumps and dips) - IEF
NMVOC	- crops	- trends (jumps and dips)

Annex 3E - LULUCF

List of tables

Table 3E.1 Estimation of forest percentage and forest area.

Equation	Description
$X_j = \frac{A_j}{A_{15,j}}$	The forest percentage (X) of the *j*th sample plot (SSU) is estimated as the forested area (*A*) divided by the total area of the 15 m radius sample plot ($A_{15,j}$).
$\bar{X}_Z = \frac{1}{n_Z}\sum_Z X_j R_j$	Average forest percentage ($\bar{X}$) of all inventoried plots (SSU) with forest status *Z* based on aerial photos. R_j is an indicator variable that is 1 for inventoried plots and 0 otherwise. n_Z is the number of inventoried plots identified as forest or OWL from the air photos.
$\bar{X} = \frac{1}{n}\left(\sum_{j=1}^{n} X_j R_j + N_{21}\bar{X}_1 + N_{22}\bar{X}_2\right)$	Overall average forest percentage ($\bar{\bar{X}}$). *n* is the total number of inventoried and non-inventoried sample plots. N_{21} and N_{22} is the number of non-inventoried sample plots with forest and OWL, respectively.
$A_{Forest} = \bar{\bar{X}} \cdot A_{Total}$	Total forest area. A_{Total} is the total land area, $\bar{\bar{X}}$ is the estimated forest percentage and A_{Forest} is the total forest area.

Table 3E.2 Estimation of forest area with a specific characteristic.

Equation	Description
$\bar{X}_k = \frac{\sum_{j=1}^{n} R_{jk} A_j}{\sum_{j=1}^{n} A_j}$	Proportion of the forest area with a given characteristic ($\bar{X}_k$). R_{jk} is an indicator variable which is 1 if the the forest area on the *j*'th sample plots has the *k*'th characteristic and 0 otherwise. A_j is the sample plot area and *n* is the total number of inventoried sample plots with forest cover.
$A_k = \bar{X}_k \cdot A_{Forest}$	Total area with a given characteristic (A_k). $\bar{X}_k$ is the estimated proportion of the forest area with the *k*'th characteristic and A_{Forest} is the total forest area.

Table 3E.3 Estimation of diameter-height equations.

Equation	Description
$h_{ij} = 13 + \left(\bar{h}_j - 13\right) \cdot \exp\left(\alpha_1 \cdot \left(1 - \frac{\bar{d}_j}{d_{ij}}\right) + \alpha_2 \cdot \left(\frac{1}{\bar{d}_j} - \frac{1}{d_{ij}}\right)\right)$	Site specific dh-regression for calculating height of trees not measured for height. h_{ij} and d_{ij} is the height and diameter of the i'th tree on the j'th sample plot. $\bar{h}_j$ and $\bar{d}_j$ are the average height and diameter of trees measured for height on the *j*th sample plot. α_1 and α_2 are species and growth-region specific parameters
$h_{ij} = 13 + \beta_1 \cdot \exp(-\frac{\beta_2}{d_{ij}})$	General dh-regression for calculating height of trees not measured for height. h_{ij} and d_{ij} is the height and diameter of the i'th tree on the j'th sample plot. β_1 and β_2 are species and growth-region specific parameters

Table 3E.4 Estimation of quadratic mean diameter.

Equation	Description
$g_{ij} = \frac{\pi}{4} d_{ij}^2$	Basal area (*g*) of the *i*th tree on the *j*th plot is calculated from the diameter at breast height (*d*) (1.3 m above ground) assuming a circular stem form.
$G_j = \sum_{i=1}^{m} \frac{1}{A_{c,ij}} g_{ij}$	Basal area per hectare (*G*) the jth sample plot is calculated as the scaled sum of individual tree basal areas. Basal area (*g*) of the *i*th tree on the *j*th sample plot is scaled according to the plot area ($A_{c,ij}$) of the *c*'th concentric circle (c=3,5; 10; 15 m).
$N_j = \sum_{i=1}^{m} \frac{1}{A_{c,ij}}$	Stem number per hectare (*N*) the *j*th sample plot is calculated as the scaled number of individual trees. The *i*th tree on the *j*th sample plot is scaled according to the plot area ($A_{c,ij}$) of the *c*'th concentric circle (c=3,5; 10; 15 m).
$D_{g,j} = \sqrt{\frac{4}{\pi} \frac{G_j}{N_J}}$	The mean squared diameter is calculated from the calculated basal area and stem number for each plot.

Table 3E.5 Estimation of biomass and carbon of trees.

Equation	Description
$v_{ij} = F\left(d_{ij}, h_{ij}, D_{g,j}\right)$	The volume (*v*) of the *i*'th tree on the *j*th sample plots is calculated using the existing volume functions (*F*) using the tree diameter and height and the quadratic mean diameter.
$B_{ij} = V_{ij} \cdot Density_{ij}$	Biomass (*B*) of the *i*th tree on the *j*th sample plot is estimated as the total volume (V_{Tot}) times the species specific density.
$E_{ij} = F\left(d_{ij}, h_{ij}\right)$	Expansion factor model for beech and Norway spruce
$v_{tot,ij} = B_{ij} \cdot E_{ij}$	The total above and below ground volume (v_{tot}) of the ith tree on the jth sample plot. B_{ij} is the calculated above-ground biomass of the tree and *E* is the expansion factor.
$C_{ij} = B_{ij} \cdot 0.5$	Carbon of the *i*th tree on the *j*th sample plot is calculated as the biomass (*B*) times 0.5.

Table 3E.6 Estimation of total biomass and carbon pools.

Equation	Description
$$V_{cj} = \frac{1}{A_{cj}} \sum_{i=1}^{m} R_{c,i} v_{ij}$$	Volume, biomass or carbon per hectare (*V*) of the *c*th concentric circle on the *j*th sample plot (*c*=3,5; 10; 15 m). R_c is an indicator variable that is 1 if the *i*th tree is measured on the *c*th circle and 0 otherwise. $A_{c,ij}$ is the area of the *j*th sample plot and *c*th concentric circle; *m* is the number of trees on the *jth* sample plot.
$$\overline{V}_c = \frac{\sum_{j=1}^{n} A_{cj} V_{cj}}{\sum_{j=1}^{n} A_{cj}}$$	The average area weighted volume, biomass or carbon per hectare ($\overline{V}$) of the *c*th concentric circle. $A_{c,ij}$ is the area of the *j*th sample plot and *c*th concentric circle; *n* is the number of sample plots.
$$\overline{\overline{V}} = \overline{V}_{3,5} + \overline{V}_{10} + \overline{V}_{15}$$	The overall average volume, biomass or carbon per hectare ($\overline{\overline{V}}$) is estimated as the sum of the average volume, biomass or carbon per hectare ($\overline{V}_c$) for the three concentric circles (*c*=3.5, 10 and 15)
$$V = \overline{\overline{V}} \cdot A_{Skov}$$	Total volume, biomass or carbon *V* is the overall average volume, biomass or carbon per hectare ($\overline{\overline{V}}$) times the forest area A_{Forest}.

Table 3E.7 Estimation of biomass and carbon with a given characteristic.

Equation	Description
$$V_{cj,k} = \frac{1}{A_{cj}} \sum_{i=1}^{m} R_{c,ij} R_{k,ij} v_{ij}$$	Volume, biomass or carbon per hectare (*V*) with the *k*th characteristic of the *c*th concentric circle on the *j*th sample plot (c=3,5; 10; 15 m). R_c is an indicator variable that is 1 if the *i*th tree is measured on the *c*th circle and 0 otherwise. R_k is an indicator variable that is 1 if the tree has *k*th characteristic and 0 otherwise. $A_{c,ij}$ is the area of the *j*th sample plot and *c*th concentric circle; *m* is the number of trees on the *j*th sample plot.
$$\overline{V}_{c,k} = \frac{\sum_{j=1}^{n} A_{cj} V_{cj,k}}{\sum_{j=1}^{n} A_{cj}}$$	The average area weighted volume, biomass or carbon per hectare ($\overline{V}$) with the *k*th characteristic of the cth concentric circle. $A_{c,ij}$ is the area of the *j*th sample plot and *c*th concentric circle; *m* is the number of trees on the *j*th sample plot.
$$\overline{\overline{V}}_k = \overline{V}_{3,5,k} + \overline{V}_{10,k} + \overline{V}_{15,k}$$	The overall average volume, biomass or carbon per hectare with the *k*th characteristic ($\overline{\overline{V}}$) is estimated as the sum of the average volume, biomass or carbon per hectare ($\overline{V}_{c,k}$) for the three concentric circles (*c*=3.5, 10 and 15)
$$V_k = \overline{\overline{V}}_k \cdot A_{Forest}$$	Total volume, biomass or carbon with the k^{th} characteristic (V_k) is the overall average volume, biomass or carbon per hectare ($\overline{V}_k$) times the forest area A_{Forest}.

Table 3E.8 Estimation of biomass and carbon content of dead wood.

Equation	Description
$v_{s,ij} = F\left(d_{s,ij}, h_{s,ij}, D_{g,j}\right)$	The volume (v_s) of the *i*th standing, dead tree on the *j*th sample plots is calculated using the existing volume functions (*F*) using the tree diameter and height and the squared mean diameter.
$v_{l,ij} = \frac{\pi}{4} d_{l,ij}^2 \cdot l_{l,ij}$	Volume of lying dead trees (v_l) is calculated as the length (l) and the ith tree on the jth sample plot times the cross sectional area. The cross sectional area is calculated from the mid-diameter (d_l) of the dead wood.
$B_{s,ij} = v_{s,ij} \cdot D_{ij} \cdot r_{k,ij}$ $B_{l,ij} = v_{l,ij} \cdot D_{ij} \cdot r_{k,ij}$	Biomass of the *i*th standing (B_s) or lying (B_l) tree on the jth sample plot is calculated as the volume (v_s or v_l) times the species specific density (D) and a the *k*th reduction factor according to the structural decay of the wood observed in the field.
$B_{s,tot,ij} = B_{s,ij} \cdot E_{ij}$	The total above and below ground volume ($B_{s,tot}$) of the *i*th standing, dead tree on the *j*th sample plot. v_s is the calculated biomass of the tree and E is the expansion factor.
$K_{s,ij} = B_{s,ij} \cdot 0.5$ $K_{l,ij} = B_{l,ij} \cdot 0.5$	Carbon in standing or lying dead wood (C_s or C_l) is calculated as the biomass (B_s or B_l) times 0.5.

Table 3E.9 Estimation of total biomass and carbon pools of dead wood.

Equation	Description
$V_{D,cj} = \frac{1}{A_{cj}} \sum_{i=1}^{m} R_c v_{s,ij} + R_c v_{l,ij}$	Deadwood volume, biomass or carbon pools per hectare (V_D) for the *c*th circle and the *j*th sample plot. v_s and v_l is the volume of standing and lying deadwood respectively. R_c is an indicator variable that is 1 if the tree is measured in the *c*th circle and 0 otherwise. A_C is the sample plot area of the *c*th circle. *m* is the number of trees within the *j*th sample plot.
$\overline{V}_{D,c} = \frac{\sum_{j=1}^{n} A_{cj} V_{cj}}{\sum_{j=1}^{n} A_{cj}}$	The average area weighted deadwood volume, biomass or carbon per hectare ($\overline{V}_D$) of the cth concentric circle. $A_{c,ij}$ is the area of the jth sample plot and cth concentric circle; *n* is the number of sample plots.
$\overline{\overline{V}}_D = \overline{V}_{D,3,5} + \overline{V}_{D,10} + \overline{V}_{D,15}$	The overall average deadwood volume, biomass or carbon per hectare ($\overline{\overline{V}}_D$) is estimated as the sum of the average volume, biomass or carbon per hectare ($\overline{V}_{D,c}$) for the three concentric circles (c=3.5, 10 and 15)
$V_D = \overline{\overline{V}}_D \cdot A_{Forest}$	Total deadwood volume, biomass or carbon V_D is the overall average deadwood volume, biomass or carbon per hectare ($\overline{\overline{V}}_D$) times the forest area A_{Forest}.

Table 3E.10 Estimation of forest floor carbon.

Equation	Description
$C_{floor,s,j} = Depth_j \cdot A_j \cdot B_s \cdot F_{s,j}$	Forest floor carbon ($C_{floor,s,j}$) of the *s*th species, on the *j*th plot with an area of *A*. B_s is the species specific forest floor density and *F* is the fraction of species *s*.
$C_{floor,j} = \sum_{s=1}^{k} C_{floor,s,j}$	Total forest floor carbon on the jth plot.
$C_{floor} = \frac{\sum_{j=1}^{n} C_{floor,j}}{\sum_{j=1}^{n} A_j} \cdot A_{Forest}$	Total forest floor carbon is estimated as the area weighted average forest floor carbon content times the total forest area.

Table 3E.11 Hectares grown in the different areas of Denmark.

	Denmark	Copenhagen area	Bornholm	Zealand	Funen	Southern Jutland	Eastern Jutland	Western Jutland	Northern Jutland
Winter wheat	743911	14984	14941	159521	86704	121584	122810	79914	143452
Spring wheat	13753	583	375	3862	582	2694	1764	1768	2125
Rye	51336	4017	80	4816	2753	9409	9384	7422	13454
Winter barley	142560	2459	2691	16869	13665	30254	32248	21518	22856
Spring barley	425510	6614	4091	97731	30227	86358	41749	96536	62203
Oat	41907	1835	538	2924	1724	9889	4850	7908	12239
Triticale and other cereals for maturity	50192	385	409	4276	1736	10185	8734	11705	12763
Pulses for maturity	10349	80	44	2318	680	1540	1544	2448	1695
Potatoes for seed	5189	43	0	513	146	1260	173	2488	567
Potatoes for starch production	16637	0	0	0	68	3944	412	8793	3420
Potatoes for consumption	16312	493	19	1600	986	4719	1027	5485	1984
Sugar beet for sugar production	39074	35	0	38571	438	9	13	0	8
Sugar bean for feeding	4118	67	40	162	133	987	470	1231	1028
Winter rape	163436	6456	2054	38341	22824	25266	28691	14552	25253
Spring rape	1372	73	0	584	42	103	201	35	333
Lin seed	90	1	0	1	4	1	2	82	0
Other industrial seed	823	21	1	537	23	88	84	45	24
Grass and other seeds for seed production	66655	1200	1818	26276	13326	4904	7561	6670	4901
Lucerne	6405	67	87	763	820	3009	493	737	428
Green maize for silage	172168	981	1893	6349	10023	69325	12591	37600	33407
Green cereals for silage	62845	722	210	1747	927	18213	4138	16546	20344
Other green feeding stuff	26	0	0	0	0	0	3	24	0
Grass and clover fields in rotation	320914	9798	2939	22024	11361	99547	32764	72147	70334
Vegetables in fields	8043	349	24	2106	1502	514	1608	1497	444
Green peas for consumption	2677	51	0	2159	334	31	32	40	32
Flowers and other ornamentals	92	4	0	39	17	7	2	23	0
Apples	1684	60	5	562	746	73	141	34	64
Pears	357	19	1	125	163	18	21	7	5
Strawberries	1137	47	3	369	208	161	164	89	98
Cherries	1743	47	0	1051	619	8	4	1	11
Black currant	1935	91	1	472	672	211	363	16	110
Other fruits and berries	927	29	6	263	377	124	88	18	24
Nurseries	1521	87	0	154	342	347	172	331	88
Permanent grass outside rotation	199859	10533	1021	28762	12429	47085	23693	32442	43894
Set-a-side with grass	9874	504	164	2155	715	1407	938	1919	2072

Continued

Christmas trees	19521	402	67	2697	2618	2802	4607	2764	3566
Other crops	16569	610	49	1893	986	3048	2143	4041	3799
Without crops	24866	707	514	5090	2044	5487	3908	3253	3863
Total agricultural area	2646400	64451	34083	477685	222964	564612	349589	442128	490888
Green houses	490	28	1	90	272	18	59	13	10

Table 3E.12 Crop yield from Statistics Denmark in 2010 distributed regions, Hhg crop ha^{-1}.

	Denmark	Copenhagen and North Zealand	Bornholm	Zealand	Funen	Southern Jutland	Eastern Jutland	Western Jutland	North-ern Jutland
Winter wheat	66.6	70.3	65.2	73.9	72	66.5	69.3	59	57.2
Spring wheat	46.2	45.6	41.3	46.9	35.4	47.7	45.4	44.6	48.5
Rye	48.9	54.8	44.4	55.4	66.2	48.3	48.3	43.3	45.5
Triticale	48.6	49.2	43.8	58.7	56.4	46	50.4	48.8	46.3
Winter barley	54.3	52.5	57.1	63.1	62.3	55.6	56.7	45.3	46.4
Spring barley	51	47.3	50.7	56.7	51.7	49.3	51.5	47.4	49.7
Oat and mixed cereals	48.1	50.4	48	48.1	49.6	47.6	46.7	46.1	50.3
Winter rape	34.9	33.6	39.9	38	37.7	35.1	33.2	30.9	31.8
Spring rape	22.7	26.1	..	18.2	37.6	32.4	25.9	20.1	23.9
Pulses for maturity	32.3	30.8	30.9	28	34.4	32.1	36.2	31.8	35.8
Straw, gathered	32.8	33.9	33.1	37	36.5	31.9	34.5	28.6	29.8
Potatoes for seed	282	275	..	275	275	275	300	299	238
Potatoes for starch production	413	..	..	..	410	408	450	403	442
Potatoes for consumption	340	406	420	414	289	327	314	348	311
Sugar beet for sugar production	614	583	..	615	583	583	583	583	583
Sugar bean for feeding	666	656	703	656	524	654	655	644	727
Lucerne	514	516	706	486	532	533	469	463	496
Green maize for silage	354	468	445	479	317	360	359	332	344
Green cereals for silage	174	199	241	202	169	187	164	165	167
Grass and clover fields in rotation	438	403	459	404	449	449	453	447	419
Permanent grass outside rotation	158	163	142	170	187	159	152	152	146
Secondary grass crop yields	44	51	24	26	31	51	38	44	46

Table 3E.13 Area input format for Eastern Jutland to C-TOOL in 2010. FK represent the soil type (Color Code (Farve Kode))

Region	AFG07_txt	time	FK1	FK2	FK3	FK4	FK5	FK6	FK7	SUM
Eastern Jutland	Set-a-side with grass	2010	120	17	373	208	32	2	186	938
Eastern Jutland	Pulses for maturity	2010	456	75	539	419	45	0	9	1544
Eastern Jutland	Sugar bean for feeding	2010	67	14	279	78	5	0	27	470
Eastern Jutland	Vegetables in fields	2010	279	40	945	254	1	0	120	1640
Eastern Jutland	Grass and other seeds for seed production	2010	566	188	3274	2812	441	7	273	7561
Eastern Jutland	Grass and clover fields in rotation	2010	3801	391	15947	6729	1096	32	4770	32767
Eastern Jutland	Oat	2010	804	56	2309	1278	135	8	259	4850
Eastern Jutland	Lin seed	2010	1	0	1	0	0	0	0	2
Eastern Jutland	Strawberries	2010	4	0	99	55	3	0	4	164
Eastern Jutland	Potatoes	2010	245	97	917	254	3	0	97	1612
Eastern Jutland	Green cereals for silage	2010	622	117	2011	775	96	0	518	4138
Eastern Jutland	Lucerne	2010	6	0	327	127	17	0	16	493
Eastern Jutland	Green maize for silage	2010	1900	262	7863	1839	221	11	495	12591
Eastern Jutland	Rye	2010	3253	391	4062	1115	35	0	527	9384
Eastern Jutland	Sugar beet for sugar production	2010	0	0	0	13	0	0	0	13
Eastern Jutland	Triticale and other cereals for maturity	2010	1261	162	4449	1165	126	18	444	7625
Eastern Jutland	Winter barley	2010	2250	203	17101	10283	1240	35	1114	32226
Eastern Jutland	Winter wheat	2010	4591	1207	55394	46819	8213	311	6275	122810
Eastern Jutland	Winter rape	2010	1490	230	15092	9827	1229	27	796	28691
Eastern Jutland	Spring barley	2010	4567	744	20270	12210	1557	16	2385	41749
Eastern Jutland	Spring wheat	2010	30	0	756	591	43	0	344	1764
Eastern Jutland	Spring rape	2010	39	0	79	109	18	0	39	285
Eastern Jutland	Other crops	2010	880	0	4426	565	24	0	156	6051
Eastern Jutland	Permanent grass outside rotation	2010	4101	701	8855	3284	617	54	6068	23682

Table 3E.14 Average annual temperatures for Denmark, 1977-2012, °C.

Year	Average	Year	Average
1977	7.675464	2000	9.175
1978	7.675464	2001	8.158333
1979	7.675464	2002	9.208333
1980	7.2	2003	8.708333
1981	7.15	2004	8.733333
1982	7.975	2005	8.783333
1983	8.375	2006	9.358333
1984	7.891667	2007	9.416667
1985	6.5	2008	9.366667
1986	6.933333	2009	8.775
1987	6.55	2010	6.908333
1988	8.475	2011	8.916667
1989	9.175	2012	8.275
1990	9.233333	2013	8.325
1991	8.108333		
1992	8.958333		
1993	7.558333		
1994	8.608333		
1995	8.183333		
1996	6.833333		
1997	8.5		
1998	8.2		
1999	8.85		

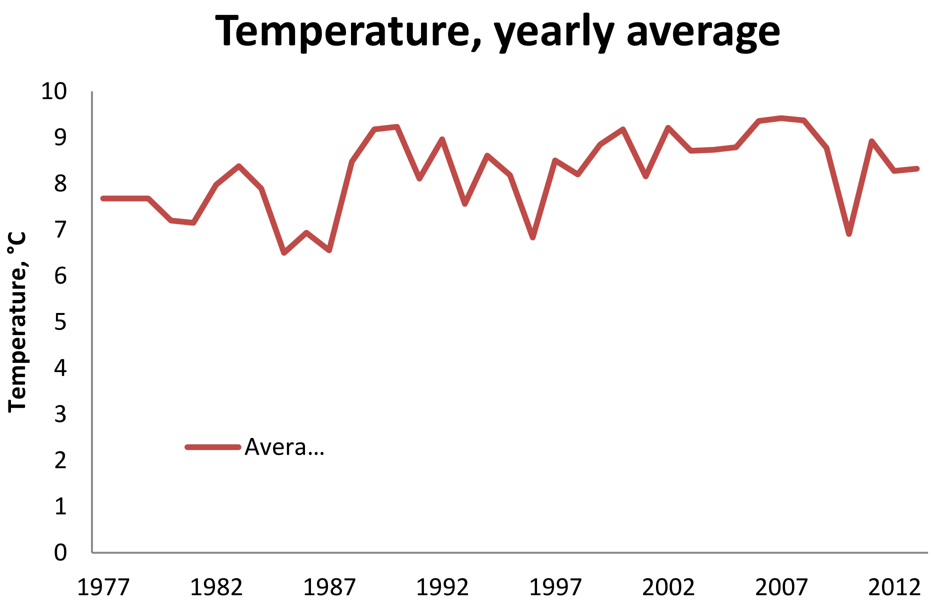

Figure 3E.1 Average annual temperatures for Denmark, 1977-2013, °C.

Annex 3F - Waste

Annex 3F-1 Emissions from the waste sector, 1990-2013

Table 3F-1.1 Emissions for the waste sector, Gg CO_2 equivalents.

		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
5.A. Solid waste disposal	CH_4	1,774	1,775	1,755	1,736	1,652	1,556	1,511	1,421	1,343	1,354
5.B. Biological treatment of solid waste	CH_4	35	38	42	46	49	47	54	63	66	76
5.B. Biological treatment of solid waste	N_2O	12	14	15	17	18	22	24	28	57	104
5.C. Incineration and open burning of waste	CH_4	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
5.C. Incineration and open burning of waste	N_2O	0.19	0.19	0.19	0.20	0.20	0.21	0.20	0.20	0.20	0.21
5.D. Waste water treatment and dis-charge	CH_4	99	100	100	100	101	102	103	105	105	106
5.D. Waste water treatment and dis-charge	N_2O	101	98	87	104	110	104	87	82	84	81
5.E. Other	CO_2	18	18	19	18	18	20	20	19	18	19
5.E. Other	CH_4	0.32	1.98	2.12	1.91	1.92	2.17	2.20	2.06	1.88	2.00
5. Waste	total	2,040	2,045	2,020	2,022	1,949	1,853	1,802	1,719	1,675	1,742
Continued		2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
5.A. Solid waste disposal	CH_4	1276	1327	1247	1264	1132	1099	1137	1084	1049	1003
5.B. Biological treatment of solid waste	CH_4	81	76	85	88	81	85	91	100	92	100
5.B. Biological treatment of solid waste	N_2O	154	148	230	224	60	60	71	88	87	98
5.C. Incineration and open burning of waste	CH_4	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02
5.C. Incineration and open burning of waste	N_2O	0.21	0.21	0.22	0.22	0.22	0.23	0.26	0.27	0.27	0.28
5.D. Waste water treatment and dis-charge	CH_4	107	107	107	108	108	109	109	109	109	110
5.D. Waste water treatment and dis-charge	N_2O	87	81	93	74	73	81	70	81	94	70
5.E. Other	CO_2	18	18	18	19	18	18	19	19	21	21
5.E. Other	CH_4	1.98	1.98	1.98	1.98	1.98	1.98	1.98	1.98	1.98	1.98
5. Waste	total	1,725	1,760	1,782	1,780	1,473	1,454	1,498	1,484	1,455	1,405
Continued		2010	2011	2012	2013						
5.A. Solid waste disposal	CH_4	931	925	879	844						
5.B. Biological treatment of solid waste	CH_4	77	97	89	126						
5.B. Biological treatment of solid waste	N_2O	75	95	87	123						
5.C. Incineration and open burning of waste	CH_4	0.02	0.02	0.02	0.02						
5.C. Incineration and open burning of waste	N_2O	0.28	0.26	0.26	0.26						
5.D. Waste water treatment and dis-charge	CH_4	111	111	112	113						
5.D. Waste water treatment and dis-charge	N_2O	73	77	70	74						
5.E. Other	CO_2	18	18	16	16						
5.E. Other	CH_4	1.99	2.04	1.83	1.80						
5. Waste	total	1,287	1,325	1,255	1,298						

Annex 3F-2 Solid Waste Disposal on Land, 6A

The following Table 3F-2.1 shows the total waste production in Denmark, divided after means of handling. (DEPA, 1996a, 1998a, 1999a, 2001a, 2001b, 2002a, 2004a, 2004b, 2005a, 2006a, 2006b, 2008, 2010, 2011a, 2013)

Table 3F-2.1 All nationally produced waste categorised after handling method, collected for the ISAG database 1994-2009 and 2013.

Year	Recycled	Combusted	Landfilled, total waste		Landfilled, organic waste		Special treatment	Temporary storage	Total
	Gg	Gg	Gg	%	Gg	%	Gg	Gg	Gg
1994	6,157	2,216	2,630	24	811	7	102	0	11,105
1995	7,046	2,306	1,969	17	776	7	145	0	11,466
1996	7,787	2,507	2,524	20	808	6	95	0	12,912
1997	8,046	2,622	2,103	16	699	5	86	0	12,857
1998	7,542	2,740	1,868	15	699	6	84	0	12,233
1999	7,815	2,929	1,552	13	674	5	17	0	12,313
2000	8,461	3,064	1,489	11	601	5	17	0	13,031
2001	8,101	3,221	1,317	10	362	3	20	109	12,768
2002	8,382	3,344	1,194	9	265	2	22	163	13,105
2003	8,218	3,287	981	8	194	2	20	108	12,614
2004	8,746	3,437	1,024	8	161	1	16	136	13,359
2005	9,545	3,473	983	7	147	1	18	191	14,210
2006	10,768	3,489	1,002	6	164	1	19	181	15,459
2007	10,480	3,584	984	6	186	1	20	167	15,235
2008	10,725	3,590	1,072	7	156	1	21	167	15,575
2009	9,536	3,386	779	6	109	1	18	152	13,872
2010	8,028	3,390	2,203	16	207	1	115	60	13,795
2011	7,439	3,354	2,428	18	323	2	200	81	13,377
2012	7,916	3,204	2,276	17	256	2	167	65	13,758
2013	9,559	3,141	2,310	14	229	1	120	207	16,299

* Data from the new waste reporting system, i.e. 2010-2013, is subject to increased uncertainty and still undergoing quality control by the Danish EPA.

Table 3F-2.2 presents the annual net emission of methane generated from the amount of landfilled waste and deducted the recovered methane and the oxidised methane; calculated using the FOD model.

Table 3F-2.2 Annual amounts of deposited waste, gross methane emission, recovered methane collected for biogas production, oxidised methane in the top layer and resulting net emission for the Danish SWDS.

Year	Landfilled waste	Gross methane	Recovered methane	Methane oxidised in the top layers	Net methane emission	
	Gg	Gg CH_4	Gg CH_4	Gg CH_4	Gg CH_4	Gg CO_2 eq
1990	3,190	79.4	0.5	7.9	71.0	1,774
1991	3,050	79.6	0.7	7.9	71.0	1,775
1992	2,910	79.4	1.5	7.8	70.2	1,755
1993	2,770	78.9	1.8	7.7	69.4	1,736
1994	2,630	78.1	4.7	7.3	66.1	1,652
1995	1,969	76.8	7.6	6.9	62.2	1,556
1996	2,524	75.5	8.3	6.7	60.4	1,511
1997	2,103	74.5	11.4	6.3	56.8	1,421
1998	1,868	73.2	13.5	6.0	53.7	1,343
1999	1,552	71.9	11.7	6.0	54.2	1,354
2000	1,489	68.0	11.3	5.7	51.0	1,276
2001	1,317	69.2	10.2	5.9	53.1	1,327
2002	1,194	66.9	11.4	5.5	49.9	1,247
2003	981	64.3	8.1	5.6	50.5	1,264
2004	1,024	61.6	11.3	5.0	45.3	1,132
2005	983	58.8	9.9	4.9	44.0	1,099
2006	1,002	56.1	5.6	5.1	45.5	1,137
2007	984	53.7	5.5	4.8	43.4	1,084
2008	1,072	51.6	5.0	4.7	41.9	1,049
2009	779	49.3	4.8	4.5	40.1	1,003
2010	2,203	47.1	5.7	4.1	37.2	931
2011	2,428	45.0	3.9	4.1	37.0	925
2012	2,276	43.3	4.2	3.9	35.1	879
2013	2,310	41.4	3.9	3.8	33.8	844

Tables 3F-2.3 presents activity data for Solid Waste Disposal on Land allocated according to 18 defined waste types classified according to their content of degradable organic matter, DOC_i, half-life time, $t_{½}$.

As presented, the basis year of the FOD model is the year 1940. For a detailed description of back-calculation of the time series from the New waste data system (2010-2012) to 1960, the reader is referred to Thomsen and Hjelgaard (2015).

Table 3F-2.3 Annual amounts of deposited inert and decomposable waste allocated according to 18 identified waste types characterised according to their DOC_i and decomposition rate quantified by their half-life times, $t_{½}$.(cf. Table 7.2.2 in the main report).

Year	1940	1941	1942	1943	1944	1945	1946	1947	1948	1949
Food	72	72	72	72	72	72	72	72	72	72
Paper and cardboard	116	116	116	116	116	116	116	116	116	116
Wood	95	95	95	95	95	95	95	95	95	95
Plastic*	16	16	16	16	16	16	16	16	16	16
Textile, fur and leather	3	3	3	3	3	3	3	3	3	3
Biodegradable garden waste	86	86	86	86	86	86	86	86	86	86
Chemicals, inert*	4	4	4	4	4	4	4	4	4	4
Electric & Hazardous*	0	0	0	0	0	0	0	0	0	0
Glass*	23	23	23	23	23	23	23	23	23	23
Metal*	83	83	83	83	83	83	83	83	83	83
Scrap vehicles*	54	54	54	54	54	54	54	54	54	54
Demolition	146	146	146	146	146	146	146	146	146	146
Soil & Stone*	240	240	240	240	240	240	240	240	240	240
Particulate matter and dust*	17	17	17	17	17	17	17	17	17	17
Sludge, inert*	56	56	56	56	56	56	56	56	56	56
Sludge, degradable	131	131	131	131	131	131	131	131	131	131
Ash & Slag*	150	150	150	150	150	150	150	150	150	150
Other not combustible waste*	354	354	354	354	354	354	354	354	354	354
Total, [Gg]	1,645	1,645	1,645	1,645	1,645	1,645	1,645	1,645	1,645	1,645
Total inert, [Gg]	998	998	998	998	998	998	998	998	998	998
Year	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959
Food	72	72	72	72	72	72	72	72	72	72
Paper and cardboard	116	116	116	116	116	116	116	116	116	116
Wood	95	95	95	95	95	95	95	95	95	95
Plastic*	16	16	16	16	16	16	16	16	16	16
Textile, fur and leather	3	3	3	3	3	3	3	3	3	3
Biodegradable garden waste	86	86	86	86	86	86	86	86	86	86
Chemicals, inert*	4	4	4	4	4	4	4	4	4	4
Electric & Hazardous*	0	0	0	0	0	0	0	0	0	0
Glass*	23	23	23	23	23	23	23	23	23	23
Metal*	83	83	83	83	83	83	83	83	83	83
Scrap vehicles*	54	54	54	54	54	54	54	54	54	54
Demolition	146	146	146	146	146	146	146	146	146	146
Soil & Stone*	240	240	240	240	240	240	240	240	240	240
Particulate matter and dust*	17	17	17	17	17	17	17	17	17	17
Sludge, inert*	56	56	56	56	56	56	56	56	56	56
Sludge, degradable	131	131	131	131	131	131	131	131	131	131
Ash & Slag*	150	150	150	150	150	150	150	150	150	150
Other not combustible waste*	354	354	354	354	354	354	354	354	354	354
Total, [Gg]	1,645	1,645	1,645	1,645	1,645	1,645	1,645	1,645	1,645	1,645
Total inert, [Gg]	998	998	998	998	998	998	998	998	998	998

Continued										
Year	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969
Food	72	72	72	72	72	72	72	72	72	72
Paper and cardboard	116	116	116	116	116	116	116	116	116	116
Wood	95	95	95	95	95	95	95	95	95	95
Plastic*	16	16	16	16	16	16	16	16	16	16
Textile, fur and leather	3	3	3	3	3	3	3	3	3	3
Biodegradable garden waste	86	86	86	86	86	86	86	86	86	86
Chemicals, inert*	4	4	4	4	4	4	4	4	4	4
Electric & Hazardous*	0	0	0	0	0	0	0	0	0	0
Glass*	23	23	23	23	23	23	23	23	23	23
Metal*	83	83	83	83	83	83	83	83	83	83
Scrap vehicles*	54	54	54	54	54	54	54	54	54	54
Demolition	146	146	146	146	146	146	146	146	146	146
Soil & Stone*	240	240	240	240	240	240	240	240	240	240
Particulate matter and dust*	17	17	17	17	17	17	17	17	17	17
Sludge, inert*	56	56	56	56	56	56	56	56	56	56
Sludge, degradable	131	131	131	131	131	131	131	131	131	131
Ash & Slag*	150	150	150	150	150	150	150	150	150	150
Other not combustible waste*	354	354	354	354	354	354	354	354	354	354
Total, [Gg]	1,645	1,645	1,645	1,645	1,645	1,645	1,645	1,645	1,645	1,645
Total inert, [Gg]	998	998	998	998	998	998	998	998	998	998
Year	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979
Food	72	78	85	91	98	104	111	117	124	131
Paper and cardboard	116	126	137	147	158	168	179	189	200	210
Wood	95	103	112	120	129	138	146	155	163	172
Plastic*	16	17	19	20	22	23	25	26	28	29
Textile, fur and leather	3	3	3	3	4	4	4	4	4	5
Biodegradable garden waste	86	94	101	109	117	125	132	140	148	156
Chemicals, inert*	4	4	5	5	5	6	6	6	7	7
Electric & Hazardous*	0	0	0	0	0	0	0	0	0	1
Glass*	23	25	27	29	31	33	36	38	40	42
Metal*	83	91	98	106	114	121	129	136	144	151
Scrap vehicles*	54	59	64	69	74	78	83	88	93	98
Demolition	146	159	172	186	199	212	225	239	252	265
Soil & Stone*	240	262	284	306	328	350	372	393	415	437
Particulate matter and dust*	17	18	20	21	23	24	26	27	29	30
Sludge, inert*	56	62	67	72	77	82	87	92	97	103
Sludge, degradable	131	143	155	167	179	191	203	215	227	239
Ash & Slag*	150	164	177	191	205	218	232	246	259	273
Other not combustible waste*	354	386	418	450	482	514	547	579	611	643
Total, [Gg]	1,645	1,795	1,945	2,094	2,244	2,393	2,543	2,692	2,842	2,992
Total inert, [Gg]	998	1,088	1,179	1,270	1,360	1,451	1,542	1,632	1,723	1,814
Year	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
Food	137	144	150	157	163	170	157	145	133	122
Paper and cardboard	221	231	242	252	263	273	253	234	215	197
Wood	181	189	198	207	215	224	220	216	211	207
Plastic*	31	32	33	35	36	38	36	33	31	29
Textile, fur and leather	5	5	5	6	6	6	6	6	5	5
Biodegradable garden waste	164	171	179	187	195	203	188	174	161	148
Chemicals, inert*	8	8	8	9	9	9	9	9	8	8
Electric & Hazardous*	1	1	1	1	1	1	1	1	1	1
Glass*	44	46	48	50	52	54	51	47	44	40
Metal*	159	167	174	182	189	197	195	193	191	188
Scrap vehicles*	103	108	113	118	123	127	123	118	114	109

Continued										
Demolition	278	292	305	318	332	345	332	320	308	295
Soil & Stone*	459	481	503	525	546	568	548	527	507	487
Particulate matter and dust*	32	33	35	36	38	39	38	36	35	34
Sludge, inert*	108	113	118	123	128	133	124	115	107	99
Sludge, degradable	251	263	275	287	299	311	289	268	248	229
Ash & Slag*	287	300	314	328	341	355	383	408	431	450
Other not combustible waste*	675	707	740	772	804	836	797	758	720	683
Total, [Gg]	3,141	3,291	3,440	3,590	3,739	3,889	3,749	3,609	3,469	3,330
Total inert, [Gg]	1,905	1,995	2,086	2,177	2,267	2,358	2,303	2,246	2,187	2,126
Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Food	112	102	92	83	74	52	62	48	40	30
Paper and cardboard	180	164	148	134	120	84	101	78	64	49
Wood	201	196	190	184	178	261	183	183	239	272
Plastic*	27	25	23	21	20	14	18	14	12	10
Textile, fur and leather	5	5	5	4	4	3	4	3	3	2
Biodegradable garden waste	136	124	113	102	92	65	79	62	51	40
Chemicals, inert*	8	7	7	7	6	5	6	5	4	4
Electric & Hazardous*	1	1	0	0	0	0	0	0	0	0
Glass*	37	34	31	29	26	19	23	18	15	12
Metal*	184	181	176	172	167	128	168	143	129	110
Scrap vehicles*	105	100	95	91	86	64	83	69	61	51
Demolition	283	270	258	246	233	175	224	186	166	138
Soil & Stone*	466	446	425	405	384	309	404	304	368	370
Particulate matter and dust*	32	31	29	28	26	0	0	0	0	1
Sludge, inert*	91	83	76	69	63	44	54	43	36	28
Sludge, degradable	211	193	176	160	110	136	155	138	136	144
Ash & Slag*	466	479	489	496	650	145	715	483	216	16
Other not combustible waste*	646	610	575	540	391	465	245	325	327	278
Total, [Gg]	3,190	3,050	2,910	2,770	2,630	1,969	2,524	2,103	1,868	1,552
Total inert, [Gg]	2,062	1,996	1,928	1,858	1,820	1,193	1,715	1,404	1,169	878
Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Food	26	21	17	9	5	5	6	6	3	1
Paper and cardboard	43	34	28	15	7	8	10	9	6	1
Wood	255	78	18	4	2	3	5	23	5	2
Plastic*	9	7	6	5	5	5	4	4	4	3
Textile, fur and leather	2	2	2	1	1	1	1	2	1	1
Biodegradable garden waste	35	29	24	13	7	7	10	10	7	2
Chemicals, inert*	4	3	3	2	2	1	1	3	2	1
Electric & Hazardous*	1	1	4	103	84	84	90	108	126	7
Glass*	11	9	7	6	5	5	4	4	4	2
Metal*	107	97	90	75	80	78	81	81	90	66
Scrap vehicles*	49	72	67	40	26	49	47	10	7	72
Demolition	132	117	106	87	91	87	89	87	95	69
Soil & Stone*	271	327	307	171	234	174	158	155	201	203
Particulate matter and dust*	0	1	1	0	0	0	0	2	0	0
Sludge, inert*	25	21	17	13	12	11	10	8	8	5
Sludge, degradable	107	81	71	65	49	38	43	49	39	32
Ash & Slag*	9	15	42	64	51	34	39	52	164	46
Other not combustible waste*	403	403	386	308	364	396	402	372	310	264
Total, [Gg]	1,489	1,317	1,194	981	1,024	983	1,002	984	1072	779
Total inert, [Gg]	888	955	929	787	863	836	837	799	916	670
Year	2010	2011	2012	2013						
Food	1	1	1	1						
Paper and cardboard	3	3	2	4						

Continued				
Wood	11	19	12	9
Plastic*	7	8	10	5
Textile, fur and leather	4	4	3	4
Biodegradable garden waste	0	31	7	8
Chemicals, inert*	1	1	0	0
Electric & Hazardous*	0	0	2	0
Glass*	6	5	3	4
Metal*	180	156	133	124
Scrap vehicles*	21	17	2	0
Demolition	164	239	213	194
Soil & Stone*	1676	1774	1762	1851
Particulate matter and dust*	3	5	25	9
Sludge, inert*	3	10	11	9
Sludge, degradable	24	25	17	9
Ash & Slag*	52	44	18	36
Other not combustible waste*	47	85	56	42
Total, [Gg]	2,203	2,428	2,276	2,310
Total inert, [Gg]	1,997	2,105	2,020	2,080

*Waste types characterised as inert, i.e. $DOC_i = 0$

** The reason for the seemingly increased amounts of waste deposited at landfills is due to the fact that only a part of the fraction soil and stones were included in the old ISAG waste statistics, while none is included in the new waste data system as may be observed from Table 3F-2.2 (DEPA, 2013). The DEPA report on waste statistics for 2011 (2013) does however include a separate accounting of the soil and stones. In the NIR all waste fraction deposited at landfills are included (Thomsen and Hjelgaard, 2015)

Table 3F.2.4 shows the change in reported European waste codes in the reporting years 2014 and 2015; allocated according to 18 characterised waste types. The change reflects the implementation of the new reporting procedures subject to ad hoc quality assurance by the Danish EPA.

Table 3F.2.4 European waste codes allocated according to 18 characterised waste types of which 11 are inert waste types are marked**.

EWC-Code	EWC-Description	Reporting year 2012-2014 (inventory data for the time range 2010-2012)	Reporting Year 2015 (Inventory data for the year 2013)
1	**WASTES RESULTING FROM EXPLORATION, MINING,QUARRYING, AND PHYSICAL AND CHEMICAL TREATMENT OF MINERALS**		
01 01	**waste from mineral excavation**		
01 01 01	waste from mineral metalliferous excavation	Metal**	Metal**
01 01 02	waste from mineral non-metalliferous excavation		
01 03	**wastes from physical and chemical processing of metalliferous miner-als**		
01 03 04*	acid-generating tailings from processing of sulphide ore		
01 03 05*	other tailings containing dangerous substances	Metal**	Metal**
01 03 06	tailings other than those mentioned in 01 03 04 and 01 03 05	Metal**	Metal**
01 03 07*	other wastes containing dangerous substances from physical and chemical processing of metalliferous minerals		
01 03 08	dusty and powdery wastes other than those mentioned in 01 03 07		
01 03 09	red mud from alumina production other than the wastes mentioned in 01 03 07		
01 03 99	wastes not otherwise specified	Metal**	Metal**
01 04	**wastes from physical and chemical processing of non-metalliferous minerals**		
01 04 07*	wastes containing dangerous substances from physical and chemical pro-cessing of non-metalliferous minerals		
01 04 08	waste gravel and crushed rocks other than those mentioned in 01 04 07	Soil & Stone**	Soil & Stone**
01 04 09	waste sand and clays		
01 04 10	dusty and powdery wastes other than those mentioned in 01 04 07		
01 04 11	wastes from potash and rock-salt processing other than those mentioned in 01 04 07		
01 04 12	tailings and other wastes from washing and cleaning of minerals other than those mentioned in 01 04 07 and 01 04 11		
01 04 13	wastes from stone cutting and sawing other thant hose mentioned in 01 04 07		
01 04 99	wastes not otherwise specified	Soil & Stone**	Soil & Stone**
01 05	**drilling muds and other drilling wastes**		
01 05 04	fresh-water drilling muds and wastes	Soil & Stone**	Soil & Stone**
01 05 05*	oil-containing drilling muds and wastes		
01 05 06*	drilling muds and other drilling wastes containing dangerous substances		
01 05 07	barite-containing drilling muds and wastes other than those mentioned in 01 05 05 and 01 05 06		
01 05 08	chloride-containing drilling muds and wastes other than those mentioned in 01 05 05 and 01 05 06		
01 05 99	wastes not otherwise specified	Soil & Stone**	Soil & Stone**
2	**WASTES FROM AGRICULTURE, HORTICULTURE, AQUACULTURE, FORESTRY, HUNTING AND FISHING, FOOD PREPARATION AND PRO-CESSING**		
02 01	**Wastes from agriculture, horticulture, aquaculture, forestry, hunting and fishing**		
02 01 01	sludges from washing and cleaning	Sludge, degradable	Sludge, degradable
02 01 02	animal-tissue waste		
02 01 03	plant-tissue waste		
02 01 04	waste plastics (except packaging)	Plastic**	Plastic**
02 01 06	animal faeces, urine and manure (including spoiled straw), effluent, collected separately and treated off-site	Sludge, degradable	Sludge, degradable
02 01 07	waste from forestry	Wood	Wood
02 01 08*	agrochemical waste containing dangerous substances	Sludge, degradable	Sludge, degradable
02 01 09	agrochemical waste other than those mentioned in 02 01 08	Sludge, degradable	Sludge, degradable
02 01 10	waste metal	Metal**	Metal**
02 01 99	wastes not otherwise specified	Sludge, degradable	Sludge, degradable

02 02	**wastes from the preparation and processing of meat, fish and other foods of animal origin**		
02 02 01	sludges from washing and cleaning		
02 02 02	animal-tissue waste		
02 02 03	materials unsuitable for consumption or processing	Food	Food
02 02 04	sludges from on-site effluent treatment		
02 02 99	waste not otherwise specified	Food	Food
02 03	**wastes from fruit, vegetables, cereals, edible oils, cocoa, coffee, tea and tabacco preparation and processing; conserve production; yeast and yeast extract production, molasses preparation and fermentation**	Ash & Slag	Ash & Slag
02 03 01	sludges from washing, cleaning, peeling, centrifuging and separation		
02 03 02	waste from preserving agents		
02 03 03	wastes from solvent extraction		
02 03 04	materials unsuitable for consumption or processing	Food	Food
02 03 05	aludges from on-site effluent treatment		
02 03 99	wastes not otherwise specified	Food	Food
02 04	**wastes from sugar processing**	Ash & Slag	Ash & Slag
02 04 01	soil from cleaning and washing beet		
02 04 02	off-specification calcium carbonate		
02 04 03	sludges from on-site effluent treatment		
02 04 99	wastes not otherwise specified		
02 05	**wastes from the diary products industry**	Sludge, degradable	Sludge, degradable
02 05 01	materials unsuitable for consumption or processing		
02 05 02	sludges from on-site effluent treatment		
02 05 99	wastes not otherwise specified		
02 06	**wastes from the baking and confectionery industry**	Food	Food
02 06 01	materials unsuitable for consumption or processing	Food	Food
02 06 02	wastes from preserving agents		
02 06 03	sludges from on-site effluent treatment		
02 06 99	wastes not otherwise specified	Food	Food
02 07	**wastes from the production of alcoholic and non-alcoholic beverages (except coffee, tea and cocoa)**	Sludge, degradable	Sludge, degradable
02 07 01	wastes from washing, cleaning and mechanical reduction of raw materials		
02 07 02	wastes from spirits distillation	Sludge, degradable	Sludge, degradable
02 07 03	wastes from chemical treatment		
02 07 04	materials unsuitable for consumption or processing		
02 07 05	sludges from on-site effluent treatment		
02 07 99	wastes not otherwise specified	Sludge, degradable	Sludge, degradable
3	**WASTES FROM WOOD PROCESSING AND THE PRODUCTION OF PANELS AND FURNITURE, PULP, PAPER AND CARDBOARD**		
03 01	**wastes from wood processing and the production of panels and furniture**	Other not combustible waste	Other not combustible waste
03 01 01	waste bark and cork		
03 01 04*	sawdust, shavings, cuttings, wood, particle board and veneer containing dangerous substances		
03 01 05	sawdust, shavings, cuttings, wood, particle board and veneer other than those mentioned in 03 01 04	Wood	Wood
03 01 99	wastes not otherwise specified	Wood	Wood
03 02	**wastes from wood preservation**	Sludge, degradable	Sludge, degradable
03 02 01*	non-halogenated organic wood preservatives		
03 02 02*	organochlorinated wood preservatives		
03 02 03*	organometallic wood preservatives		
03 02 04*	inorganic wood preservatives		
03 02 05*	other wood preservatives containing dangerous substances		
03 02 99	wood preservatives not otherwise specified		
03 03	**wastes from pulp, paper and cardboard production and processing**		
03 03 01	waste bark and wood	Wood	Wood
03 03 02	green liquor sludge (from recovery og cooking liquor)		
03 03 05	de-inking sludges from paper recycling	Sludge, degradable	Sludge, degradable

03 03 07	mechanically separated rejects from pulping of waste paper and cardboard		
03 03 08	wastes from sorting of paper and cardboard destined for recycling		
03 03 09	lime mud waste		
03 03 10	fibre rejects, fibre-, filler- and coating-sludges from mechanical separation		
03 03 11	sludges from on-site effluent treatment other than those mentioned in 03 03 10	Sludge, degradable	Sludge, degradable
03 03 99	wastes not otherwise specified	Wood	Wood
4	**WASTES FROM THE LEATHER, FUR AND TEXTILE INDUSTRIES**		
04 01	**wastes from the leather and fur industry**		
04 01 01	fleshings and lime split wastes		
04 01 02	liming waste		
04 01 03*	degreasing wastes containing solvents without a liquid phase		
04 01 04	tanning liquor containing chromium		
04 01 05	tanning liquor free of chromium		
04 01 06	sludges, in particular from on-site effluent treatment containing chromium		Particulate matter and dust**
04 01 07	sludges, in particular from on-site effluent treatment free of chromium		
04 01 08	waste tanned leather (blue sheetings, shavings, cuttings, buffing dust) containing chromium	Textile, fur and leather	Textile, fur and leather
04 01 09	wastes from dressing and finishing		
04 01 99	wastes not otherwise specified		
04 02	**wastes from the textile industry**		
04 02 09	wastes from composite materials (impregnated textile, elastomes, plastomer)		
04 02 10	organic matter from natural products (for example grease, wax)		
04 02 14*	wastes from finishing containing organic solvents		
04 02 15	wastes from finishing other than those mentioned in 04 02 14		
04 02 16*	dyestuffs and pigments containing dangerous substances		
04 02 17	dyestuffs and pigments other than those mentioned in 04 02 16		
04 02 19*	sludges from on-site effluent treatment containing dangerous substances		
04 02 20	sludges from on-site effluent treatment other than those mentioned in 04 02 19	Sludge, degradable	Sludge, degradable
04 02 21	wastes from unprocessed textile fibres		
04 02 22	wastes from processed textile fibres		
04 02 99	wastes not otherwise specified		
5	**WASTES FROM PETROLEUM REFINING, NATURAL GAS PURIFICATION AND PYROLYTIC TREATMENT OF COAL**		
05 01	**wastes from petroleum refining**		
05 01 02*	desalter sludges		
05 01 03*	tank bottom sludges		
05 01 04*	acid alkyl sludges		
05 01 05*	oil spills		
05 01 06*	oily sludges from maintenance operations of the plant or equipment		
05 01 07*	acid tars		
05 01 08*	other tars		
05 01 09*	sludges from on-site effluent treatment containing dangerous substances		
05 01 10	sludges from on-site effluent treatment other than those mentioned in 05 01 09		
05 01 11*	wastes from cleaning of fuels with bases		
05 01 12*	oil containing acids		
05 01 13	boiler feedwater sludges		
05 01 14	wastes from cooling columns		
05 01 15*	spent filter clays		
05 01 16	sulphur-containing wastes from petroleum desulphurisation		
05 01 17	bitumen		
05 01 99	wastes not otherwise specified		
05 06	**wastes from the pyrolytic treatment of coal**		
05 06 01*	acid tars		

05 06 03*	other tars		
05 06 04	wastes from cooling columns		
05 06 99	wastes not otherwise specified		
05 07	**wastes from natural gas purification and transportation**		
05 07 01*	wastes containing mercury		
05 07 02	wastes containing sulphur		
05 07 99	wastes not otherwise specified		
6	**WASTES FROM INORGANIC CHEMICAL PROCESSES**		
06 01	**wastes from the manufacture, formulation, supply and use (MFSU) of acids**	Food	Demolition**
06 01 01*	sulphuric acid and sulphurous acid		
06 01 02*	hydrochloric acid		
06 01 03*	hydrochloric acid		
06 01 04*	phosphoric and phosphorous acid		
06 01 05*	nitric acid and nitrous acid		
06 01 06*	other acids		
06 01 99	wastes not otherwise specified		
06 02	**wastes from the MFSU of bases**		
06 02 01*	calcuim hydroxide		
06 02 03*	ammonium hydroxide		
06 02 04*	sodium and potassium hydroxide	Chemicals, inert**	Chemicals, inert**
06 02 05*	other bases		
06 02 99	wastes not otherwise specified		
06 03	**wastes from the MFSU of salts and their solutions and metallic oxides**		
06 03 11*	solid salts and solutions containing cyanides		
06 03 13*	solid salts and solutions containing heavy metals	Chemicals, inert**	Chemicals, inert**
06 03 14	solid salts and solutions other than those mentioned in 06 03 11 and 06 03 13		
06 03 15*	metallic oxides containing heavy metals		
06 03 16	metallic oxides other than those mentioned in 06 03 15		
06 03 99	wastes not otherwise specified		
06 04	**metal-containing wastes other than those mentioned in 06 03**		
06 04 03*	wastes containing arsenic		
06 04 04*	wastes containing mercury		
06 04 05*	wastes containing other heavy metals	Chemicals, inert**	Chemicals, inert**
06 04 99	wastes not otherwise specified		
06 05	**sludges from on-site effluent treatment**		
06 05 02*	sludges from on-site effluent treatment containing dangerous substances		
06 05 03	sludges from on-site effluent treatment other than those mentioned in 06 05 02	Sludge, degradable	Sludge, degradable
06 06	**wastes from the MFSU of sulphur chemicals, sulphur chemical processes and desulphurisation processes**		
06 06 02*	wastes containing dangerous sulphides		
06 06 03	wastes containing sulphides other than those mentioned in 06 06 02		
06 06 99	wastes not otherwise specified		
06 07	**wastes from the MFSU of halogens and halogen chemical processes**		
06 07 01*	wastes containing asbestos from electrolysis		
06 07 02*	activated carbon from chlorine production		
06 07 03*	barium sulphate sludge containing mercury		
06 07 04*	solutions and acids, for example contact acid		
06 07 99	wastes not otherwise specified		
06 08	**wastes from the MFSU of silicon and silicon derivatives**		
06 08 02*	waste containing dangerous silicones		
06 08 99	wastes not otherwise specified	Chemicals, inert**	Chemicals, inert**
06 09	**wastes from the MSFU of phosphorous chemicals and phosphorous chemical processes**		
06 09 02	phosphorous slag		

06 09 03*	calcium-based reaction wastes containing or contaminated with dangerous substances		
06 09 04	calcium-based reaction wastes other than those mentioned in 06 09 03		
06 09 99	wastes not otherwise specified		Chemicals, inert**
06 10	**wastes from the MFSU of nitrogen chemicals, nitrogen chemical processes and fertiliser manufacture**		
06 10 02*	wastes containing dangerous substances		
06 10 99	wastes not otherwise specified		
06 11	**wastes from the manufacture of inorganic pigments and opacificiers**		
06 11 01	calcium-based reaction wastes from titanium dioxide production		
06 11 99	wastes not otherwise specified		
06 13	**wastes from inorganic chemical processes not otherwise specified**		
06 13 01*	inorganic plant protection products, wood-preserving agents and other biocides.		
06 13 02*	spent activated carbon (except 06 07 02)		
06 13 03	carbon black		
06 13 04*	wastes from asbestos processing		
06 13 05*	soot		
06 13 99	wastes not otherwise specified		
7	**WASTES FROM ORGANIC CHEMICAL PROCESSES**		
07 01	**wastes from the manufacture, formulation, supply anduse (MFSU) of basic organic chemicals**		
07 01 01*	aqueous washing liquids and mother liquors		
07 01 03*	organic halogenated solvents, washing liquids and mother liquors		
07 01 04*	other organic solvents, washing liquids and mother liquors		
07 01 07*	halogenated still bottoms and reaction residues		
07 01 08*	other still bottoms and reaction residues		
07 01 09*	halogenated filter cakes and spent absorbents		
07 01 10*	other filter cakes and spent absorbents	Sludge, inert	Sludge, inert
07 01 11*	sludges from on-site effluent treatment containing dangerous substances		
07 01 12	sludges from on-site effluent treatment other than those mentioned in 07 01 11		
07 01 99	wastes not otherwise specified	Sludge, degradable	Sludge, degradable
07 02	**wastes from the MFSU of plastics, synthetic rubber and man-made fibres**		
07 02 01*	aqueous washing liquids and mother liquors		
07 02 03*	organic halogenated solvents, washing liquids and mother liquors		
07 02 04*	other organic solvents, washing liquids and mother liquors		
07 02 07*	halogenated still bottoms and reaction residues		
07 02 08*	other still bottoms and reaction residues		
07 02 09*	halogenated filter cakes and spent absorbents		
07 02 10*	other filter cakes and spent absorbents		
07 02 11*	sludges from on-site effluent treatment containing dangerous substances		
07 02 12	sludges from on-site effluent treatment other than those mentioned in 07 02 11		
07 02 13	waste plastic		Plastic**
07 02 14*	wastes from additives containing dangerous substances		
07 02 15	wastes from additives other than those mentioned in 07 02 14	Sludge, degradable	Sludge, degradable
07 02 16*	waste containing dangerous silicones		
07 02 17	waste containing silicones other than those mentionned in 07 02 16		
07 02 99	wastes not otherwise specified	Plastic**	Plastic**
07 03	**wastes from the MFSU of organic dyes and pigments (except 06 11)**		
07 03 01*	aqueous washing liquids and mother liquors		
07 03 03*	organic halogenated solvents, washing liquids and mother liquors		
07 03 04*	other organic solvents, washing liquids and mother liquors		
07 03 07*	halogenated still bottoms and reaction residues		
07 03 08*	other still bottoms and reaction residues		
07 03 09*	halogenated filter cakes and spent absorbents		

07 03 10*	other filter cakes and spent absorbents		
07 03 11*	sludges from on-site effluent treatment containing dangerous substances		
07 03 12	sludges from on-site effluent treatment other than those mentioned in 07 03 11		
07 03 99	wastes not otherwise specified	Sludge, degradable	Sludge, degradable
07 04	**wastes from the MFSU of organic plant protection products (except 02 01 08 and 02 01 09), wood preserving agents (except 0302) and other biocides**		
07 04 01*	aqueous washing liquids and mother liquors		
07 04 03*	organic halogenated solvents, washing liquids and mother liquors		
07 04 04*	other organic solvents, washing liquids and mother liquors		
07 04 07*	halogenated still bottoms and reaction residues		
07 04 08*	other still bottoms and reaction residues		
07 04 09*	halogenated filter cakes and spent absorbents		
07 04 10*	other filter cakes and spent absorbents		
07 04 11*	sludges from on-site effluent treatment containing dangerous substances		
07 04 12	sludges from on-site effluent treatment other than those mentioned in 07 04 11		
07 04 13*	solid wastes containing dangerous substances		
07 04 99	wastes not otherwise specified		
07 05	**wastes from the MFSU of pharmaceuticals**		
07 05 01*	aqueous washing liquids and mother liquors		
07 05 03*	organic halogenated solvents, washing liquids and mother liquors	Sludge, degradable	Sludge, degradable
07 05 04*	other organic solvents, washing liquids and mother liquors		
07 05 07*	halogenated still bottoms and reaction residues		
07 05 08*	other still bottoms and reaction residues		
07 05 09*	halogenated filter cakes and spent absorbents		
07 05 10*	other filter cakes and spent absorbents		
07 05 11*	sludges from on-site effluent treatment containing dangerous substances		
07 05 12	sludges from on-site effluent treatment other than those mentioned in 07 05 11		
07 05 13*	solid wastes containing dangerous substances		
07 05 14	solid wastes other than those mentioned in 07 05 13		
07 05 99	wastes not otherwise specified		
07 06	**wastes from the MFSU of fats, grease, soaps, detergents, disinfectants and cosmetics**		
07 06 01*	aqueous washing liquids and mother liquors		
07 06 03*	organic halogenated solvents, washing liquids and mother liquors		
07 06 04*	other organic solvents, washing liquids and mother liquors		
07 06 07*	halogenated still bottoms and reaction residues		
07 06 08*	other still bottoms and reaction residues		
07 06 09*	halogenated filter cakes and spent absorbents		
07 06 10*	other filter cakes and spent absorbents		
07 06 11*	sludges from on-site effluent treatment containing dangerous substances		
07 06 12	sludges from on-site effluent treatment other than those mentioned in 07 06 11		
07 06 99	wastes not otherwise specified	Sludge, degradable	Sludge, degradable
07 07	**wastes from the MFSU of fine chemicals and chemical products not otherwise specified**		
07 07 01*	aqueous washing liquids and mother liquors		
07 07 03*	organic halogenated solvents, washing liquids and mother liquors		
07 07 04*	other organic solvents, washing liquids and mother liquors		
07 07 07*	halogenated still bottoms and reaction residues		
07 07 08*	other still bottoms and reaction residues		
07 07 09*	halogenated filter cakes and spent absorbents		
07 07 10*	other filter cakes and spent absorbents		
07 07 11*	sludges from on-site effluent treatment containing dangerous substances		
07 07 12	sludges from on-site effluent treatment other than those mentioned in 07 07 11		

07 07 99	wastes not otherwise specified		
8	**WASTES FROM THE MANUFACTURE, FORMULATION, SUPPLY AND USE (MFSU) OF COATINGS (PAINTS, VARNISHES AND VITREOUS ENAMELS), ADHESIVES,SEALANTS AND PRINTING INKS**		
08 01	**wastes from MFSU and removal of paint and varnish**		
08 01 11*	waste paint and varnish containing organic solvents or other dangerous substances		
08 01 12	waste paint and varnish other than those mentioned in 08 01 11	Sludge, degradable	Sludge, degradable
08 01 13*	sludges from paint or varnish containing organic solvents or other dangerous substances		
08 01 14	sludges from paint or varnish other than those mentioned in 08 01 13		
08 01 15*	aqueous sludges containing paint or varnish containing organic solvents or other dangerous substances		
08 01 16	aqueous sludges containing paint or varnish other than those mentioned in 08 01 15		
08 01 17*	waste paint and varnish removal containing organic solvents or other dangerous substances		
08 01 18	waste paint and varnish removal other than those mentioned in 08 01 17		
08 01 19*	aqueous suspensions containing paint or varnish containing organic solvents or other dangerous substances		
08 01 20	aqueous suspensions containing paint or varnish other than those mentioned in 08 01 19		
08 01 21*	waste paint and varnish remover		
08 01 99	wastes not otherwise specified		
08 02	**wastes from MFSU of other coatings (including ceramic materials)**		
08 02 01	waste coating powders		
08 02 02	aqueous sludges containing ceramic materials		
08 02 03	aqueous suspensions containing ceramic materials		
08 02 99	wastes not otherwise specified		
08 03	**wastes from MFSU of printing inks**		
08 03 07	aqueous sludges containing ink		
08 03 08	aqueous liquid waste containing ink		
08 03 12*	waste ink containing dangerous substances		
08 03 13	waste ink other than those mentioned in 08 03 12		
08 03 14*	ink sludges containing dangerous substances		
08 03 15	ink sludges other than those mentioned in 08 03 14		
08 03 16*	waste etching solutions		
08 03 17*	waste printing toner containing dangerous substances		
08 03 18	waste printing toner other than those mentioned in 08 03 17		
08 03 19*	disperse oil		
08 03 99	wastes not otherwise specified		
08 04	**wastes from MFSU of adhesives and sealants (including waterproofing products)**		
08 04 09*	waste adhesives and sealants containing organic solvents or other dangerous substances		
08 04 10	waste adhesives and sealants other than those mentioned in 08 04 09	Chemicals, inert**	Chemicals, inert**
08 04 11*	adhesive and sealant sludges containing organic solvents or other dangerous substances		
08 04 12	adhesive and sealant sludges other than those mentioned in 08 04 11		
08 04 13*	aqueous sludges containing adhesives and sealants containing organic solvents or other dangerous substances		
08 04 14	aqueous sludges containing adhesives and sealants other than those mentioned in 08 04 13		
08 04 15*	aqueous liquid waste containing adhesives and sealants containing organic solvents or other dangerous substances		
08 04 16	aqueous liquid waste containing adhesives and sealants other than those mentioned in 08 04 15		
08 04 17*	rosin oil		
08 04 99	wastes not otherwise specified	Chemicals, inert**	Chemicals, inert**
08 05	**wastes not otherwise specified in 08**		
08 05 01*	waste isocyanates		
9	**WASTES FROM THE PHOTOGRAPHIC INDUSTRY**		
09 01	**wastes from the photographic industry**		

09 01 01*	water-based developer and activator solutions		
09 01 02*	water-based offset plate developer solutions		
09 01 03*	solvent-based developer solutions		
09 01 04*	fixed solutions		
09 01 05*	bleach solutions and bleach fixer solutions		
09 01 06*	wastes containing silver from on-site treatment of photographic wastes		
09 01 07	photographic film and paper containing silver or silver compounds		
09 01 08	photographic film and paper free of silver or silver compounds		
09 01 10	single-use cameras without batteries		
09 01 11*	single-use cameras containing batteries included in 16 06 01, 16 06 02 or 16 06 03		
09 01 12	single-use cameras containing batteries other than those mentioned in 09 01 11		
09 01 13*	aqueous liquid waste from on-site reclamation of silver other than those mentioned in 09 01 06		
09 01 99	wastes not otherwise specified		
10	**WASTES FROM THERMAL PROCESSES**		
10 01	**wastes from power stations and other combustion plants (except 19)**		
10 01 01	bottom ash, slag and boiler dust (excluding boiler dust mentioned in 10 01 04)	Ash & Slag	Ash & Slag
10 01 02	coal fly ash		
10 01 03	fly ash from peat and untreated wood	Ash & Slag	Ash & Slag
10 01 04*	oil fly ash and -boiler dust		
10 01 05	calcium-based reaction wastes from flue-gas desulphurisation in solid form		
10 01 07	calcium-based reaction wastes from flue-gas desulphurisation in sludge form		
10 01 09*	sulphuric acid	Chemicals, inert**	Chemicals, inert**
10 01 13*	fly ash from emulsified hydrocarbons used as fuel	Ash & Slag	Ash & Slag
10 01 14*	bottom ash, slag and boiler dust from co-incineration containing dangerous substances	Ash & Slag	Ash & Slag
10 01 15	bottom ash, slag and boiler dust from co-incineration other than those mentioned in 10 01 14	Ash & Slag	Ash & Slag
10 01 16*	fly ash from co-incineration containing dangerous substances	Ash & Slag	Ash & Slag
10 01 17	fly ash from co-incineration other than those mentioned in 10 01 16	Ash & Slag	Ash & Slag
10 01 18*	wastes from gas cleaning containing dangerous substances	Ash & Slag	Ash & Slag
10 01 19	wastes from gas cleaning other than those mentioned in 10 01 05, 10 01 07 and 10 01 18	Ash & Slag	Ash & Slag
10 01 20*	sludges from on-site effluent treatment containing dangerous substances		
10 01 21	sludges from on-site effluent treatment other than those mentioned in 10 01 20		
10 01 22*	aqueous sludges from boiler cleansing containing dangerous substances		
10 01 23	aqueous sludges from boiler cleansing other than those mentioned in 10 01 22		
10 01 24	sands from fluidised beds		
10 01 25	wastes from fuel storage and preparation of coal-fires power plants		
10 01 26	wastes from cooling-water treatment		
10 01 99	wastes not otherwise specified	Ash & Slag	Ash & Slag
10 02	**wastes from the iron and steel industry**		
10 02 01	wastes from the processing of slag		
10 02 02	unprocessed slag		
10 02 07*	solid wastes from gas treatment containing dangerous substances		
10 02 08	solid wastes from gas treatment other than those mentioned in 10 02 07		
10 02 10	mill scales		
10 02 11*	wastes from cooling-water treatment containing oil		
10 02 12	wastes from cooling-water treatment other than those mentioned in 10 02 11		
10 02 13*	sludges and filter cakes from gas treatment containing dangerous substances		
10 02 14	sludges and filter cakes from gas treatment other than those mentioned in 10 02 13		
10 02 15	other sludges and filter cakes	Sludge, inert	Sludge, inert
10 02 99	wastes not otherwise specified	Metal**	Metal**
10 03	**wastes from aluminium thermal metallurgy**		

10 03 02	anode scraps		
10 03 04*	primary production slags		
10 03 05	waste alumina		
10 03 08*	salt slags from secondary production		
10 03 09*	black drosses from secondary production		
10 03 15*	skimmings that are flammable or emit, upon contact with water, flammable gases in dangerous quantities		
10 03 16	skimmings other than those mentioned in 10 03 15		
10 03 17*	tar-containing wastes from anode manufacture		
10 03 18	carbon-containing wastes from anode manufacture other than those mentioned in 10 03 17		
10 03 19*	flue-gas dust containing dangerous substances		
10 03 20	flue-gas dust other than those mentioned in 10 03 19		
10 03 21*	other particulates and dust (including ball-mill dust) containing dangerous substances		
10 03 22	other particulates and dust (including ball-mill dust) other than those mentioned in 10 03 21		
10 03 23*	solid wastes from gas treatment containing dangerous substances		
10 03 24	solid wastes from gas treatment other than those mentioned in 10 03 23		
10 03 25*	sludges and filter cakes from gas treatment containing dangerous substances		
10 03 26	sludges and filter cakes from gas treatment other than those mentioned in 10 03 25		
10 03 27*	wastes from cooling-water treatment containing oil		
10 03 28	wastes from cooling-water treatment other than those mentioned in 10 03 27		
10 03 29*	wastes from treatment of salt slags and black drosses containing dangerous substances		
10 03 30	wastes from treatment of salt slags and black drosses other than those mentioned in 10 03 29		
10 03 99	wastes not otherwise specified	Ash & Slag	Ash & Slag
10 04	**wastes from lead thermal metallurgy**		
10 04 01*	slags from primary and secondary production		
10 04 02*	dross and skimmings from primary and secondary production		
10 04 03*	calcium arsenate		
10 04 04*	flue-gas dust		
10 04 05*	other particulates and dust		
10 04 06*	solid wastes from gas treatment		
10 04 07*	sludges and filter cakes from gas treatment		
10 04 09*	wastes from cooling-water treatment containing oil		
10 04 10	wastes from cooling-water treatment other than those mentioned in 10 04 09		
10 04 99	wastes not otherwise specified		
10 05	**wastes from zinc thermal metallurgy**		
10 05 01	slags from primary and secondary production		
10 05 03*	flue-gas dust		
10 05 04	other particulates and dust		
10 05 05*	solid waste from gas treatment		
10 05 06*	sludges and filter cakes from gas treatment		
10 05 08*	wastes from cooling-water treatment containing oil		
10 05 09	wastes from cooling-water treatment other than those mentioned in 10 05 08		
10 05 10*	dross and skimmings that are flammable or emit, upon contact with water, flammable gases in dangerous quantities		
10 05 11	dross and skimmings other than those mentioned in 10 05 10		
10 05 99	wastes not otherwise specified		
10 06	**wastes from copper thermal metallurgy**		
10 06 01	slags from primary and secondary production		
10 06 02	dross and skimmings from primary and secondary production		
10 06 03*	flue-gas dust		
10 06 04	other particulates and dust		Metal**
10 06 06*	solid wastes from gas treatment		
10 06 07*	sludges and filter cakes from gas treatment		

10 06 09*	wastes from cooling-water treatment containing oil		
10 06 10	wastes from cooling-water treatment other than those mentioned in 10 06 09		
10 06 99	wastes not otherwise specified		
10 07	**wastes from silver, gold and platinum thermal metallurgy**		
10 07 01	slags from primary and secondary production		
10 07 02	dross and skimmings from primary and secondary production		
10 07 03	solid wastes from gas treatment		
10 07 04	other particulates and dust		
10 07 05	sludges and filter cakes from gas treatment		
10 07 07*	wastes from cooling-water treatment containing oil		
10 07 08	wastes from cooling-water treatment other than those mentioned in 10 07 07		
10 07 99	wastes not otherwise specified		
10 08	**wastes from other non-ferrous thermal metallurgy**		
10 08 04	particulates and dust		
10 08 08*	salt slag from primary and secondary production		
10 08 09	other slags		
10 08 10*	dross and skimmings that are flammable or emit, upon contact with water, flammable gases in dangerous quantities		
10 08 11	dross and skimmings other than those mentioned in 10 08 10		
10 08 12*	tar-containing wastes from anode manufacture		
10 08 13	carbon-containing wastes from anode manufacture other than those mentioned in 10 03 12		
10 08 14	anode scrap		
10 08 15*	flue-gas dust containing dangerous substances		
10 08 16	flue-gas dust other than those mentioned in 10 08 15		
10 08 17*	sludges and filter cakes from flue-gas treatment containing dangerous substances		
10 08 18	sludges and filter cakes from flue-gas treatment other than those mentioned in 10 08 17		
10 08 19*	wastes from cooling-water treatment containing oil		
10 08 20	wastes from cooling-water treatment other than those mentioned in 10 08 19		
10 08 99	wastes not otherwise specified		
10 09	**wastes from casting of ferrous pieces**		
10 09 03	furnace slag	Ash & Slag	Ash & Slag
10 09 05*	casting cores and moulds which have not undergone pouring containing dangerous substances		
10 09 06	casting cores and moulds which have not undergone pouring other than those mentioned in 10 09 05		
10 09 07*	casting cores and moulds which have undergone pouring containing dangerous substances		
10 09 08	casting cores and moulds which have undergonepouring other than those mentioned in 10 09 07	Metal**	Metal**
10 09 09*	flue-gas dust containing dangerous substances		
10 09 10	flue-gas dust other than those mentioned in 10 09 09		
10 09 11*	other particulates containing dangerous substances		
10 09 12	other particulates other than those mentioned in 10 09 11	Particulate matter and dust**	Particulate matter and dust**
10 09 13*	waste binders containing dangerous substances		
10 09 14	waste binders other than those mentioned in 10 09 13		
10 09 15*	waste crack-indicating agent containing dangerous substances		
10 09 16	waste crack-indicating agent other than those mentioned in 10 10 15		
10 09 99	wastes not otherwise specified		
10 10	**wastes from casting of non-ferrous pieces**		
10 10 03	furnace slag	Ash & Slag	Ash & Slag
10 10 05*	casting cores and moulds which have not undergone pouring containing dangerous substances		
10 10 06	casting cores and moulds which have not undergone pouring other than those mentioned in 10 10 05		
10 10 07*	casting cores and moulds which have undergone pouring containing dangerous substances	Metal**	Metal**
10 10 08	casting cores and moulds which have undergone pouring other than those mentioned in 10 10 07		Metal**
10 10 09*	flue-gas dust containing dangerous substances		

10 10 10	flue-gas dust other than those mentioned in 10 10 09		
10 10 11*	other particulates containing dangerous substances		
10 10 12	other particulates other than those mentioned in 10 10 11	Metal**	Metal**
10 10 13*	waste binders containing dangerous substances		
10 10 14	waste binders other than those mentioned in 10 10 13		
10 10 15*	waste crack-indicating agent containing dangerous substances		
10 10 16	waste crack-indicating agent other than those mentioned in 10 09 15		
10 10 99	wastes not otherwise specified	Metal**	Metal**
10 11	**wastes from manufacture of glass and glass products**		
10 11 03	waste glass-based fibrous materials		Glass**
10 11 05	particulates and dust		Particulate matter and dust**
10 11 09*	waste preparation mixture before thermal processing containing dangerous substances		
10 11 10	waste preparation mixture before thermal processing other than those mentioned in 10 11 09		
10 11 11*	waste glass in small particles and glass powder containing heavy metals (e.g. from cathode ray tubes)		
10 11 12	waste glass other than those mentioned in 10 11 11	Glass**	Glass**
10 11 13*	glass-polishing and -grinding sludge containing dangerous substances		
10 11 14	glass-polishing and -grinding sludge other than those mentioned in 10 11 13		Glass**
10 11 15*	solid wastes from flue-gas treatment containing dangerous substances		
10 11 16	solid wastes from flue-gas treatment other than those mentioned in 10 11 15		
10 11 17*	sludges and filter cakes from flue-gas treatment containing dangerous substances		
10 11 18	sludges and filter cakes from flue-gas treatment other than those mentioned in 10 11 17		
10 11 19*	solid wastes from on-site effluent treatment containing dangerous substances		
10 11 20	solid wastes from on-site effluent treatment other than those mentioned in 10 11 19		
10 11 99	wastes not otherwise specified	Glass**	Glass**
10 12	**wastes from manufacture of ceramic goods, bricks, tiles and construction products**		
10 12 01	waste preparation mixture before thermal processing		
10 12 03	particulates and dust		
10 12 05	sludges and filter cakes from gas treatment		
10 12 06	discarded moulds		
10 12 08	waste ceramics, bricks, tiles and construction products (after thermal processing)		Demolition**
10 12 09*	solid wastes from gas treatment containing dangerous substances		
10 12 10	solid wastes from gas treatment other than those mentioned in 10 12 09		Chemicals, inert**
10 12 11*	wastes from glazing containing heavy metals		
10 12 12	wastes from glazing other than those mentioned in 10 12 11		
10 12 13	sludge from on-site effluent treatment		
10 12 99	wastes not otherwise specified	Particulate matter and dust**	Particulate matter and dust**
10 13	**wastes from manufacture of cement, lime and plaster and articles and products made from them**		
10 13 01	waste preparation mixture before thermal processing	Particulate matter and dust**	Particulate matter and dust**
10 13 04	wastes from calcination and hydration of lime	Particulate matter and dust**	Particulate matter and dust**
10 13 06	particulates and dust (except 10 13 12 and 10 13 13)	Particulate matter and dust**	Particulate matter and dust**
10 13 07	sludges and filter cakes from gas treatment	Sludge, inert	Sludge, inert
10 13 09*	wastes from asbestos-cement manufacture containing asbestos		
10 13 10	wastes from asbestos-cement manufacture other than those mentioned in 10 13 09		
10 13 11	wastes from cement-based composite materials other than those mentioned in 10 13 09 and 10 13 10	Particulate matter and dust**	Particulate matter and dust**
10 13 12*	solid wastes from gas treatment containing dangerous substances		
10 13 13	solid wastes from gas treatment other than those mentioned in 10 13 12	Ash & Slag	Ash & Slag
10 13 14	waste concrete and concrete sludge		
10 13 99	wastes not otherwise specified	Particulate matter and dust**	Particulate matter and dust**
10 14	**waste from crematoria**		

10 14 01*	waste from gas cleaning containing mercury		
11	**WASTES FROM CHEMICAL SURFACE TREATMENT AND COATING OF METALS AND OTHER MATERIALS; NON-FERROUS HYDRO-METALLURGY**		
11 01	**wastes from chemical surface treatment and coating of metals and other materials (eg. galvanic processes, zinc coating processes, pick-ling processes, etching, phosphatiing, alkaline degreasing, anodising)**		
11 01 05*	pickling acids		
11 01 06*	acids not otherwise specified		
11 01 07*	pickling bases		
11 01 08*	phosphatising sludges		
11 01 09*	sludges and filter cakes containing dangerous substances	Sludge, inert	Sludge, inert
11 01 10	sludges and filter cakes other than those mentioned in 11 01 09		
11 01 11*	aqueous rinsing liquids containing dangerous substances		
11 01 12	aqueous rinsing liquids other than those mentioned in 11 01 11		
11 01 13*	degreasing wastes containing dangerous substances		
11 01 14	degreasing wastes other than those mentioned in 11 01 13		
11 01 15*	eluate and sludges from membrane systems or ion exchange systems containing dangerous substances		
11 01 16*	saturated or spent ion exchange resins		
11 01 98*	other wastes containing dangerous substances		
11 01 99	wastes not otherwise specified		
11 02	**wastes from non-ferrous hydrometallurgical processes**		
11 02 02*	sludges from zinc hydrometallurgy (incl. jarosite, goethite)		
11 02 03	wastes from the production of anodes for aqueous electrolytical processes		
11 02 05*	wastes from copper hydrometallurgical processes containing dangerous substances		
11 02 06	wastes from copper hydrometallurgical processes other than those men-tioned in 11 02 05		
11 02 07*	other wastes containing dangerous substances		
11 02 99	wastes not otherwise specified		
11 03	**sludges and solids from tempering processes**		
11 03 01*	wastes containing cyanide		
11 03 02*	other wastes		
11 05	**wastes from hot galvanising processes**		
11 05 01	hard zinc		
11 05 02	zinc ash		
11 05 03*	solid wastes from gas treatment		
11 05 04*	spent flux		
11 05 99	wastes not otherwise specified		
12	**WASTES FROM SHAPING AND PHYSICAL AND MECHANICAL SUR-FACE TREATMENT OF METALS AND PLASTICS**		
12 01	**wastes from shaping and physical and mechanical surface treatment of metals and plastics**		
12 01 01	ferrous metal filings and turnings	Metal**	Metal**
12 01 02	ferrous metal dust and particles	Metal**	Metal**
12 01 03	non-ferrous metal filings and turnings		
12 01 04	non-ferrous metal dust and particles		Particulate matter and dust**
12 01 05	plastics shavings and turnings	Plastic**	Plastic**
12 01 06*	mineral-based machining oils containing halogens (except emulsions and solutions)	Sludge, degradable	Sludge, degradable
12 01 07*	mineral-based machining oils free of halogens (except emulsions and solu-tions)		
12 01 08*	machining emulsions and solutions containing halogens		
12 01 09*	machining emulsions and solutions free of halogens		
12 01 10*	synthetic machining oils		
12 01 12*	spent waxes and fats		
12 01 13	welding wastes		
12 01 14*	machining sludges containing dangerous substances		
12 01 15	machining sludges other than those mentioned in 12 01 14		
12 01 16*	waste blasting material containing dangerous substances	Particulate matter and dust**	Particulate matter and dust**

12 01 17	waste blasting material other than those mentioned in 12 01 16	Particulate matter and dust**	Particulate matter and dust**
12 01 18*	metal sludge (grinding, honing and lapping sludge) containing oli		
12 01 19*	readily biodegradable machining oil		
12 01 20*	spent grinding bodies and grinding materials containing dangerous substanc-es	Particulate matter and dust**	Particulate matter and dust**
12 01 21	spent grinding bodies and grinding materials other than those mentioned in 12 01 20	Particulate matter and dust**	Particulate matter and dust**
12 01 99	wastes not otherwise specified	Particulate matter and dust**	Particulate matter and dust**
12 03	**wastes from water and steam degreasing processes(except 11)**		
12 03 01*	aqueous washing liquids		
12 03 02*	steam degreasing wastes		
13	**OIL WASTES AND WASTES OF LIQUID FUELS (except edibleoils, and those in chapters 05, 12 and 19)**		
13 01	**waste hydraulic oils**	Particulate matter and dust**	Particulate matter and dust**
13 01 01*	hydraulic oils, containing PCBs (PCBs are here defined as in Directive 96/59/EC)		
13 01 04*	chlorinated emulsions		
13 01 05*	non-chlorinated emulsions		
13 01 09*	mineral-based chlorinated hydraulic oils		
13 01 10*	mineral-based non-chlorinated hydraulic oils		
13 01 11*	synthetic hydraulic oils		
13 01 12*	readily biodegradable hydraulic oils		
13 01 13*	other hydraulic oils		
13 02	**waste engine, gear and lubricating oils**	Sludge, inert	Sludge, inert
13 02 04*	mineral-based chlorinated engine, gear and lubricating oils		
13 02 05*	mineral-based non-chlorinated engine, gear and lubricating oils		
13 02 06*	synthetic engine, gear and lubricating oils		
13 02 07*	readily biodegradable engine, gear and lubricating oils		
13 02 08*	other engine, gear and lubricating oils		
13 03	**waste insulating and heat transmission oils**		
13 03 01*	insulating or heat transmission oils containing PCBs (PCBs are here defined as in Directive 96/59/EC)		
13 03 06*	mineral-based chlorinated insulating and heat transmission oils other than those mentioned in 13 03 01		
13 03 07*	mineral-based non-chlorinated insulating and heat transmission oils		
13 03 08*	synthetic insulating and heat transmission oils		
13 03 09*	readily biodegradable insulating and heat transmission oils		
13 03 10*	other insulating and heat transmission oils		
13 04	**bilge oils**	Sludge, degradable	Sludge, degradable
13 04 01*	bilge oils from inland navigation	Sludge, degradable	Sludge, degradable
13 04 02*	bilge oils from jetty sewers		
13 04 03*	bilge oils from other navigation		
13 05	**oil/water separator contents**	Sludge, degradable	Sludge, degradable
13 05 01*	solids from grit chambers and oil/water separators	Sludge, degradable	Sludge, degradable
13 05 02*	sludge from oil/water separators		
13 05 03*	interceptor sludges		
13 05 06*	oil from oil/water separators		
13 05 07*	oily waster from oil/water separators		
13 05 08*	mixtures of wastes from grit chambers and oil/water separators	Sludge, degradable	Sludge, degradable
13 07	**wastes of liquid fuels**	Sludge, inert	Sludge, inert
13 07 01*	fuel oil and diesel		
13 07 02*	petrol		
13 07 03*	other fuels (including mixtures)		
13 08	**oil wastes not otherwise specified**		
13 08 01*	desalter sludges or emulsions		
13 08 02*	other emulsions		
13 08 99*	wastes not otherwise specified		
14	**WASTE ORGANIC SOLVENTS, REFRIGERANTS AND PROPELLANTS (except 07 and 08)**		

14 06	**waste organic solvents, refrigerants and foam/aerosol propellants**		
14 06 01*	chlorofluorocarbons, HCFC, HFC		
14 06 02*	other halogenated solvents and solvent mixtures		
14 06 03*	other solvents and solvent mixtures		
14 06 04*	sludges or solid wastes containing halogenated solvents		
14 06 05*	sludges or solid wastes containing other solvents		
15	**WASTE PACKAGING; ABSORBENTS, WIPING CLOTHS, FILTERMA-TERIALS AND PROTECTIVE CLOTHING NOT OTHERWISE SPECIFIED**		
15 01	**packaging (including separately collected municipal packaging waste)**		
15 01 01	paper and cardboard packaging	Paper and cardboard	Paper and cardboard
15 01 02	plastic packaging	Plastic**	Plastic**
15 01 03	wooden packaging	Wood	Wood
15 01 04	metallic packaging		Metal**
15 01 05	composite packaging	Metal**	Metal**
15 01 06	mixed packaging	Metal**	Metal**
15 01 07	glass packaging		
15 01 09	textile packaging		
15 01 10*	packaging containing residues of or contaminated by dangerous substances	Metal**	Metal**
15 01 11*	metallic packaging containing a dangerous solid porous matrix (e.g. asbes-tos), including empty pressure containers		
15 02	**absorbents, filter materials, wiping cloths and protective clothing**		
15 02 02*	absorbents, filter materials (including oil filters not otherwise specified), wiping cloths, protective clothing contaminated by dangerous substances		
15 02 03	absorbents, filter materials, wiping cloths and protective clothing other than those mentioned in 15 02 02		Textile, fur and leather
16	**WASTES NOT OTHERWISE SPECIFIED IN THE LIST**		
16 01	**end-of-life vehicles from different means of transport (including off-road machinery) and wastes from dismantling of end-of-life vehicles and vehicle maintenance (except 13, 14, 16 06 and 16 08)**		
16 01 03	end-of-life tyres	Plastic**	Plastic**
16 01 04*	end-of-life vehicles	Scrap vehicles**	Scrap vehicles**
16 01 06	end-of-life vehicles, containing neither liquids nor other hazardous compo-nents		
16 01 07*	oil filters		
16 01 08*	components containing mercury		
16 01 09*	components containing PCBs (PCBs are here defined as in Directive 96/59/EC)		
16 01 10*	explosive components (e.g. air bags)		
16 01 11*	brake pads containing asbestos		
16 01 12	brake pads other than those mentioned in 16 01 11		
16 01 13*	brake fluids		
16 01 14*	antifreeze fluids containing dangerous substances		
16 01 15	antifreeze fluids other than those mentioned in 16 01 14		
16 01 16	tanks for liquefied gas		
16 01 17	ferrous metal		
16 01 18	non-ferrous metal		
16 01 19	plastic	Plastic**	Plastic**
16 01 20	glass	Glass**	Glass**
16 01 21*	hazardous components other than those mentioned in16 01 07 to 16 01 11 and 16 01 13 and 16 01 14		
16 01 22	components not otherwise specified		
16 01 99	wastes not otherwise specified	Scrap vehicles**	Scrap vehicles**
16 02	**wastes from electrical and electronic equipment**		
16 02 09*	transformers and capacitors containing PCBs (PCBs are here defined as in Directive 96/59/EC)		
16 02 10*	discarded equipment containing or contaminated by PCBs other than those mentioned in 16 02 09		
16 02 11*	discarded equipment containing chlorofluorocarbons, HCFC, HFC		
16 02 12*	discarded equipment containing free asbestos		
16 02 13*	discarded equipment containing hazardous components other than those mentioned in 16 02 09 to 16 02 12		

16 02 14	discarded equipment containing hazardous components (hazardous components from electrical and electronic equipment may include accumulators and batteries mentioned in 16 06 and marked as hazardous; mercury switches, glass from cathode ray tubes and other activated glass, etc.) other than those mentioned in 16 02 09 to 16 02 12		
16 02 15*	hazardous components removed from discarded equipment		
16 02 16	components removed from discarded equipment other than those mentioned in 16 02 15		
16 03	**off-specification batches and unused products**		
16 03 03*	inorganic wastes containing dangerous substances		
16 03 04	inorganic wastes other than those mentioned in 16 03 03		
16 03 05*	organic wastes containing dangerous substances		
16 03 06	organic wastes other than those mentioned in 16 03 05	Sludge, degradable	Sludge, degradable
16 04	**waste explosives**		
16 04 01*	waste ammunition		
16 04 02*	fireworks wastes		
16 04 03*	other waste explosives		
16 05	**gases in pressure containers and discarded chemicals**		
16 05 04*	gases in pressure containers (including halons) containing dangerous substances		
16 05 05	gases in pressure containers other than those mentioned in 16 05 04		
16 05 06*	laboratory chemicals consisting of or containing dangerous substances including mixtures of laboratory chemicals		
16 05 07*	discarded inorganic chemicals consisting of or containing dangerous substances		
16 05 08*	discarded organic chemicals consisting of or containing dangerous substances	Sludge, degradable	Sludge, degradable
16 05 09	discarded chemicals other than those mentioned in 16 05 06, 16 05 07 or 16 05 08	Sludge, degradable	Sludge, degradable
16 06	**batteries and accumulators**		
16 06 01*	lead batteries		
16 06 02*	Ni-Cd batteries		
16 06 03*	mercury-containing batteries		
16 06 04	alkaline batteries (except 16 06 03)		
16 06 05	other batteries and accumulators	Electric & Hazardous**	Electric & Hazardous**
16 06 06*	separately collected electrolyte from batteries and acculators		
16 07	**wastes from transport tank, storage tank and barrel cleaning (except 05 and 13)**	Sludge, degradable	Sludge, degradable
16 07 08*	wastes containing oil		
16 07 09*	wastes containing other dangerous substances		
16 07 99	wastes not otherwise specified	Sludge, degradable	Sludge, degradable
16 08	**spent catalysts**		
16 08 01	spent catalysts containing gold, silver, rhenium, rhodium, palladium, iridium or platinum (except 16 08 07)		
16 08 02*	spent catalysts containing dangerous transition metals (scandium, vanadium, manganese, Co, Cu, yttrium, niobium, hafnium, tungsten, Ti, Cr, Fe, Ni, Zn, zirconium, molybdenum and tantalum) or dangerous transition metal compounds		
16 08 03	spent catalysts containing transition metals or transition metal compounds not otherwise specified		
16 08 04	spent fluid catalytic cracking catalysts (except 16 08 07)		
16 08 05*	spent catalysts containing phosphoric acid		
16 08 06*	spent liquids used in catalysts		
16 08 07*	spent catalysts contaminated with dangerous substances		
16 09	**oxidising substances**		
16 09 01*	permanganates, e.g. potassium permanganate		
16 09 02*	chromates, e.g. potassium chromate, potassium or sodium dichromate		
16 09 03*	peroxides, e.g. hydrogen peroxide		
16 09 04*	oxidising substances, not otherwise specified		
16 10	**aqueous liquid wastes destined for off-site treatment**		
16 10 01*	aqueous liquid wastes containing dangerous substances		
16 10 02	aqueous liquid wastes other than those mentioned in 16 10 01		
16 10 03*	aqueous concentrates containing dangerous substances		

16 10 04	aqueous concentrates other than those mentioned in 16 10 03		
16 11	**waste linings and refractories**		
16 11 01*	carbon-based linings and refractories from metallurgical processes containing dangerous substances		Demolition**
16 11 02	carbon-based linings and refractories from metallurgical processes others than those mentioned in 16 11 01		Demolition**
16 11 03*	other linings and refractories from metallurgical processes containing dangerous substances		
16 11 04	other linings and refractories from metallurgical processes other than those mentioned in 16 11 03		
16 11 05*	linings and refractories from non-metallurgical processes containing dangerous substances		
16 11 06	linings and refractories from non-metallurgical processes others than those mentioned in 16 11 05		Demolition**
17	**CONSTRUCTION AND DEMOLITION WASTES (INCLUDING EXCAVATED SOIL FROM CONTAMINATED SITES)**		
17 01	**concrete, bricks, tiles and ceramics**		
17 01 01	concrete		Demolition**
17 01 02	bricks		Demolition**
17 01 03	tiles and ceramics		Demolition**
17 01 06*	mixtures of, or separate fractions of concrete, bricks, tiles and ceramics containing dangerous substances		Demolition**
17 01 07	mixtures of concrete, bricks, tiles and ceramics other than those mentioned in 17 01 06		Demolition**
17 02	**wood, glass and plastic**		
17 02 01	wood	Wood	Wood
17 02 02	glass	Glass**	Glass**
17 02 03	plastic	Plastic**	Plastic**
17 02 04*	glass, plastic and wood containing or contaminated with dangerous substances	Glass**	Glass**
17 03	**bituminous mixtures, coal tar and tarred products**		
17 03 01*	bituminous mixtures containing coal tar		Demolition**
17 03 02	bituminous mixtures other than those mentioned in 17 03 01		Demolition**
17 03 03*	coal tar and tarred products		
17 04	**metals (including their alloys)**		
17 04 01	copper, bronze, brass		
17 04 02	aluminium		
17 04 03	lead	Metal**	Metal**
17 04 04	zinc		
17 04 05	iron and steel		Metal**
17 04 06	tin		
17 04 07	mixed metals		
17 04 09*	metal waste contaminated with dangerous substances	Metal**	Metal**
17 04 10*	cables containing oil, coal tar and other dangerous substances		
17 04 11	cables other than those mentioned in 17 04 10	Electric & Hazardous**	Electric & Hazardous**
17 05	**soil (including excavated soil from contaminated sites), stones and dredging spoil**		
17 05 03*	soil and stones containing dangerous substances	Soil & Stone**	Soil & Stone**
17 05 04	soil and stones other than those mentioned in 17 05 03	Soil & Stone**	Soil & Stone**
17 05 05*	dredging spoil containing dangerous substances		
17 05 06	dredging spoil other than those mentioned in 17 05 05	Soil & Stone**	Soil & Stone**
17 05 07*	track ballast containing dangerous substances		
17 05 08	track ballast other than those mentioned in 17 05 07		Soil & Stone**
17 06	**insulation materials and asbestos-containing construction materials**		
17 06 01*	insulation materials containing asbestos		Demolition**
17 06 03*	other insulation materials consisting of or containing dangerous substances		Demolition**
17 06 04	insulation materials other than those mentioned in 17 06 01 and 17 06 03		Demolition**
17 06 05*	construction materials containing asbestos		Demolition**
17 06 06	construction materials containing asbestos, dusty		Demolition**
17 08	**gypsum-based construction material**		
17 08 01*	gypsum-based construction materials contaminated with dangerous substances		Demolition**

17 08 02	gypsum-based construction materials other than those mentioned in 17 08 01		Demolition**
17 09	**other construction and demolition wastes**		
17 09 01*	construction and demolition wastes containing mercury		Demolition**
17 09 02*	construction and demolition wastes containing PCB (e.g. PCB-containing sealants, PCB-containing resin-based floorings, PCB-containing sealed glazing units, PCB-containing capacitors) (PCBs are here defined as in Directive 96/59/EC)		Demolition**
17 09 03*	other construction and demolition wastes (including mixed wastes) containing dangerous substances		Demolition**
17 09 04	mixed construction and demolition wastes other than those mentioned in 17 09 01, 17 09 02 and 17 09 03		Demolition**
18	**WASTES FROM HUMAN OR ANIMAL HEALTH CARE AND/OR RELATED RESEARCH (except kitchen and restaurant wastes not arising from immediate health care)**		
18 01	**wastes from natal care, diagnosis, treatment or prevention of disease in humans**		
18 01 01	sharps (except 18 01 03)		
18 01 02	body parts and organs including blood bags and blood preserved (except 18 01 03)		
18 01 03*	wastes whose collection and disposal is subject to special requirements in order to prevent infection	Sludge, degradable	Sludge, degradable
18 01 04	wastes whose collection and disposal is not subject to special requirements in order to prevent infection (e.g. dressings, plaster casts, linen, disposable clothing, diapers)		
18 01 06*	chemicals consisting of or containing dangerous substances		
18 01 07	chemicals other than those mentioned in 18 01 06		
18 01 08*	cytotoxic and cytostatic medicines		
18 01 09	medicines other than those mentioned in 18 01 08		
18 01 10*	amalgam waste from dental care		
18 02	**wastes from research, diagnosis, treatment or prevention of disease involving animals**		
18 02 01	sharps (except 18 02 02)		
18 02 02*	wastes whose collection and disposal is subject to special requirements in order to prevent infection		
18 02 03	wastes whose collection and disposal is not subject to special requirements in order to prevent infection		
18 02 05*	chemicals consisting of or containing dangerous substances		
18 02 06	chemicals other than those mentioned in 18 02 05		
18 02 07*	cytotoxic and cytostatic medicines		
18 02 08	medicines other than those mentioned in 18 02 07		
19	**WASTES FROM WASTE MANAGEMENT FACILITIES, OFF-SITE WASTE WATER TREATMENT PLANTS AND THE PREPARATION OF WATER INTENDED FOR HUMAN CONSUMPTION AND WATER FOR INDUSTRIAL USE**		
19 01	**wastes from incineration or pyrolysis of waste**		
19 01 02	ferrous materials removed from bottom ash	Metal**	Metal**
19 01 05*	filter cake from gas treatment	Sludge, inert	Sludge, inert
19 01 06*	aqueous liquid wastes from gas treatment and other aqueous liquid wastes	Sludge, inert	Sludge, inert
19 01 07*	solid wastes from gas treatment	Sludge, degradable	Sludge, inert
19 01 10*	spent activated carbon from flue-gas treatment		
19 01 11*	bottom ash and slag containing dangerous substances	Ash & Slag	Ash & Slag
19 01 12	bottom ash and slag other than those mentioned in 19 01 11	Ash & Slag	Ash & Slag
19 01 13*	fly ash containing dangerous substances	Ash & Slag	Ash & Slag
19 01 14	fly ash other than those mentioned in 19 01 13	Ash & Slag	Ash & Slag
19 01 15*	boiler dust containing dangerous substances		
19 01 16	boiler dust other than those mentioned in 19 01 15		
19 01 17*	pyrolysis wastes containing dangerous substances		
19 01 18	pyrolysis wastes other than those mentioned in 19 01 17		
19 01 19	sands from fluidised beds	Ash & Slag	Ash & Slag
19 01 99	wastes not otherwise specified	Ash & Slag	Ash & Slag
19 02	**wastes from physico/chemical treatments of waste (including dechro-matation, decyanidation, neutralisation)**		
19 02 03	premixed wastes composed only of non hazardous wastes	Ash & Slag	Ash & Slag
19 02 04*	premixed wastes composed of at least one hazardous waste	Ash & Slag	Ash & Slag
19 02 05*	sludges from physico/chemical treatment containing dangerous substances	Sludge, degradable	Sludge, degradable

19 02 06	sludges from physico/chemical treatment other than those mentioned in 19 02 05		
19 02 07*	oil and concentrates from separation		
19 02 08*	liquid combustable wastes containing dangerous substances	Sludge, degradable	Sludge, degradable
19 02 09*	solid combustable wastes containing dangerous substances		
19 02 10	combustible wastes other than those mentioned in 19 02 08 and 19 02 09	Sludge, degradable	Sludge, degradable
19 02 11*	other wastes containing dangerous substances	Sludge, degradable	Sludge, degradable
19 02 99	wastes not otherwise specified	Sludge, degradable	Sludge, degradable
19 03	**stabilised/solidified wastes**		
19 03 04*	wastes marked as hazardous, partly stabilised		
19 03 05	stabilised wastes other than those mentioned in 19 03 04		
19 03 06*	wastes marked as hazardous, solidified		
19 03 07	solidified wastes other than those mentioned in 19 03 06		
19 04	**vitrified waste and wastes from vitrification**		
19 04 01	vitrified waste		
19 04 02*	fly ash and other flue-gas treatment wastes	Ash & Slag	Ash & Slag
19 04 03*	non-vitrified solid phase		
19 04 04	aquerous liquid wastes from vitrified waste tempering		
19 05	**wastes from aerobic treatment of solid wastes**	Biodegradable garden waste	Biodegradable garden waste
19 05 01	non-composted fraction of municipal and similar wastes	Biodegradable garden waste	Biodegradable garden waste
19 05 02	non-composted fraction of animal and vegetable waste	Biodegradable garden waste	Biodegradable garden waste
19 05 03	off-specification compost	Biodegradable garden waste	Biodegradable garden waste
19 05 99	wastes not otherwise specified	Biodegradable garden waste	Biodegradable garden waste
19 06	**wastes from anaerobic treatment of waste**	Food	Sludge, degradable
19 06 03	liquor from anaerobic treatment of municipal waste	Food	Food
19 06 04	digestate from anaerobic treatment of municipal waste	Food	Food
19 06 05	liquor from anaerobic treatment of animal and vegetable waste		Sludge, degradable
19 06 06	digestate from anaerobic treatment of animal and vegetable waste	Food	Food
19 06 99	wastes not otherwise specified	Food	Food
19 07	**landfill leachate**		
19 07 02*	landfill leachate containing dangerous substances		
19 07 03	landfill leachate other than those mentioned in 19 07 02		
19 08	**wastes from waste water treatment plants not otherwise specified**		
19 08 01	screenings	Sludge, inert	Sludge, inert
19 08 02	waste from desanding	Sludge, inert	Sludge, inert
19 08 05	sludge from treatment of urban waste water	Sludge, degradable	Sludge, degradable
19 08 06*	saturated or spent ion exchange resins		
19 08 07*	solutions and sludges from regeneration of ion exchangers		
19 08 08*	membrane system waste containing heavy metals		
19 08 09	grease and oil mixture from oil/water separation containing only edible oil and fats		
19 08 10*	grease and oil mixture from oil/water separation other than those mentioned in 19 08 09		
19 08 11*	sludges containing dangerous substances from biological treatment of industrial waste water		
19 08 12	sludges from biological treatment of industrial waste water other than those mentioned in 19 08 11	Sludge, degradable	Sludge, degradable
19 08 13*	sludges containing dangerous substances from other treatment of industrial waste water		
19 08 14	sludges from other treatment of industrial waste water other than those mentioned in 19 08 13	Sludge, degradable	Sludge, degradable
19 08 99	wastes not otherwise specified	Sludge, inert	Sludge, inert
19 09	**wastes from the preparation of drinking water or water for industrial use**		
19 09 01	solid waste from primary filtration and screenings	Sludge, inert	Sludge, inert
19 09 02	sludges from water clarification	Sludge, inert	Sludge, inert
19 09 03	sludges from decarbonation		
19 09 04	spent activated carbon	Sludge, inert	Sludge, inert
19 09 05	saturated or spent ion exchange resins		
19 09 06	solutions and sludges from regeneration of ion exchangers		

19 09 99	wastes not otherwise specified	Sludge, inert	Sludge, inert
19 10	**wastes from shredding of metal-containing wastes**		
19 10 01	iron and steel waste		Metal**
19 10 02	non-ferrous waste	Metal**	Metal**
19 10 03*	fluff - light fraction and dust containing dangerous substances	Metal**	Metal**
19 10 04	fluff - light fraction and dust other than those mentioned in 19 10 03		
19 10 05*	other fractions containing dangerous substances	Metal**	Metal**
19 10 06	other fractions other than those mentioned in 19 10 05		Metal**
19 11	**wastes from oil regeneration**		
19 11 01*	spent filter clays		
19 11 02*	acid tars		
19 11 03*	aqueous liquid wastes		
19 11 04*	wastes from cleaning of fuels with bases		
19 11 05*	sludges from on-site effluent treatment containing dangerous substances		
19 11 06	sludges from on-site effluent treatment other than those mentioned in 19 11 05	Sludge, degradable	Sludge, degradable
19 11 07*	wastes from flue-gas cleaning		
19 11 99	wastes not otherwise specified	Sludge, degradable	Sludge, degradable
19 12	**wastes from the mechanical treatment of waste (e.g. sorting, crushing, compacting, pelletising) not otherwise specified**		
19 12 01	paper and cardboard		
19 12 02	ferrous metal		
19 12 03	non-ferrous metal		
19 12 04	plastic and rubber	Plastic**	Plastic**
19 12 05	glass	Glass**	Glass**
19 12 06*	wood containing dangerous substances		
19 12 07	wood other than those mentioned in 19 12 06	Wood	Wood
19 12 08	textiles		
19 12 09	minerals (e.g. sand, stones)		
19 12 10	combustible waste (refuse derived fuel)	Sludge, degradable	Sludge, degradable
19 12 11*	other wastes (including mixtures of materials) from mechanical treatment of waste containing dangerous substances	Soil & Stone**	Soil & Stone**
19 12 12	other wastes (including mixtures of materials) from mechanical treatment of wastes other than those mentioned in 19 12 11	Soil & Stone**	Soil & Stone**
19 13	**wastes from soil and groundwater remediation**		
19 13 01*	solid wastes from soil remediation containing dangerous substances		
19 13 02	solid wastes from soil remediation other than those mentioned in 19 13 01	Sludge, inert	Sludge, inert
19 13 03*	sludges from soil remediation containing dangerous substances		
19 13 04	sludges from soil remediation other than those mentioned in 19 13 03		
19 13 05*	sludges from groundwater remediation containing dangerous substances		
19 13 06	sludges from groundwater remediation other than those mentioned in 19 13 05	Sludge, inert	Sludge, inert
19 13 07*	aqueous liquid wastes and aqueous concentrates from groundwater remediation containing dangerous substances		
19 13 08	aqueous liquid wastes and aqueous concentrates from groundwater remediation other than those mentioned in 19 13 07		
20	**MUNICIPAL WASTES (HOUSEHOLD WASTE AND SIMILAR COMMERCIAL, INDUSTRIAL AND INSTITUTIONAL WASTES) INCLUDING SEPARATELY COLLECTED FRACTIONS**		
20 01	**separately collected fractions (except 15 01)**		
20 01 01	paper and cardboard	Paper and cardboard	Paper and cardboard
20 01 02	glass	Glass**	Glass**
20 01 08	biodegradable kitchen and canteen waste	Food	Food
20 01 10	clothes		
20 01 11	textiles		
20 01 13*	solvents		
20 01 14*	acids		
20 01 15*	alkalines		
20 01 17*	photochemicals		

20 01 19*	pesticides		
20 01 21*	fluorescent tubes and other mercury-containing waste	Electric & Hazardous**	Electric & Hazardous**
20 01 23*	discarded equipment containing chlorofluorocarbons		
20 01 25	edible oli and fat		
20 01 26*	oli and fat ther than those mentioned in 20 01 25		
20 01 27*	paint, inks, adhesives and resins containing dangerous substances	Chemicals, inert**	Chemicals, inert**
20 01 28	paint, inks, adhesives and resins other than those mentioned in 20 01 27	Sludge, degradable	Sludge, degradable
20 01 29*	detergents containing dangerous substances		
20 01 30	detergents other than those mentioned in 20 01 29		
20 01 31*	cytotoxic and cytostatic medicines		
20 01 32	medicines other than those mentioned in 20 01 31		
20 01 33*	batteries and accumulators included in 16 06 01, 16 06 02 or 16 06 03 and unsorted batteries and accumulators containing these batteries		Electric & Hazardous**
20 01 34	batteries and accumulators other than those mentioned in 20 01 33		
20 01 35*	discarded electrical and electronic equipment other than those mentioned in 20 01 21 and 20 01 23 containing hazardous components (e.g. accumulators and batteries mentioned in 16 06, mercury switches, glass from cathode ray tubes and other activeted glass)	Electric & Hazardous**	Electric & Hazardous**
20 01 36	discarded electrical and electronic equipment other than those mentioned in 20 01 21, 20 01 23 and 20 01 35	Electric & Hazardous**	Electric & Hazardous**
20 01 37*	wood containing dangerous substances	Wood	Wood
20 01 38	wood other than those mentioned in 20 01 37	Wood	Wood
20 01 39	plastics	Plastic**	Plastic**
20 01 40	metals		
20 01 41	wastes from chimney sweeping	Particulate matter and dust**	Particulate matter and dust**
20 01 99	other fractions not otherwise specified	Other not combustible waste	Other not combustible waste
20 02	**garden and park wastes (including cemetery waste)**	Soil & Stone**	Soil & Stone**
20 02 01	biodegradable waste	Biodegradable garden waste	Biodegradable garden waste
20 02 02	soil and stones	Soil & Stone**	Soil & Stone**
20 02 03	other non-biodegradable wastes	Soil & Stone**	Soil & Stone**
20 03	**other municipal wastes**	Other not combustible waste	Other not combustible waste
20 03 01	mixed municipal waste	Other not combustible waste	Other not combustible waste
20 03 02	waste from markets	Sludge, degradable	Sludge, degradable
20 03 03	street-cleaning residues	Soil & Stone**	Soil & Stone**
20 03 04	septic tank sludge	Sludge, degradable	Sludge, degradable
20 03 06	waste from sewage cleaning	Sludge, degradable	Sludge, degradable
20 03 07	bulky waste	Other not combustible waste	Other not combustible waste
20 03 99	municipal wastes not otherwise specified	Other not combustible waste	Other not combustible waste

Table 3F.2.5 shows the allocation of waste amounts reported according to the European waste codes are presented. For a detailed documentation of the whole time series including back-calculation of the time series, the reader is referred to the methodology report verifying waste amounts and how the allocation of the old ISAG waste categories and types was performed and verified (Thomsen and Hjelgaard, 2015).

Table 3F.2.5 European waste codes allocated according to 18 characterised waste types, reporting year 2015.

Waste types	EWC codes
Food	020199*1/7, 020203, 020299, 020304, 020399, 020601, 020699, 190603, 190604, 190606, 190699, 200108
Paper and cardboard	150101, 150106*1/7, 150110*1/7, 191211*1/7, 191212*1/7, 200101
Wood	020107, 020199*1/7, 030105, 030199, 030301, 030399, 150103, 150106*1/7, 150110*1/7, 170201, 170204*1/3, 191207, 191211*1/7, 191212*1/7, 200137, 200138
Plastic*	020104, 020199*1/7, 070299, 120105, 150102, 150106*1/7, 150110*1/7, 160103, 160119, 170203, 170204*1/3, 191204, 191211*1/7, 191212*1/7, 200139, 070213
Textile, fur and leather	040108, 150106*1/7, 150110*1/7, 191211*1/7, 191212*1/7, 150203
Biodegradable garden waste	190501, 190502, 190503, 190599, 200201
Chemicals, inert*	020199*1/7, 060204, 060313, 060405, 060899, 080410, 080499, 100109, 200127, 060999,101210
Electric & Hazardous*	160605, 170411, 200121, 200135, 200136, 200133
Glass*	101112, 101199, 150106*1/7, 150110*1/7, 160120, 170202, 170204*1/3, 191205, 191211*1/7, 191212*1/7, 200102, 101103, 101114
Metal*	010101, 010305, 010306, 010399, 020110, 020199*1/7, 100299, 100908, 101007, 101012, 101099, 120101, 120102, 150105, 150106*2/7, 150110*2/7, 170403, 170409, 190102, 191002, 191003, 191005, 191211*1/7, 191212*1/7, 100604, 101008, 150104, 170405, 191001, 191006
Scrap vehicles*	160104, 160199
Demolition	020107, 020199*1/7, 030105, 030199, 030301, 030399, 150103, 150106*1/7, 150110*1/7, 170201, 170204*1/3, 191207, 191211*1/7, 191212*1/7, 200137, 200138
Soil & Stone*	010408, 010499, 010504, 010599, 170503, 170504, 170506, 191211*1/7, 191212*1/7, 200202, 200203, 200303, 170508
Particulate matter and dust*	100912, 101299, 101301, 101304, 101306, 101311, 101399, 120116, 120117, 120120, 120121, 120199, 200141, 040106, 101105, 120104
Sludge, inert*	190801, 190802, 190899, 070110, 110109, 190105, 190901, 190902, 190904, 190999, 191302, 100215, 101307, 190106, 190107, 191306
Sludge, degradable	190805, 190812, 020101, 030305, 030311, 040220, 060503, 190814, 190205, 190208, 190210, 190211, 190299, 130501, 130508, 191106, 191199, 200306, 020106, 020199*1/7, 020108, 020109, 020199*1/7, 020702, 070199, 070215, 070399, 070503, 070699, 080112, 120106, 130401, 160306, 160508, 160509, 160799, 180103, 191210, 200128, 020799, 200302, 200304, 190605
Ash & Slag*	100101, 100114, 100115, 100118, 100119, 101313, 190111, 190112, 100103, 100116, 100117, 190113, 190114, 190402, 100199, 100399, 190119, 190199, 190203, 190204, 100113, 100903, 101003
Other waste, inert*	200199, 200301, 200307, 200399

Table 3F-2.6 Fractional distribution of waste types for the whole time series 1990-2013.

Waste types	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Food	3.50	3.33	3.16	2.99	2.81	2.64	2.47	2.30	2.12	1.95
Paper and cardboard	5.65	5.37	5.10	4.82	4.55	4.27	3.99	3.72	3.44	3.17
Wood	6.32	6.43	6.54	6.65	6.77	13.26	7.27	8.68	12.81	17.50
Plastic*	0.85	0.82	0.79	0.77	0.74	0.72	0.69	0.67	0.64	0.62
Textile, fur and leather	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16
Biodegradable garden waste	4.26	4.07	3.88	3.69	3.50	3.31	3.12	2.93	2.75	2.56
Chemicals, inert*	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24
Electric & Hazardous*	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Glass*	1.17	1.12	1.08	1.03	0.99	0.94	0.90	0.85	0.81	0.76
Metal*	5.78	5.92	6.06	6.21	6.35	6.49	6.64	6.78	6.92	7.07
Scrap vehicles*	3.28	3.28	3.28	3.28	3.28	3.28	3.28	3.28	3.28	3.28
Demolition	8.87	8.87	8.87	8.87	8.87	8.87	8.87	8.87	8.87	8.87
Soil & Stone*	14.61	14.61	14.61	14.61	14.61	15.68	16.02	14.46	19.71	23.82
Particulate matter and dust*	1.01	1.01	1.01	1.01	1.01	0.00	0.00	0.00	0.00	0.05
Sludge, inert*	2.84	2.73	2.61	2.49	2.38	2.26	2.14	2.03	1.91	1.79
Sludge, degradable	6.60	6.33	6.05	5.77	4.17	6.90	6.15	6.58	7.28	9.26
Ash & Slag*	14.60	15.70	16.80	17.89	24.71	7.36	28.35	22.97	11.54	1.00
Other waste, inert*	20.25	20.00	19.75	19.50	14.85	23.61	9.70	15.47	17.52	17.91

Waste types	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Food	1.78	1.61	1.44	0.94	0.44	0.46	0.61	0.57	0.31	0.11
Paper and cardboard	2.89	2.61	2.34	1.54	0.73	0.76	1.01	0.96	0.52	0.19
Wood	17.11	5.92	1.49	0.37	0.21	0.27	0.45	2.32	0.45	0.28
Plastic*	0.59	0.57	0.54	0.52	0.49	0.47	0.44	0.41	0.39	0.36
Textile, fur and leather	0.16	0.16	0.16	0.12	0.06	0.08	0.13	0.16	0.12	0.07
Biodegradable garden waste	2.37	2.18	1.99	1.34	0.65	0.72	1.01	1.04	0.65	0.30
Chemicals, inert*	0.24	0.24	0.21	0.20	0.18	0.14	0.13	0.30	0.16	0.16
Electric & Hazardous*	0.05	0.05	0.30	10.53	8.17	8.51	9.01	11.00	11.78	0.85
Glass*	0.71	0.67	0.62	0.58	0.53	0.49	0.44	0.40	0.35	0.31
Metal*	7.21	7.35	7.50	7.64	7.78	7.93	8.07	8.21	8.36	8.50
Scrap vehicles*	3.28	5.49	5.63	4.09	2.54	4.96	4.71	1.03	0.67	9.28
Demolition	8.87	8.87	8.87	8.87	8.87	8.87	8.87	8.87	8.87	8.87
Soil & Stone*	18.22	24.86	25.69	17.43	22.85	17.70	15.77	15.72	18.79	26.11
Particulate matter and dust*	0.02	0.04	0.04	0.04	0.03	0.01	0.01	0.19	0.01	0.00
Sludge, inert*	1.68	1.56	1.44	1.33	1.21	1.09	0.98	0.86	0.74	0.62
Sludge, degradable	7.19	6.15	5.91	6.62	4.77	3.83	4.32	4.97	3.64	4.16
Ash & Slag*	0.57	1.10	3.53	6.50	4.98	3.44	3.88	5.26	15.27	5.90
Other waste, inert*	27.06	30.58	32.30	31.37	35.52	40.27	40.17	37.75	28.95	33.93

Waste types	2010	2011	2012	2013
Food	0.06	0.04	0.05	0.04
Paper and cardboard	0.15	0.14	0.11	0.18
Wood	0.48	0.77	0.51	0.40
Plastic*	0.32	0.32	0.46	0.21
Textile, fur and leather	0.17	0.17	0.14	0.18
Biodegradable garden waste	0.00	1.28	0.30	0.33
Chemicals, inert*	0.04	0.02	0.00	0.01
Electric & Hazardous*	0.00	0.00	0.07	0.01
Glass*	0.25	0.22	0.13	0.19
Metal*	8.15	6.43	5.83	5.38
Scrap vehicles*	0.97	0.71	0.07	0.00
Demolition	7.43	9.86	9.36	8.39
Soil & Stone*	76.09	73.06	77.40	80.16
Particulate matter and dust*	0.15	0.22	1.10	0.37
Sludge, inert*	0.12	0.40	0.47	0.38
Sludge, degradable	1.09	1.04	0.76	0.41
Ash & Slag*	2.38	1.83	0.80	1.56
Other waste, inert*	2.14	3.48	2.44	1.82

Annex 3F-3 Biological Treatment of Solid Waste, 5.B

Table 3F-3.1 National emissions from composting – 1990 to 2013, Mg.

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
CH_4	1386.1	1532.5	1678.7	1825.1	1972.9	1860.2	2171.0	2526.6	2628.0	3032.5
N_2O	41.5	46.2	51.1	55.9	60.6	72.8	79.4	93.1	190.6	350.0
Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
CH_4	3240.0	3059.7	3397.1	3534.3	3222.1	3419.9	3627.9	4016.7	3685.7	4011.2
N_2O	515.7	498.1	770.9	752.5	201.7	200.2	239.1	295.2	291.8	330.3
Year	2010	2011	2012	2013						
CH_4	3066.5	3863.2	3558.5	5025.0						
N_2O	252.5	318.1	293.0	413.8						

Table 3F-3.2 Activity data composting, Gg.

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Composting of garden and park waste	288	320	351	383	414	376	452	528	551	634
Composting of organic waste from households and other sources	16	19	23	26	29	40	38	47	43	49
Composting of sludge	NO	NO	NO	NO	NO	7	6	7	57	134
Home composting of garden and vegetable food waste	20	20	20	20	21	21	21	21	21	21
Total	324	359	394	429	464	444	517	603	672	838
Continued	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Composting of garden and park waste	677	630	685	716	682	737	782	876	795	847
Composting of organic waste from households and other sources	47	52	63	66	53	45	48	44	46	70
Composting of sludge	218	211	348	336	53	50	67	91	94	107
Home composting of garden and vegetable food waste	21	21	22	22	22	22	22	22	22	23
Total	963	914	1,118	1,140	810	854	919	1,033	957	1,047
Continued	2010	2011	2012	2013						
Composting of garden and park waste	648	816	751	1,061						
Composting of organic waste from households and other sources	54	67	62	88						
Composting of sludge	82	103	95	134						
Home composting of garden and vegetable food waste	18	22	20	29						
Total	800	1,008	929	1,312						

NO = Not Occurring

Annex 3F-4 Incineration and open burning of waste, 5. C

Table 3F-4.1 presents the greenhouse gas emissions from 5.C Incineration and open burning of waste for 1990-2013.

Table 3F-4.1 Overall emission of greenhouse gases from the incineration of human bodies and animal carcasses

Year		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
CH_4 emission from											
Human cremation	Mg	0.48	0.48	0.49	0.51	0.50	0.52	0.51	0.50	0.49	0.50
Animal cremation	Mg	0.03	0.03	0.03	0.03	0.03	0.04	0.04	0.04	0.04	0.07
Total	Mg	0.51	0.51	0.52	0.54	0.54	0.55	0.55	0.54	0.53	0.56
N_2O emission from											
Human cremation	Mg	0.60	0.60	0.61	0.63	0.63	0.64	0.64	0.63	0.61	0.62
Animal cremation	Mg	0.03	0.04	0.04	0.04	0.04	0.05	0.05	0.05	0.05	0.08
Total	Mg	0.64	0.63	0.65	0.68	0.67	0.69	0.68	0.68	0.67	0.71
6C. Waste incineration											
CO_2 eqvivalents	Gg	0.21	0.21	0.21	0.22	0.22	0.23	0.22	0.22	0.22	0.23
Year		2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
CH_4 emission from											
Human cremation	Mg	0.49	0.49	0.50	0.49	0.49	0.48	0.48	0.49	0.49	0.50
Animal cremation	Mg	0.08	0.08	0.08	0.08	0.10	0.14	0.20	0.23	0.24	0.24
Total	Mg	0.57	0.57	0.58	0.58	0.59	0.62	0.69	0.72	0.73	0.74
N_2O emission from											
Human cremation	Mg	0.61	0.61	0.63	0.62	0.61	0.60	0.61	0.61	0.61	0.62
Animal cremation	Mg	0.10	0.10	0.10	0.10	0.13	0.17	0.25	0.29	0.30	0.30
Total	Mg	0.71	0.72	0.73	0.72	0.74	0.77	0.86	0.90	0.92	0.93
6C. Waste incineration CO_2 eqvivalents	Gg	0.23	0.23	0.24	0.24	0.24	0.25	0.28	0.30	0.30	0.30
Year		2010	2011	2012	2013						
CH_4 emission from											
Human cremation	Mg	0.49	0.49	0.48	0.50						
Animal cremation	Mg	0.26	0.22	0.22	0.21						
Total	Mg	0.76	0.71	0.70	0.71						
N_2O emission from											
Human cremation	Mg	0.62	0.61	0.60	0.62						
Animal cremation	Mg	0.33	0.28	0.28	0.26						
Total	Mg	0.95	0.88	0.88	0.88						
6C. Waste incineration CO_2 eqvivalents	Gg	0.31	0.29	0.29	0.28						

Table 3F-4.2 presents the activity data for human cremation for 1990-2013.

Table 3F-4.2 Activity data for human cremation.

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Nationally deceased	60,926	59,581	60,821	62,809	61,099	63,127	61,043	59,898	58,453	59,179
Cremations	40,991	40,666	41,455	43,194	42,762	43,847	43,262	42,891	41,660	42,299
Cremation fraction, %	67.3	68.3	68.2	68.8	70.0	69.5	70.8	71.6	69.1	74.4

Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Nationally deceased	57,998	58,355	58,610	57,574	55,806	54,962	55,477	55,604	54,591	54,872
Cremations	41,651	41,707	42,539	41,997	41,555	40,758	41,233	41,766	41,788	42,408
Cremation fraction, %	71.8	71.5	72.6	72.9	74.5	74.2	74.3	75.1	76.6	77.3

Year	2010	2011	2012	2013
Nationally deceased	54,368	52,516	52,325	52,471
Cremations	42,050	41,248	40,909	42,349
Cremation fraction, %	77.3	78.6	79.6	80.7

Table 3F-4.3 presents the activity data for animal cremation for 1990-2013.

Table 3F-4.3 Activity data, (direct contact with all Danish pet crematoria).

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Total, Mg	150	160	170	180	190	200	210	220	235	368
Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Total, Mg	443	452	451	462	571	762	1,116	1,284	1,338	1,339
Year	2010	2011	2012	2013						
Total, Mg	1,449	1,219	1,238	1,146						

Annex 3F-5 Wastewater treatment and discharge, 5.D

Table 3F-3.1 presents the methane produced in anaerobic digester tanks, recovered for energy production, emitted from sewer system and WWTPs, primary settling tanks and biological N and P removal processes, fugitive emissions from anaerobic processes and net CH_4 emission from the *5 D. Wastewater treatment and discharge* in Denmark, 1990-2013.

Table 3F-5.1 Produced, recovered and emitted CH_4 from wastewater treatment, Gg, 1990-2013.

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
$CH_{4,AD,\ gross}$	10.57	11.06	10.14	9.57	11.77	15.37	15.85	20.15	20.39	20.90
$CH_{4,recovery}$	10.45	10.93	10.03	9.46	11.64	15.21	15.69	19.96	20.21	20.69
$CH_{4,AD,net}$	0.12	0.13	0.12	0.11	0.13	0.16	0.16	0.19	0.19	0.20
$CH_{4,sewer+MB}$	0.23	0.23	0.23	0.23	0.24	0.25	0.26	0.27	0.28	0.28
$CH_{4,st}$	3.63	3.64	3.65	3.66	3.68	3.69	3.71	3.73	3.74	3.76
$CH_{4,total}$	3.98	3.99	3.99	4.00	4.04	4.10	4.13	4.19	4.21	4.24
Continued	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
$CH_{4,AD,\ gross}$	23.20	19.72	21.71	19.61	21.40	23.12	23.96	25.63	25.92	23.44
$CH_{4,recovery}$	22.97	19.50	21.48	19.38	21.18	22.88	23.73	25.40	25.70	23.22
$CH_{4,AD,net}$	0.23	0.23	0.23	0.23	0.22	0.24	0.23	0.23	0.22	0.22
$CH_{4,sewer+MB}$	0.28	0.27	0.27	0.27	0.27	0.28	0.27	0.28	0.26	0.28
$CH_{4,st}$	3.77	3.78	3.80	3.81	3.82	3.83	3.84	3.85	3.87	3.90
$CH_{4,total}$	4.28	4.28	4.30	4.31	4.31	4.35	4.34	4.36	4.36	4.40
Continued	2010	2011	2012	2013						
$CH_{4,AD,\ gross}$	23.82	26.44	30.86	29.80						
$CH_{4,recovery}$	23.59	26.22	30.63	29.55						
$CH_{4,AD,net}$	0.22	0.22	0.24	0.26						
$CH_{4,sewer+MB}$	0.28	0.29	0.28	0.29						
$CH_{4,st}$	3.91	3.93	3.95	3.96						
$CH_{4,total}$	4.42	4.44	4.46	4.51						

Table 3F-5.2 shows the total N_2O emission originating from treatment processes at the Danish WWTPs (direct emissions) and effluents to the Danish surface waters (indirect emissions).

Table 3F-5.2 N_2O emissions from wastewater, Mg, 1990-2013.

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
N_2O, indirect	265	252	219	273	268	238	180	158	154	147
N_2O, direct	73	77	72	75	99	111	113	116	126	123
N_2O, total	339	329	292	348	368	350	292	274	280	271
Continued	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
N_2O, indirect	157	134	137	109	119	111	109	116	103	108
N_2O, direct	134	137	176	140	125	161	127	154	214	127
N_2O, total	292	272	313	249	244	272	236	270	317	235
Continued	2010	2011	2012	2013						
N_2O, indirect	109	107	104	101						
N_2O, direct	136	150	131	147						
N_2O, total	246	257	235	248						

Table 3F-5.3 presents the development in the population number and the industrial contribution to the total degradable organic waste, TOW, in the influent wastewater. The total degradable organic waste, TOW, is measured in units of, respectively, BOD (Biological Oxygen Demand) and COD (Chemical Oxygen Demand) and are provided together with the COD/BOD ratio and the amount of TOW entering WWTPs using anaerobic sludge digestion as sludge management strategy ($COD_{influent,anaerobic}$).

Table 3F-5.3 Time series for the contribution from industrial wastewater to the influent TOW at Danish wastewater treatment plants, population number, measured BOD and COD data and resulting COD/BOD ratio, 1990-2013.

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Industrial inlet [%]	2.5	2.5	2.5	5.0	13.6	22.2	30.8	39.4	48.0	41.0
Population-Estimate (1000)	5,135	5,146	5,162	5,181	5,197	5,216	5,251	5,275	5,295	5,314
TOW (Gg COD/year)	300.73	301.38	302.29	307.04	320.63	334.50	349.53	363.97	378.21	369.77
TOW (Gg BOD/year)	96.53	96.27	96.56	99.27	107.74	116.32	125.35	134.20	143.01	136.02
COD/BOD ratio	3.1	3.1	3.1	3.1	3.0	2.9	2.8	2.7	2.6	2.7
$COD_{influent,anaerobic}$ [Gg]*	88.06	92.18	84.53	79.76	98.09	128.06	132.08	167.93	169.94	174.16
Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Industrial inlet [%]	42.0	38.0	38.0	37.0	40.5	40.5	40.5	40.5	40.5	40.5
Population-Estimate (1000)	5,330	5,349	5,368	5,384	5,398	5,411	5,427	5,447	5,476	5,511
TOW (Gg COD/year)	375.02	366.04	362.45	365.41	362.60	369.31	362.10	374.46	350.00	369.75
TOW (Gg BOD/year)	148.53	145.92	146.41	152.05	139.47	140.87	142.28	148.83	120.92	140.10
COD/BOD ratio	2.5	2.5	2.5	2.4	2.6	2.6	2.5	2.5	2.9	2.6
$COD_{influent,anaerobic}$ [Gg]*	193.3	164.4	180.9	163.4	178.4	192.7	199.7	213.6	216.0	195.3
Year	2010	2011	2012	2013						
Industrial inlet [%]	40.5	40.5	40.5	40.5						
Population-Estimate (1000)	5,535	5,561	5,581	5,603						
TOW (Gg COD/year)	379.01	380.82	374.46	387.59						
TOW (Gg BOD/year)	144.55	150.92	134.64	136.40						
COD/BOD ratio	2.6	2.5	2.8	2.8						
$COD_{influent,anaerobic}$ [Gg]*	198.5	220.3	257.2	248.4						

* The amount of the influent TOW at Danish WWTP using anaerobic digestion as sludge management strategy.

Table 3F-5.4 presents the nitrogen content in the influent and effluent wastewater.

Table 3F-5.4 Nitrogen content in the influent and effluent wastewater, Mg.

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Influent wastewater to WWTPs*	14,679	15,398	14,492	15,010	19,888	22,340	22,580	23,243	25,329	24,738
Effluent wastewater from WWTP**	10,268	9,520	7,480	10,787	10,241	8,938	6,387	4,851	6,387	5,135
Effluent wastewater, total**	16,884	16,032	13,953	17,403	17,079	15,152	11,431	10,068	9,796	9,363
Continued	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Influent wastewater to WWTPs*	26,952	27,499	35,187	28,038	24,991	32,288	25,401	30,899	42,808	25,519
Effluent wastewater from WWTP	4,653	4,221	4,528	3,614	4,027	3,831	3,634	4,358	3,575	4,025
Effluent wastewater, total**	10,005	8,553	8,740	6,927	7,589	7,038	6,935	7,381	6,557	6,878
Continued	2010	2011	2012	2013						
Influent wastewater to WWTPs*	27,357	30,049	26,316	29,557						
Effluent wastewater from WWTP	4,025	3,916	3,849	3,652						
Effluent wastewater, total**	6,960	6,770	6,597	6,399						

*Data on the influent wastewater N load from municipal WWTPs are available from the Danish Water Quality Parameter Database held by the Agency for Spatial and Environmental Planning

** Effluent wastewater, total includes separate industrial discharges, rainwater conditioned effluent, scattered houses, aquaculture and effluents from WWTPs (DEPA, 1994, 1996a, 1997, 1998, 1999a, 2000, 2001a, 2002, 2003a, 2004b, 2005a, 2005b and ASEP 2007, 2009, 2010, 2011, 2012, 2013),

Table 3F-5.5 presents the per cent uncertainties on the individual parameters used for calculating the uncertainties associated with activity data and emission factors used for estimating the methane and nitrous oxide emissions from category 5.D Wastewater treatment and discharge. References are given to the equations presented in Chapter 7.5.2

Table 3F-5.5 Input parameter uncertainties, %.

Input parameters and equations	Uncertainty. %	Reference
$CH_{4,\ sewer+MB}$		Eq. 7.5.2
$EF_{sewer+MB}=B_o*MCF_{sewer+MB}$	**32**	
B_o	30	IPCC, 2006
$MCF_{sewer+MB}$	10	IPCC, 2006
$Ac_{sewer+MB}$	**24**	
TOW	24	Table 3F-5.3
$CH_{4.\ AD,\ gross}$		Eq. 7.5.3
$EF_{AD}=B_o*MCF_{AD}*f_{AD}$	**39**	
B_o	30	IPCC, 2000
MCF_{AD}	10	IPCC, 2006
F_{AD}	23	Nielsen et al., 2014
Ac_{AD}	**24**	
TOW	24	Table 3F-5.3
$CH_{4.\ st}$		Eq. 7.5.5
$EF_{st}=MCF_{st}*B_o$	**32**	
MCF_{st}	10	IPCC, 2006
B_o	30	IPCC, 2000
$Ac_{st}=f_{nc}*P*DOC_{st}$	**31**	
f_{nc}	5	IPCC, 2000
DOC_{st}	30	IPCC, 2006
P	5	IPCC, 2000
N_2O.direct		Eq. 7.5.6
$EF_{N2O.direct}$	50	Nielsen et al.,2014
$Ac_{N2O.direct}$	22	Table 3F-5.4
$m_{N.influent}$	22	Table 3F-5.4
N_2O.indirect		Eq. 7.5.8
$EF_{N2Oindirect}$	42	Nielsen et al.,2014
$D_{N.WWTP}$	59	Nielsen et al.,2014

Annex 3F-6 Other. 5.E.1 Accidental fires

Table 3F-6.1 represents an overview of total and fossil CO_2 and CH_4 emissions for accidental building and vehicles fires, respectively, and the total emission in CO_2-equivalents for the CRF category *5.E Other*.

Table 3F-6.1 Overall emission of greenhouse gasses from accidental fires, 1990-2013.

Year		**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**
CO_2 emission from											
Accidental building fires	Gg	63.12	65.13	70.74	62.21	62.58	72.24	73.00	67.49	60.37	64.92
- of which non-biogenic	Gg	11.41	11.77	12.78	11.24	11.31	13.05	13.19	12.19	10.91	11.73
Accidental vehicle fires	Gg	6.13	6.17	6.20	6.42	6.44	6.54	6.67	6.66	6.75	6.80
Total. non-biogenic	Gg	17.54	17.94	18.99	17.66	17.75	19.60	19.86	18.85	17.65	18.53
CH_4 emission from											
Accidental building fires	Mg	64.15	66.17	71.84	63.19	63.55	73.35	74.11	68.55	61.31	65.95
Accidental vehicle fires	Mg	12.77	12.86	12.92	13.36	13.42	13.64	13.89	13.87	14.06	14.16
Total	Mg	12.77	79.03	84.77	76.56	76.97	86.99	88.00	82.41	75.36	80.11
5.E. Waste											
CO_2-eqvivalents	Gg	17.86	19.92	21.11	19.57	19.67	21.77	22.06	20.91	19.54	20.53
Year		**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
CO_2 emission from											
Accidental building fires	Gg	63.80	63.28	61.51	69.52	60.15	62.42	64.18	76.34	72.60	69.64
- of which non-biogenic	Gg	11.53	11.44	11.12	12.57	10.87	11.29	11.60	13.67	13.34	12.58
Accidental vehicle fires	Gg	6.87	6.87	6.84	6.78	6.73	6.86	7.11	5.68	8.15	8.49
Total. non-biogenic	Gg	18.40	18.31	17.96	19.35	17.60	18.14	18.71	19.35	21.49	21.07
CH_4 emission from											
Accidental building fires	Mg	64.87	64.51	62.77	71.00	61.46	63.77	65.62	75.18	74.63	71.34
Accidental vehicle fires	Mg	14.32	14.31	14.25	14.12	14.02	14.29	14.81	11.83	16.98	17.68
Total	Mg	79.2	78.8	77.0	85.1	75.5	78.1	80.4	87.0	91.6	89.0
6D. Waste other											
CO_2-eqvivalents	Gg	20.38	20.28	19.88	21.47	19.49	20.10	20.72	21.53	23.78	23.30
Year		**2010**	**2011**	**2012**	**2013**						
CO_2 emission from											
Accidental building fires	Gg	61.68	67.58	60.51	58.88						
- of which non-biogenic	Gg	11.09	12.15	10.79	10.58						
Accidental vehicle fires	Gg	7.26	6.30	5.56	5.41						
Total. non-biogenic	Gg	18.35	18.45	16.36	15.99						
CH_4 emission from											
Accidental building fires	Mg	64.61	68.46	61.67	60.62						
Accidental vehicle fires	Mg	15.12	13.12	11.59	11.27						
Total	Mg	79.7	81.6	73.3	71.9						
6D. Waste other											
CO_2-eqvivalents	Gg	20.34	20.49	18.19	17.78						

Table 3F-6.2 presents the occurrence of all accidental fires. building fires and vehicle fires. 1990-2013. Building and vehicle fires do not make up for all the national accidental fires. The total number of registered fires also include a portion of fires that does not fit into either building or vehicle fires. these are here called “Other fires” and will include e.g. a chair burning at a marked but mainly consist of “unknown/other” objects at “unknown/other open” locations.

Table 3F-6.2 Occurrence of accidental fires, 1990-2013.

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
All fires	17,025	17,589	19,124	16,803	16,918	19,543	19,756	18,236	16,320	17,538
Building fires	10,187	10,524	11,443	10,054	10,123	11,694	11,821	10,911	9,765	10,494
Vehicle fires	3,354	3,465	3,767	3,310	3,333	3,850	3,892	3,592	3,215	3,455
Other fires	3,485	3,600	3,914	3,439	3,463	4,000	4,043	3,732	3,340	3,589
Continued	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
All fires	17,174	16,894	16,362	18,443	15,927	16,551	16,965	18,263	20,643	18,930
Building fires	10,276	10,108	9,790	11,035	9,530	9,903	10,151	12,527	12,124	10,652
Vehicle fires	3,383	3,328	3,223	3,633	3,137	3,260	3,342	3,223	4,068	3,930
Other fires	3,515	3,458	3,349	3,775	3,260	3,387	3,472	2,513	4,451	4,348
Continued	2010	2011	2012	2013						
All fires	16,728	16,157	14,084	14,546						
Building fires	9,325	11,447	9,932	9,893						
Vehicle fires	3,459	3,255	2,889	2,841						
Other fires	3,944	1,455	1,263	1,764						

Table 3F-6.3 presents the full scale equivalent activity data of accidental building fires.

Table 3F-6.3 Accidental building fires full scale equivalent activity data.

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Container fires	750	775	842	740	745	861	870	803	719	772
Detached house fires	777	802	873	767	772	892	901	832	745	800
Undetached house fires	231	238	259	228	229	265	268	247	221	237
Apartment building fires	367	379	412	362	365	421	426	393	352	378
Industry building fire	320	331	360	316	318	368	372	343	307	330
Additional building fires	437	451	490	431	434	501	507	468	418	450
Continued	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Container fires	756	744	721	812	701	729	747	958	962	799
Detached house fires	784	771	747	841	727	755	774	757	886	876
Undetached house fires	233	229	222	250	216	224	230	343	278	208
Apartment building fires	370	364	353	398	343	357	366	405	433	413
Industry building fire	323	318	308	347	300	311	319	435	346	344
Additional building fires	440	433	420	473	408	424	435	483	523	466
Continued	2010	2011	2012	2013						
Container fires	594	729	584	584						
Detached house fires	833	818	742	761						
Undetached house fires	194	206	181	162						
Apartment building fires	348	362	327	316						
Industry building fire	281	334	298	275						
Additional building fires	429	740	610	619						

Table 3F-6.4a, b and c presents emission factors for 1990-2013 for accidental fires in detached houses, undetached houses and apartment buildings respectively.

Table 3F-6.4a Emission factors for accidental detached building fires, 1990-2013.

Year		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
CO_2 - total	Mg	30.6	30.5	30.5	30.5	30.5	30.4	30.3	30.4	30.4	30.4
CO_2 - biogenic	Mg	25.0	24.9	24.8	24.9	24.8	24.8	24.7	24.8	24.7	24.8
CO_2 - non-biogenic	Mg	5.7	5.7	5.6	5.7	5.6	5.6	5.6	5.6	5.6	5.6
CH_4	kg	40.6	40.4	40.3	40.4	40.3	40.2	40.2	40.3	40.2	40.3
Year		2000	2001	2002	2003	2004	2005	2006	2007	2008	2009

CO_2 - total	Mg	30.7	31.3	31.6	31.8	31.9	31.8	32.0	31.4	31.6	31.7
CO_2 - biogenic	Mg	25.0	25.5	25.7	25.9	26.0	25.9	26.1	25.6	25.7	25.9
CO_2 - non-biogenic	Mg	5.7	5.8	5.9	5.9	5.9	5.9	5.9	5.8	5.8	5.9
CH_4	kg	40.6	41.5	41.8	42.1	42.3	42.1	42.4	41.6	41.8	42.0
Year		2010	2011	2012	2013						
CO_2 - total	Mg	32.0	32.3	32.4	32.4						
CO_2 - biogenic	Mg	26.1	26.3	26.4	26.4						
CO_2 - non-biogenic	Mg	5.9	6.0	6.0	6.0						
CH_4	kg	42.3	42.7	43.0	43.0						

Table 3F-6.4b Emission factors for accidental undetached building fire, 1990-2013.

Year		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
CO_2 - total	Mg	25.3	25.2	25.2	25.2	25.2	25.2	25.3	25.4	25.5	25.6
CO_2 - biogenic	Mg	20.6	20.6	20.5	20.5	20.5	20.6	20.6	20.7	20.7	20.8
CO_2 - non-biogenic	Mg	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7
CH_4	kg	33.5	33.4	33.4	33.4	33.4	33.4	33.5	33.6	33.7	33.8
Year		2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
CO_2 - total	Mg	25.7	25.7	25.7	25.8	25.8	25.7	25.8	25.9	26.0	26.1
CO_2 - biogenic	Mg	20.9	20.9	21.0	21.0	21.0	21.0	21.0	21.1	21.2	21.3
CO_2 - non-biogenic	Mg	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8
CH_4	kg	34.0	34.0	34.1	34.1	34.2	34.1	34.2	34.3	34.5	34.6
Year		2010	2011	2012	2013						
CO_2 - total	Mg	26.2	26.0	26.2	26.2						
CO_2 - biogenic	Mg	21.4	21.2	21.4	21.4						
CO_2 - non-biogenic	Mg	4.9	4.8	4.9	4.9						
CH_4	kg	34.7	34.4	34.7	34.7						

Table 3F-6.4c Emission factors for accidental apartment building fires, 1990-2013.

Year		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
CO_2 - total	Mg	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.7
CO_2 - biogenic	Mg	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0
CO_2 - non-biogenic	Mg	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7
CH_4	kg	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5
Year		2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
CO_2 - total	Mg	14.7	14.7	14.8	14.8	14.8	14.8	14.9	15.0	15.0	15.1
CO_2 - biogenic	Mg	12.0	12.0	12.0	12.0	12.1	12.1	12.1	12.2	12.2	12.3
CO_2 - non-biogenic	Mg	2.7	2.7	2.7	2.7	2.7	2.7	2.8	2.8	2.8	2.8
CH_4	kg	19.5	19.5	19.5	19.6	19.6	19.7	19.7	19.8	19.9	20.0
Year		2010	2011	2012	2013						
CO_2 - total	Mg	15.1	15.2	15.2	15.2						
CO_2 - biogenic	Mg	12.3	12.4	12.4	12.4						
CO_2 - non-biogenic	Mg	2.8	2.8	2.8	2.8						
CH_4	kg	20.0	20.2	20.2	20.2						

Table 3F-6.5 states the average building floor space. 1990-2013.

Table 3F-6.5 Average floor space in building types.

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Detached houses	156	156	155	155	155	155	155	155	155	155
Undetached houses	129	128	128	128	128	129	129	129	130	130
Apartment buildings	75	75	75	75	75	75	75	75	75	75
Industrial buildings	500	500	500	500	500	500	500	500	500	500
Additional buildings	20	20	20	20	20	20	20	20	20	20
Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Detached houses	156	160	161	162	163	162	163	160	161	162
Undetached houses	131	131	131	131	132	131	132	132	133	133
Apartment buildings	75	75	75	75	75	76	76	76	77	77
Industrial buildings	500	500	500	500	500	500	500	500	500	500
Additional buildings	20	20	20	20	20	20	20	20	20	20
Year	2010	2011	2012	2013						
Detached houses	163	164	165	166						
Undetached houses	134	132	134	133						
Apartment buildings	77	78	78	78						
Industrial buildings	500	500	500	500						
Additional buildings	20	20	20	20						

Table 3F-6.6a-c presents the number of nationally registered vehicles and the number of full scale equivalent accidental vehicle fires, 1990-2013.

Table 3F-6.6a Number of nationally registered vehicles and full scale equivalent vehicle fires

	Passenger Cars		Buses		Light Duty Vehicles		Heavy Duty Vehicles	
	Registered	FSE fires	Registered	FSE fires	Registered	FSE fires	Registered	FSE fires
1990	1,645,454	479	8,109	12	192,317	19	45,664	58
1991	1,649,168	480	9,989	14	197,435	19	45,494	58
1992	1,659,795	483	11,259	16	202,802	20	45,510	58
1993	1,678,919	488	13,513	19	211,755	21	46,228	59
1994	1,672,022	486	14,261	20	219,639	21	47,329	60
1995	1,733,242	504	14,371	21	228,074	22	48,077	61
1996	1,792,971	522	14,594	21	234,404	23	48,319	61
1997	1,840,845	535	14,690	21	240,762	23	48,785	62
1998	1,877,740	546	14,894	21	249,462	24	49,697	63
1999	1,905,855	554	14,953	21	259,214	25	50,443	64
2000	1,916,364	557	15,051	22	272,386	27	50,227	64
2001	1,932,440	562	15,005	22	283,031	28	49,885	63
2002	1,946,073	566	14,971	21	295,581	29	49,208	62
2003	1,948,717	567	14,989	22	309,614	30	48,653	62
2004	1,967,432	572	14,997	22	336,038	33	48,318	61
2005	2,012,216	585	15,131	22	372,674	36	49,311	63
2006	2,093,809	609	15,243	22	414,625	40	50,777	64
2007	2,155,940	518	15,052	16	402,558	19	51,832	46
2008	2,187,104	666	14,854	24	398,717	44	50,606	71
2009	2,201,550	729	14,794	23	373,687	48	46,585	67
2010	2,246,675	646	14,577	23	362,385	38	44,813	60
2011	2,281,539	584	13,915	13	343,355	43	43,640	54
2012	2,326,778	514	13,177	11	318,668	32	42,326	53
2013	2,373,251	514	12,629	11	306,421	32	41,999	53

Table 3F-6.6b Number of nationally registered vehicles and full scale equivalent vehicle fires

	Motorcycles/Mopeds		Caravans		Train		Ship	
	Registe-	FSE fires	Registered	FSE fires	Registe-	FSE fires	Registered	FSE fires
1990	163,133	58	86,257	24	7,156	9	2,324	26
1991	162,357	57	88,278	24	7,212	9	2,312	26
1992	157,912	56	90,299	25	7,438	9	2,307	26
1993	155,325	55	93,150	26	7,496	9	2,140	24
1994	153,365	54	94,551	26	7,117	8	2,027	22
1995	165,272	58	95,831	26	6,854	8	1,911	21
1996	178,188	63	97,592	27	6,631	8	1,841	20
1997	191,772	68	99,931	27	6,428	8	1,761	19
1998	205,129	72	102,302	28	5,861	7	1,696	19
1999	219,577	78	104,852	29	5,525	7	1,695	19
2000	233,309	82	106,935	29	4,907	6	1,759	19
2001	243,020	86	108,924	30	4,561	5	1,797	20
2002	253,375	89	110,995	30	4,169	5	1,878	21
2003	256,438	91	113,338	31	4,048	5	1,838	20
2004	263,472	93	116,930	32	3,273	4	1,783	20
2005	273,904	97	121,350	33	3,195	4	1,792	20
2006	287,840	102	126,011	35	3,002	4	1,789	20
2007	302,900	99	131,708	36	2,617	2	1,755	20
2008	308,538	122	136,905	45	2,588	3	1,728	20
2009	307,335	128	140,366	34	2,489	5	1,742	22
2010	301,562	83	142,354	37	2,740	2	1,773	16
2011	295,488	91	142,764	34	2,943	3	1,768	21
2012	295,798	82	142,654	33	3,055	2	1,772	14
2013	296,522	82	142,667	33	3,048	2	1,781	14

Table 3F-6.6c Number of nationally registered vehicles and full scale equivalent vehicle fires

	Airplane		Tractor		Combined Harvester		Bicycle	Other Transport	Machine
	Registered	FSE fires	Registered	FSE fires	Registered	FSE fires	FSE fires	FSE fires	FSE fires
1990	1,055	1	131,880	82	33,594	56			
1991	1,059	1	131,637	82	32,542	54			
1992	1,066	1	128,205	80	31,460	52			
1993	1,059	1	129,747	81	31,502	52			
1994	1,063	1	123,596	77	29,775	49			
1995	1,058	1	130,028	81	27,986	46			
1996	1,088	1	120,480	75	28,609	47			
1997	1,094	1	124,067	77	25,418	42			
1998	1,091	1	115,509	72	25,452	42			
1999	1,087	1	115,978	72	22,961	38			
2000	1,070	1	111,736	69	23,272	39			
2001	1,089	1	110,300	69	22,811	38			
2002	1,149	1	108,865	68	22,349	37			
2003	1,083	1	107,430	67	21,888	36			
2004	1,055	1	105,994	66	21,426	36			
2005	1,073	1	104.551	65	20,965	35			
2006	1,039	1	102,603	64	20,504	34			
2007	1,058	1	99,237	52	20,042	19	2	85	75
2008	1,077	1	95,872	62	19,581	34	4	97	135
2009	1,122	1	92,507	64	19,119	43	3	93	111
2010	1,152	1	89,141	77	15,986	32	4	58	94
2011	1,132	0	85,776	59	14,990	21	3	50	111
2012	1,111	0	82,410	68	13,994	18	2	50	115
2013	1,069	0	79,045	68	12,998	18			

Table 3F-6.7 presents the average weight of passenger cars, buses, vans, trucks and motorcycles/mopeds in 1990-2013.

Table 3F-6.7 Average weight of different vehicle categories, kg, 1990-2013.

	Cars	Buses	Vans	Trucks	Motorcycles/ Mopeds
1990	850	10,000	2,000	15,000	86
1991	850	10,000	2,000	15,000	88
1992	850	10,000	2,000	15,000	91
1993	901	10,068	2,297	14,732	93
1994	908	10,512	2,382	14,674	96
1995	923	10,807	2,492	14,801	97
1996	935	10,899	2,638	14,928	98
1997	948	10,950	2,746	14,987	99
1998	964	10,960	2,848	15,111	100
1999	982	11,140	2,964	15,223	102
2000	999	11,195	3,103	15,214	103
2001	1,012	11,312	3,238	14,888	105
2002	1,024	11,387	3,333	14,486	107
2003	1,039	11,479	3,442	14,026	109
2004	1,052	11,572	3,561	13,599	112
2005	1,068	11,560	3,793	13,258	116
2006	1,086	11,684	4,120	13,179	120
2007	1,105	11,753	4,505	13,268	124
2008	1,122	11,700	4,710	13,246	127
2009	1,134	11,642	4,682	12,802	130
2010	1,144	11,804	4,498	11,883	133
2011	1,154	11,907	4,296	11,291	135
2012	1,160	11,625	4,150	10,844	136
2013	1,162	11,463	4,046	10,861	134

The following Table 3F-6.8 shows the annual amount of combusted vehicle in accidental fires.

Table 3F-6.8 Burnt mass of different vehicle and machine categories, Mg.

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Passenger cars	407	408	410	440	442	465	488	508	527	544
Buses	116	143	162	195	215	223	228	231	234	239
Light duty vehicles	37	38	40	47	51	55	60	64	69	75
Heavy duty vehicles	869	865	866	864	881	902	915	927	952	974
Motorcycle. moped	5	5	5	5	5	5	6	7	7	8
Other transport	-	-	-	-	-	-	-	-	-	-
Caravan	30	31	32	35	35	36	38	39	41	42
Train	128	129	133	132	125	121	118	115	106	100
Ship	257	256	255	238	236	228	222	213	205	209
Airplane	12	12	12	11	11	11	12	12	12	12
Bicycle	-	-	-	-	-	-	-	-	-	-
Tractor	180	180	175	203	201	221	217	232	224	235
Combined harvester	593	584	573	583	559	533	553	499	506	463
Machine	-	-	-	-	-	-	-	-	-	-
Total	2,634	2,650	2,661	2,753	2,760	2,803	2,856	2,847	2,884	2,901
Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Passenger cars	557	569	580	589	602	625	662	572	748	827
Buses	242	244	245	247	249	251	256	182	283	264
Light duty vehicles	82	89	96	104	117	138	166	86	207	223
Heavy duty vehicles	969	942	904	865	833	829	849	608	936	863
Motorcycle. moped	8	9	9	10	10	11	11	11	14	15
Other transport	-	-	-	-	-	-	-	47	54	53
Caravan	44	45	47	48	51	53	56	59	75	57
Train	89	81	72	68	53	51	47	33	39	63
Ship	218	225	236	233	228	229	231	234	230	253
Airplane	12	12	12	11	10	10	10	8	13	13
Bicycle	-	-	-	-	-	-	-	0	0	0
Tractor	237	244	248	252	258	271	288	235	290	301
Combined harvester	476	473	470	466	462	458	442	231	415	533
Machine	-	-	-	-	-	-	-	33	61	50
Total	2,933	2,932	2,918	2,893	2,873	2,925	3,018	2,340	3,366	3,516
Year	2010	2011	2012	2013						
Passenger cars	739	674	592	555						
Buses	266	160	130	121						
Light duty vehicles	171	185	133	118						
Heavy duty vehicles	715	606	579	455						
Motorcycle. moped	10	12	11	11						
Other transport	33	29	29	26						
Caravan	63	59	57	59						
Train	24	28	23	18						
Ship	189	249	160	100						
Airplane	7	3	5	5						
Bicycle	0	0	0	0						
Tractor	347	254	283	330						
Combined harvester	398	271	236	402						
Machine	43	51	53	53						
Total	3,006	2,580	2,291	2,253						

Annex 3F-7 Recalculations to the waste sector

Table 3F-7.1 Changes in emissions from Solid Waste Disposal compared with the CRF reported last year.

SWDS	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
CH_4, previous inventory	Gg	65.0	65.4	64.8	64.3	61.2	57.6	56.0	52.6	49.7	50.3
CH_4, recalculated	Gg	71.0	71.0	70.2	69.4	66.1	62.2	60.4	56.8	53.7	54.2
Change, CO_2-equivalents	Gg	148.2	141.1	134.3	127.9	121.8	116.1	110.6	105.5	100.6	95.9
Change	%	9.1	8.6	8.3	8.0	8.0	8.1	7.9	8.0	8.1	7.6
Continued	Unit	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
CH_4, previous inventory	Gg	49.9	49.6	46.5	47.4	42.3	41.1	42.7	40.7	39.4	37.8
CH_4, recalculated	Gg	51.0	53.1	49.9	50.5	45.3	44.0	45.5	43.4	41.9	40.1
Change, CO_2-equivalents	Gg	29.3	87.3	83.4	79.6	76.0	72.6	69.4	66.3	63.4	58.9
Change	%	2.4	7.0	7.2	6.7	7.2	7.1	6.5	6.5	6.4	6.2
Continued	Unit	2010	2011	2012	2013						
CH_4, previous inventory	Gg	34.3	34.8	33.2							
CH_4, recalculated	Gg	37.2	37.0	35.1	33.8						
Change, CO_2-equivalents	Gg	73.4	54.4	47.7							
Change	%	8.6	6.3	5.7							

Table 3F-7.2 Changes in emissions from Biological treatment of Solid Waste compared with the CRF reported last year.

Biological treatment of Solid Waste, 5.B	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
CH_4, previous inventory	Mg	1386	1533	1679	1825	1973	1860	2171	2527	2628	3033
CH_4, recalculated	Mg	1386	1533	1679	1825	1973	1860	2171	2527	2628	3033
N_2O, previous inventory	Mg	41	46	51	56	61	73	79	93	191	350
N_2O, recalculated	Mg	41	46	51	56	61	73	79	93	191	350
Change, CO_2-equivalents	Mg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Change	%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Continued	Unit	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
CH_4, previous inventory	Mg	3240	3060	3397	3534	3222	3420	3628	4017	3686	4011
CH_4, recalculated	Mg	3240	3060	3397	3534	3222	3420	3628	4017	3686	4011
N_2O, previous inventory	Mg	516	498	771	753	202	200	239	295	292	330
N_2O, recalculated	Mg	516	498	771	753	202	200	239	295	292	330
Change, CO_2-equivalents	Mg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Change	%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Continued	Unit	2010	2011	2012	2013						
CH_4, previous inventory	Mg	4095	4204	4306							
CH_4, recalculated	Mg	3073	3862	3554	5027						
N_2O, previous inventory	Mg	355	381	409							
N_2O, recalculated	Mg	253	318	293	414						
Change, CO_2 equivalents	Gg	-55.97	-27.50	-53.40							
Change	%	-26.88	-12.57	-23.26							

Table 3F-7.3 Changes in emissions from Incineration and open burning of waste compared with the CRF reported last year.

Incineration and open burning of waste	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
CH_4, previous inventory	Mg	0.51	0.51	0.52	0.54	0.54	0.55	0.55	0.54	0.53	0.56
CH_4, recalculated	Mg	0.51	0.51	0.52	0.54	0.54	0.55	0.55	0.54	0.53	0.56
N_2O, previous inventory	Mg	0.64	0.63	0.65	0.68	0.67	0.69	0.68	0.68	0.67	0.71
N_2O, recalculated	Mg	0.64	0.63	0.65	0.68	0.67	0.69	0.68	0.68	0.67	0.71
Change, CO_2-equivalents	Gg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Change	%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Continued	Unit	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
CH_4, previous inventory	Mg	0.57	0.57	0.58	0.58	0.59	0.62	0.69	0.72	0.73	0.74
CH_4, recalculated	Mg	0.57	0.57	0.58	0.58	0.59	0.62	0.69	0.72	0.73	0.74
N_2O, previous inventory	Mg	0.71	0.72	0.73	0.72	0.74	0.77	0.86	0.90	0.92	0.93
N_2O, recalculated	Mg	0.71	0.72	0.73	0.72	0.74	0.77	0.86	0.90	0.92	0.93
Change, CO_2-equivalents	Gg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Change	%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Continued	Unit	2010	2011	2012	2013						
CH_4, previous inventory	Mg	0.76	0.71	0.70							
CH_4, recalculated	Mg	0.76	0.71	0.70	0.71						
N_2O, previous inventory	Mg	0.95	0.88	0.88							
N_2O, recalculated	Mg	0.95	0.88	0.88	0.88						
Change, CO_2 equivalents	Gg	0.00	0.00	0.00							
Change	%	0.00	0.00	0.00							

Table 3F-7.4 Changes in emissions from Wastewater Treatment and Discharge compared with the CRF reported last year.

Wastewater Treatment and Discharge	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
CH_4, previous inventory	Gg	3.12	3.12	3.13	3.15	3.19	3.23	3.30	3.36	3.37	3.35
CH_4, recalculated	Gg	3.98	3.99	3.99	4.00	4.04	4.10	4.13	4.19	4.21	4.24
N_2O, previous inventory	Gg	0.34	0.33	0.29	0.35	0.37	0.35	0.29	0.27	0.28	0.27
N_2O, recalculated	Gg	0.34	0.33	0.29	0.35	0.37	0.35	0.29	0.27	0.28	0.27
Change, CO_2 equivalents	Gg	21.50	21.71	21.49	21.24	21.36	21.81	20.91	20.85	21.06	22.28
Change	%	12.02	12.33	13.01	11.63	11.29	11.80	12.34	12.58	12.55	13.56

Continued	Unit	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
CH_4, previous inventory	Gg	3.48	3.48	3.40	3.47	3.41	3.45	3.46	3.49	3.41	3.50
CH_4, recalculated	Gg	4.28	4.28	4.30	4.31	4.31	4.35	4.34	4.36	4.36	4.40
N_2O, previous inventory	Gg	0.29	0.27	0.31	0.25	0.24	0.27	0.24	0.27	0.32	0.24
N_2O, recalculated	Gg	0.29	0.27	0.31	0.25	0.24	0.27	0.24	0.27	0.32	0.24
Change, CO_2 equivalents	Gg	20.03	20.22	22.36	21.11	22.41	22.49	22.08	21.73	23.64	22.47
Change	%	11.53	12.05	12.54	13.13	14.18	13.46	14.09	12.95	13.16	14.26

Continued	Unit	2010	2011	2012	2013
CH_4, previous inventory	Gg	3.53	3.56	3.52	
CH_4, recalculated	Gg	4.42	4.44	4.46	4.51
N_2O, previous inventory	Gg	0.25	0.26	0.23	
N_2O, recalculated	Gg	0.25	0.26	0.23	0.25
Change, CO_2 equivalents	Gg	22.35	22.01	23.53	
Change	%	13.84	13.30	14.88	

Table 3F-7.5 Changes in emissions from Waste Other compared with the CRF reported last year.

Waste Other	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
CO_2, previous inventory	Gg	17.54	17.94	18.99	17.66	17.75	19.60	19.86	18.85	17.65	18.53
CO_2, recalculated	Gg	17.54	17.94	18.99	17.66	17.75	19.60	19.86	18.85	17.65	18.52
CH_4, previous inventory	Gg	0.08	0.08	0.08	0.08	0.08	0.09	0.09	0.08	0.08	0.08
CH_4, recalculated	Gg	0.08	0.08	0.08	0.08	0.08	0.09	0.09	0.08	0.08	0.08
Change, CO_2 equivalents	Gg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Change	%	0.00	0.00	0.00	0.00	-0.01	-0.01	-0.01	-0.01	-0.02	-0.02
Continued	Unit	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
CO_2, previous inventory	Gg	18.40	18.31	17.96	19.35	17.60	18.14	18.71	19.35	21.49	21.07
CO_2, recalculated	Gg	18.40	18.30	17.95	19.34	17.60	18.13	18.70	19.29	21.42	21.02
CH_4, previous inventory	Gg	0.08	0.08	0.08	0.09	0.08	0.08	0.08	0.09	0.09	0.09
CH_4, recalculated	Gg	0.08	0.08	0.08	0.09	0.08	0.08	0.08	0.09	0.09	0.09
Change, CO_2 equivalents	Gg	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.02	-0.07	-0.07	-0.05
Change	%	-0.03	-0.04	-0.04	-0.04	-0.05	-0.06	-0.08	-0.31	-0.31	-0.22
Continued	Unit	2010	2011	2012	2013						
CO_2, previous inventory	Gg	18.35	18.45	16.36							
CO_2, recalculated	Gg	18.30	18.34	16.29	15.97						
CH_4, previous inventory	Gg	0.08	0.08	0.07							
CH_4, recalculated	Gg	0.08	0.08	0.07	0.07						
Change, CO_2 equivalents	Gg	-0.05	-0.11	-0.07							
Change	%	-0.23	-0.54	-0.37							

Table 3F-7.6 Changes in emissions from the waste sector compared with the CRF reported last year.

Waste	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
CO_2, previous inventory	Gg	17.5	17.9	19.0	17.7	17.7	19.6	19.9	18.9	17.7	18.5
CO_2, recalculated	Gg	17.5	17.9	19.0	17.7	17.7	19.6	19.9	18.8	17.7	18.5
CH_4, previous inventory	Gg	69.6	70.1	69.7	69.4	66.4	62.8	61.6	58.6	55.8	56.8
CH_4, recalculated	Gg	76.4	76.6	76.0	75.4	72.2	68.3	66.8	63.6	60.7	61.5
N_2O, previous inventory	Gg	0.4	0.4	0.3	0.4	0.4	0.4	0.4	0.4	0.5	0.6
N_2O, recalculated	Gg	0.4	0.4	0.3	0.4	0.4	0.4	0.4	0.4	0.5	0.6
Change, CO_2-equivalents	Gg	-169.7	-162.8	-155.8	-149.1	-143.2	-137.9	-131.5	-126.3	-121.6	-118.2
Change	%	-9.1	-8.6	-8.4	-8.0	-7.9	-8.0	-7.9	-7.9	-7.8	-7.3
Continued	Unit	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
CO_2, previous inventory	Gg	18.4	18.3	18.0	19.3	17.6	18.1	18.7	19.4	21.5	21.1
CO_2, recalculated	Gg	18.4	18.3	17.9	19.3	17.6	18.1	18.7	19.3	21.4	21.0
CH_4, previous inventory	Gg	56.7	56.2	53.4	54.4	49.0	48.0	49.9	48.3	46.6	45.4
CH_4, recalculated	Gg	58.6	60.5	57.6	58.5	52.9	51.8	53.5	51.8	50.1	48.6
N_2O, previous inventory	Gg	0.8	0.8	1.1	1.0	0.4	0.5	0.5	0.6	0.6	0.6
N_2O, recalculated	Gg	0.8	0.8	1.1	1.0	0.4	0.5	0.5	0.6	0.6	0.6
Change, CO_2-equivalents	Gg	-49.4	-107.6	-105.7	-100.7	-98.4	-95.1	-91.5	-88.1	-87.1	-81.5
Change	%	-2.9	-6.5	-6.3	-6.0	-7.2	-7.0	-6.5	-6.3	-6.4	-6.2
Continued	Unit	2010	2011	2012	2013						
CO_2, previous inventory	Gg	18.35	18.45	16.36							
CO_2, recalculated	Gg	18.30	18.34	16.29	15.97						
CH_4, previous inventory	Gg	42.0	42.7	41.1							
CH_4, recalculated	Gg	44.8	45.4	43.2	43.4						
N_2O, previous inventory	Gg	0.60	0.64	0.64							
N_2O, recalculated	Gg	0.50	0.58	0.53	0.66						
Change, CO_2-equivalents	Gg	-100.7	-86.5	-87.1							
Change	%	-9.3	-7.8	-8.1							

Annex 4 - Information on the energy statistics

This description of the Danish energy statistics has been prepared by Denmark's National Environmental Research Institute, NERI (now DCE) in co-operation with the Danish Energy Agency (DEA) as background information to the Danish National Inventory Report (NIR).

The Danish energy statistics system

DEA is responsible for the Danish energy balance. Main contributors to the energy statistics outside DEA are Statistics Denmark and Danish Energy Association (before Association of Danish Energy Companies). The statistics is performed using an integrated statistical system building on an Access database and Excel spreadsheets.

The DEA follows the recommendations of the International Energy Agency as well as Eurostat.

The national energy statistics is updated annually and all revisions are immediately included in the published statistics, which can be found on the DEA homepage[1]. It is an easy task to check for breaks in a series because the statistics is 100 % time-series oriented.

The national energy statistics does not include Greenland and Faroe Islands.

For historical reasons, DEA receive monthly information from the Danish oil companies regarding Danish deliveries of oil products to Greenland and Faroe Islands. However, the monthly (MOS) and annual (AOS) reporting of oil statistics to Eurostat and IEA exclude Greenland and Faroe Islands. For all other energy products, the Danish figures are also excluding Greenland and Faroe Islands.

Reporting to the Danish Energy Agency

The Danish Energy Agency receives monthly statistics for the following fuel groups:

- Crude oil and oil products
    - Monthly data from 46 oil companies, the main purpose is monitoring oil stocks according to the oil preparedness system
- Natural gas
    - Fuel/flare from platforms in the North Sea
    - Natural gas balance from the regulator Energinet.dk (National monopoly)
- Coal and coke
    - Power plants (94 %)
    - Industry companies (4 %)
    - Coal and coke traders (2 %)
- Electricity

[1] http://www.ens.dk/EN-US/INFO/FACTSANDFIGURES/ENERGY_STATISTICS_AND_INDICATORS/ANNUAL%20STATISTICS/Sider/Forside.aspx

- Monthly reporting by e-mail from the regulator Energinet.dk (National monopoly)
    - The statistics covers:
        - Production by type of producer
        - Own use of electricity
        - Import and export by country
        - Domestic supply (consumption + distribution loss)
- Town gas (quarterly) from two town gas producers
- The large central power plants also report monthly consumption of biomass

Annual data includes renewable energy including waste. The DEA conducts a biannual survey on wood pellets and wood fuel. Statistics Denmark conducts biannual surveys on the energy consumption in the service and industrial sectors. Statistics Denmark prepares annual surveys on forest (wood fuel) & straw.

Other annual data sources include:

- DEA
    - Survey on production of electricity and heat and fuels used
    - Survey on end use of oil
    - Survey on end use of natural gas
    - Survey on end use of coal and coke
- DCE, Aarhus University
    - Energy consumption for domestic air transport
- Danish Energy Association (Association of Danish Energy companies)
    - Survey on electricity consumption
- Ministry of Taxation
    - Border trade
- Centre for Biomass Technology
    - Annual estimates of final consumption of straw and wood chips

Annual revisions

In general, DEA follows the same procedures as in the Danish national account. This means that normally only figures for the last two years are revised.

Aggregating the energy statistics on SNAP level

The sectors used in the official energy statistics have been mapped to SNAP categories, used in the Danish emission database. DCE aggregates the official energy statistics to SNAP level based on a source correspondence table.

In cooperation between DEA and DCE, a fuel correspondence table has been developed mapping the fuels used by the DEA in the official energy statistics with the fuel codes used in the Danish national emission database. The fuel correspondence table between fuel categories used by the DEA, DCE and IPCC is presented in Annex 3A-3.

The mapping between the energy statistics and the SNAP and fuel codes used by DCE can be seen in the table below.

Table 3A-9.1 Correspondence between the Danish national energy statistics and the SNAP nomenclature (only stationary combustion part shown).

Unit: TJ	Enduse		Transformation	
	SNAP	Fuel	SNAP	Fuel
Energy Sector				
Extraction and Gasification				
- Extraction				
- - Natural Gas	010504	301A		
- Gasification				
- - Biogas, Landfill				
- - Biogas, Other				
- - Electricity				
Refineries				
- Used for Refining				
- - Crude Oil				
- - Refinery Feedstocks				
- - Electricity				
- - District Heating				
- Own Use				
- - Refinery Gas	010306	308A		
- - LPG	010306	303A		
- - Gas-/Diesel Oil	010306	204A		
- - Fuel Oil	010306	203A		
- Net Production				
- - Refinery Gas				
- - LPG				
- - Naphtha (LVN)				
- - Aviation Gasoline				
- - Motor Gasoline				
- - JP4				
- - Other Kerosene				
- - JP1				
- - Gas-/Diesel Oil				
- - Fuel Oil				
- - Petroleum Coke				
- - White Spirit				
- - Lubricants				
- - Bitumen				
Distribution				
- Electricity Used in Distribution				
- - Elelctricity Distribution				
- - District Heating Distribution				
- - Gas Distribution				
Transformation Sector				
Large-scale Power Units				
- Fuels Used for Power Production				
- - Gas-/Diesel Oil			010100	204A
- - Fuel Oil			010100	203A
- - Electricity Plant Coal			010100	102A
- - Straw			010100	117A
- Own Use				
- - Electricity				
- Gross Production				
- - Electricity				
Large-Scale CHP Units				
- Fuels Used for Power Production				
- - Refinery Gas			010300	308A
- - LPG			010100	303A
- - Naphtha (LVN)			010100	210A
- - Gas-/Diesel Oil			010100	204A
- - Fuel Oil			010100	203A
- - Petroleum Coke			010100	110A
- - Orimulsion			010100	225A
- - Natural Gas			010100	301A
- - Electricity Plant Coal			010100	102A
- - Straw			010100	117A
- - Wood Chips			010100	111A
- - Wood Pellets			010100	111A
- - Wood Waste			010100	111A
- - Biogas, Landfill			010100	309A
- - Biogas, Sludge			010100	309A
- - Biogas, Others			010100	309A

Continued			
- - Waste, Non-renewable		010100	114A
- - Wastes, Renewable		010100	114A
- Fuels Used for Heat Production			
- - Refinery Gas		010300	308A
- - LPG		010100	303A
- - Naphtha (LVN)		010100	210A
- - Gas-/Diesel Oil		010100	204A
- - Fuel Oil		010100	203A
- - Petroleum Coke		010100	110A
- - Orimulsion		010100	225A
- - Natural Gas		010100	301A
- - Electricity Plant Coal		010100	102A
- - Straw		010100	117A
- - Wood Chips		010100	111A
- - Wood Pellets		010100	111A
- - Wood Waste		010100	111A
- - Biogas, Landfill		010100	309A
- - Biogas, Sludge		010100	309A
- - Biogas, Other		010100	309A
- - Wastes, Non-renewable		010100	114A
- - Wastes, Renewable		010100	114A
- Own Use			
- - Electricity			
- - District Heating			
- Production			
- - Electricity, Gross			
- - District Heating, Net			
Small-Scale CHP Units			
- Fuels Used for Power Production			
- - Gas-/Diesel Oil		010100	204A
- - Fuel Oil		010100	203A
- - Natural Gas		010100	301A
- - Hard Coal		010100	102A
- - Straw		010100	117A
- - Wood Chips		010100	111A
- - Wood Pellets		010100	111A
- - Wood Waste		010100	111A
- - Biogas, Landfill		010100	309A
- - Biogas, Sludge		010100	309A
- - Biogas, Other		010100	309A
- - Waste, Non-renewable		010100	114A
- - Wastes, Renewable		010100	114A
- Fuels Used for Heat Production			
- - Gas-/Diesel Oil		010100	204A
- - Fuel Oil		010100	203A
- - Natural Gas		010100	301A
- - Coal		010100	102A
- - Straw		010100	117A
- - Wood Chips		010100	111A
- - Wood Pellets		010100	111A
- - Wood Waste		010100	111A
- - Biogas, Landfill		010100	309A
- - Biogas, Sludge		010100	309A
- - Biogas, Other		010100	309A
- - Wastes, Non-renewable		010100	114A
- - Wastes, Renewable		010100	114A
- Own Use			
- - Electricity			
- - District Heating			
- Production			
- - Electricity, Gross			
- - District Heating, Net			
Wind Turbines			
- Used for Power Production			
- - Wind Power			
- Gross Production			
- - Electricity			
Hydro Power Units			
- Used for Power Production			
- - Hydro Power			
- Gross Production			
- - Electricity			

Continued			
District Heating Units			
- Fuels Used for Heat Production			
- - Refinery Gas		010300	308A
- - LPG		010200	303A
- - Gas-/Diesel Oil		010200	204A
- - Fuel Oil		010200	203A
- - Waste Oil		010200	203A
- - Petroleum Coke		010200	110A
- - Natural Gas		010200	301A
- - Electricity Plant Coal		010200	102A
- - Coal		010200	102A
- - Solar Energy			
- - Geothermal Energy			
- - Straw		010200	117A
- - Wood Chips		010200	111A
- - Wood Pellets		010200	111A
- - Wood Waste		010200	111A
- - Biogas, Landfill		010200	309A
- - Biogas, Sludge		010200	309A
- - Biogas, Other		010200	309A
- - Wastes, Non-renewable		010200	114A
- - Wastes, Renewable		010200	114A
- - Fish Oil		010200	215A
- - Electricity for Heat Pumps			
- Own Use			
- - District Heating			
- Net Production			
- - District Heating			
Autoproducers, Electricity Only			
- Fuels Used for Power Production			
- - Natural Gas		030100	301A
- - Solar Energy			
- - Biogas, Landfill		030100	309A
- - Biogas, Sewage Sludge		030100	309A
- - Biogas, Other		030100	309A
- Gross Production			
- - Electricity			
Autoproducers, CHP Units			
- Fuels Used for Power Production			
- - Refinery Gas		010300	308A
- - Gas-/Diesel Oil		030100	204A
- - Fuel Oil		030100	203A
- - Waste Oil		030100	203A
- - Natural Gas		030100	301A
- - Coal		030100	102A
- - Straw		030100	117A
- - Wood Chips		030100	111A
- - Wood Pellets		030100	111A
- - Wood Waste		030100	111A
- - Biogas, Landfill		030100	309A
- - Biogas, Sludge		030100	309A
- - Biogas, Other		030100	309A
- - Fish Oil		030100	215A
- - Wastes, Non-renewable		010100	114A
- - Wastes, Renewable		010100	114A
- Fuels Used for Heat Production		030100	114A
- - Refinery Gas		010300	308A
- - Gas-/Diesel Oil		030100	204A
- - Fuel Oil		030100	203A
- - Waste Oil		030100	203A
- - Natural Gas		030100	301A
- - Coal		030100	102A
- - Wood Chips		030100	111A
- - Wood Waste		030100	111A
- - Biogas, Landfill		030100	309A
- - Biogas, Sludge		030100	309A
- - Biogas, Other		030100	309A
- - Wastes, Non-renewable		010100	114A
- - Wastes, Renewable		010100	114A
- Production			
- - Electricity, Gross			
- - District Heating, Net			

Continued				
Autoproducers, Heat Only				
- Fuels Used for Heat Production				
- - Gas-/Diesel Oil			030100	204A
- - Fuel Oil			030100	203A
- - Waste Oil			030100	203A
- - Natural Gas			030100	301A
- - Straw			030100	117A
- - Wood Chips			030100	111A
- - Wood Chips			030100	111A
- - Wood Waste			030100	111A
- - Biogas, Landfill			030100	309A
- - Biogas, Sludge			030100	309A
- - Biogas, Other			030100	309A
- - Wastes, Non-renewable			010200	114A
- - Wastes, Renewable			010200	114A
- - Heat Pumps				
- Net Production				
- - District Heating				
Gas Works Gas Units	030106	301A		
- Fuels Used for Production of District Heating				
- - Refinery Gas				
- - LPG				
- - Naphtha (LVN)				
- - Gas-/Diesel Oil				
- - Natural Gas				
- - Hard Coal				
- Production				
- - Gas Works Gas				
- - Coke				
Distribution Losses				
- Distribution Losses etc.				
- - Natural Gas				
- - Electricity				
- - District Heating				
- - Gas Works Gas				
Consumption Sector				
- Non-energy Use				
- - White Spirit				
- - Lubricants				
- - Bitumen				
Transport				
Military Transport				
- Aviation Gasoline				
- Motor Gasoline				
- JP4				
- JP1				
- Gas-/Diesel Oil				
Road				
- LPG				
- Motor Gasoline				
- Other Kerosene	020200	206A		
- Gas-/Diesel Oil				
- Fuel Oil				
- Bioethanol				
- Biodielsel				
Rail				
- Motor Gasoline				
- Other Kerosene				
- Gas-/Diesel Oil				
- Electricity				
Domestic Sea Transport				
- LPG	Transport			
- Other Kerosene	Transport			
- Gas-/Diesel Oil	Transport			
- Fuel Oil	Transport			
Domestic Aviation				
- LPG	Transport			
- Aviation Gasoline	Transport			
- Motor Gasoline	Transport			
- Other Kerosene	020100	206A		

Continued			
- JP1	Transport		
International Aviation			
- Aviation Gasoline	Transport		
- JP1	Transport		
Agriculture and Foresty			
- LPG	Transport		
- Motor Gasoline	Transport		
- Other Kerosene	020300	206A	
- Gas-/Diesel Oil	Transport		
- Fuel Oil	020300	203A	
- Petroleum Coke	020300	110A	
- Natural Gas	020300	301A	
- Coal	020300	102A	
- Brown Coal Briquettes	020300	106A	
- Straw	020300	117A	
- Wood Chips	020300	111A	
- Wood Waste	020300	111A	
- Biogas, Other	020300	309A	
- Heat Pumps			
- Electricity			
Horticulture			
- LPG	Transport		
- Motor Gasoline	Transport		
- Gas-/Diesel Oil	Transport		
- Fuel Oil	020300	203A	
- Petroleum Coke	020300	110A	
- Natural Gas	020300	301A	
- Coal	020300	102A	
- Wood Waste	020300	111A	
- Electricity			
- District Heating			
Fishing			
- LPG	Transport		
- Motor Gasoline	Transport		
- Other Kerosene	Transport		
- Gas-/Diesel Oil	Transport		
- Fuel Oil	Transport		
Manufacturing Industry			
- Refinery Gas	030100	308A	
- LPG	Transport		
- Naphtha (LVN)	Transport		
- Motor Gasoline	Transport		
- Other Kerosene	030100	206A	
- Gas-/Diesel Oil	Transport		
- Fuel Oil	030100	203A	
- Waste Oil	030100	203A	
- Petroleum Coke	030100	110A	
- Natural Gas	030100	301A	
- Coal	030100	102A	
- Coke	030100	107A	
- Brown Coal Briquettes	030100	106A	
- Wood Pellets	030100	111A	
- Wood Waste	030100	111A	
- Biogas, Landfill	030100	111A	
- Biogas, Sludge	030100	309A	
- Biogas, Other	030100	309A	
- Wastes, Non-renewable	030100	114A	
- Wastes, Renewable	030100	114A	
- Heat Pumps			
- Electricity			
- District Heating			
- Gas Works Gas	030100	301A	
Construction			
- LPG	031500	303A	
- Motor Gasoline	Transport		
- Other Kerosene	031500	206A	
- Gas-/Diesel Oil	Transport		
- Fuel Oil	031500	203A	
- Natural Gas	031500	301A	
- Electricity			
Wholesale			
- LPG	020100	303A	

Continued			
- Motor Gasoline	020100	206A	
- Other Kerosene	020100	204A	
- Gas-/Diesel Oil	020100	203A	
- Petroleum Coke	020100	110A	
- Natural Gas	020100	301A	
- Wood Waste	020100	111A	
- Electricity			
- District Heating			
Retail Trade			
- LPG	020100	303A	
- Other Kerosene	020100	206A	
- Gas-/Diesel Oil	020100	204A	
- Fuel Oil	020100	203A	
- Petroleum Coke	020100	110A	
- Natural Gas	020100	301A	
- Electricity			
- District Heating			
Private Service			
- LPG	020100	303A	
- Other Kerosene	020100	206A	
- Gas-/Diesel Oil	020100	204A	
- Fuel Oil	020100	203A	
- Waste Oil	020100	203A	
- Petroleum Coke	020100	110A	
- Natural Gas	020100	301A	
- Wood Chips	020100	111A	
- Wood Waste	020100	111A	
- Biogas, Landfill	020100	309A	
- Biogas, Sludge	020100	309A	
- Biogas, Other	020100	309A	
- Wastes, Non-renewable	020100	114A	
- Wastes, Renewable	020100	114A	
- Electricity			
- District Heating			
- Gas Works Gas	020100	301A	
Public Service			
- LPG	020100	303A	
- Other Kerosene	020100	206A	
- Gas-/Diesel Oil	020100	204A	
- Fuel Oil	020100	203A	
- Petroleum Coke	020100	110A	
- Natural Gas	020100	301A	
- Coal	020100	102A	
- Brown Coal Briquettes	020100	106A	
- Solar Energy			
- Wood Chips	020100	111A	
- Wood Pellets	020100	111A	
- Electricity			
- District Heating			
- Gas Works Gas	020100	301A	
Single Family Houses			
- LPG	020200	303A	
- Motor Gasoline	Transport		
- Other Kerosene	020200	206A	
- Gas-/Diesel Oil	020200	204A	
- Fuel Oil	020200	203A	
- Petroleum Coke	020200	110A	
- Natural Gas	020200	301A	
- Coal	020200	102A	
- Coke	020200	107A	
- Brown Coal Briquettes	020200	106A	
- Solar Energy			
- Straw	020200	117A	
- Firewood	020200	111A	
- Wood Chips	020200	111A	
- Wood Pellets	020200	111A	
- Biodiesel	020200	215A	
- Heat Pumps			
- Electricity			
- District Heating			
- Gas Works Gas	020200	301A	

Continued			
Multi-family Houses			
- LPG	020200	303A	
- Other Kerosene	020200	206A	
- Gas-/Diesel Oil	020200	204A	
- Fuel Oil	020200	203A	
- Petroleum Coke	020200	110A	
- Natural Gas	020200	301A	
- Coal	020200	102A	
- Coke	020200	107A	
- Brown Coal Briquettes	020200	106A	
- Solar Energy			
- Electricity			
- District Heating			
- Gas Works Gas	020200	301A	

Annex 5 - Assessment of completeness and (potential) sources and sinks of greenhouse gas emissions and removals excluded

GHG inventory

The Danish greenhouse gas emission inventories for 1990-2013 include all sources identified by the 2006 IPCC Guidelines. Some very minor sources have not been estimated due to lack of methodology, activity data or emission factors, i.e.:

Direct and indirect CH_4 emissions from agricultural soils are not estimated. Direct and indirect soil emissions are considered of minor importance for CH_4. No methodology is available in the IPCC Guidelines.

Several possible sources of CH_4 in the LULUCF sector are also reported as not estimated. For more detail please see Chapter 7.

Emissions of N_2O from accidental fires are reported as not estimated due to lack of emission factors.

KP-LULUCF inventory

The KP-LULUCF inventory is considered complete. Please see Chapter 11 for further documentation.

Annex 6 - Additional information to be considered as part of the annual inventory submission and the supplementary information required under Article 7, paragraph 1, of the Kyoto Protocol or other useful reference information

Tables A6.1 to A6.5 below contain the information publically available in this report. Table A6.6 includes the list of discrepancies identified by the ITL (no discrepancies in the 2015 submission).

Table A6.1 Total quantities of Kyoto Protocol units by account type at beginning of reported year.

	Unit type					
Account type	AAUs	ERUs	RMUs	CERs	tCERs	lCERs
Party holding accounts	136 096 740	12 763 022	6 102 283	7 104 476	NO	NO
Entity holding accounts	3 809	215 426	NO	176 327	NO	NO
Article 3.3/3.4 net source cancellation accounts	45 099	NO	552 195	NO		
Non-compliance cancellation accounts	NO	NO	NO	NO		
Other cancellation accounts	161 400	13 374	NO	5 132	NO	NO
Retirement account	131 237 240	2 284 518	288 245	2 558 075	NO	NO
tCER replacement account for expiry	NO	NO	NO	NO	NO	
lCER replacement account for expiry	NO	NO	NO	NO		
lCER replacement account for reversal of storage	NO	NO	NO	NO		NO
lCER replacement account for non-submission of certification report	NO	NO	NO	NO		NO
Total	267 544 288	15 276 340	6 942 723	9 844 010	NO	NO

Table A6.2a Annual internal transactions.

Transaction type	Additions						Subtractions					
	Unit type						Unit type					
	AAUs	ERUs	RMUs	CERs	tCERs	lCERs	AAUs	ERUs	RMUs	CERs	tCERs	lCERs
Article 6 issuance and conversion												
Party-verified projects		NO					NO		NO			
Independently verified projects		NO					NO		NO			
Article 3.3 and 3.4 issuance or cancellation												
3.3 Afforestation and reforestation			NO				NO	NO	600 177	NO		
3.3 Deforestation			NO				NO	NO	200 408	NO		
3.4 Forest management			65 304				NO	NO	NO	NO		
3.4 Cropland management			1 912 386				NO	NO	NO	NO		
3.4 Grazing land management			NO				NO	NO	237 363	NO		
3.4 Revegetation			NO				NO	NO	NO	NO		
Article 12 afforestation and reforestation												
Replacement of expired tCERs							NO	NO	NO	NO	NO	
Replacement of expired lCERs							NO	NO	NO	NO		
Replacement for reversal of storage							NO	NO	NO	NO		NO
Replacement for non-submission of certification report							NO	NO	NO	NO		NO
Other cancellation							NO	67 702	NO	21 936	NO	NO
Sub-total		NO	1 977 690				NO	67 702	1 037 948	21 936	NO	NO

Table A6.2a Annual internal transactions.

	Retirement - Unit type					
Transaction type	AAUs	ERUs	RMUs	CERs	tCERs	lCERs
Retirement	NO	NO	NO	NO	NO	NO

Table A6.2b Annual external transactions.

	Additions - Unit type						Subtractions - Unit type					
Transfers and acquisitions	AAUs	ERUs	RMUs	CERs	tCERs	lCERs	AAUs	ERUs	RMUs	CERs	tCERs	lCERs
SE	NO	NO	NO	58	NO	NO	NO	NO	NO	NO	NO	NO
EU	NO	NO	NO	31 915	NO	NO	NO	126 106	NO	266 340	NO	NO
CDM	NO	NO	NO	750 334	NO	NO	NO	NO	NO	NO	NO	NO
CH	NO	142 009	NO	NO	NO	NO	NO	142 009	NO	NO	NO	NO
PL	NO	56 457	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Sub-total	NO	198 466	NO	782 307	NO	NO	NO	268 115	NO	266 340	NO	NO
Additional information												
Independently verified ERUs								NO				

Table A6.2c Total annual transactions.

	AAUs	ERUs	RMUs	CERs	tCERs	lCERs	AAUs	ERUs	RMUs	CERs	tCERs	lCERs
Total (Sum of tables 2a and 2b)	NO	198 466	1 977 690	782 307	NO	NO	NO	335 817	1 037 948	288 276	NO	NO

Table A6.3 Expiry, cancellation and replacement.

	Expiry, cancellation and requirement to replace Unit type		Replacement Unit type					
Transaction or event type	tCERs	lCERs	AAUs	ERUs	RMUs	CERs	tCERs	lCERs
Temporary CERs (tCERS)								
Expired in retirement and replacement accounts	NO							
Replacement of expired tCERs			NO	NO	NO	NO	NO	
Expired in holding accounts	NO							
Cancellation of tCERs expired in holding accounts	NO							
Long-term CERs (lCERs)								
Expired in retirement and replacement accounts		NO						
Replacement of expired lCERs			NO	NO	NO	NO		
Expired in holding accounts		NO						
Cancellation of lCERs expired in holding accounts		NO						
Subject to replacement for reversal of storage		NO						
Replacement for reversal of storage			NO	NO	NO	NO		NO
Subject to replacement for non-submission of certification report		NO						
Replacement for non-submission of certification report			NO	NO	NO	NO		NO
Total			NO	NO	NO	NO	NO	NO

Table A6.4 Total quantities of Kyoto Protocol units by account type at end of reported year.

Account type	Unit type: AAUs	ERUs	RMUs	CERs	tCERs	lCERs
Party holding accounts	136 096 740	12 763 022	7 042 025	7 681 651	NO	NO
Entity holding accounts	3 809	78 075	NO	93 183	NO	NO
Article 3.3/3.4 net source cancellation accounts	45 099	NO	1 590 143	NO		
Non-compliance cancellation accounts	NO	NO	NO	NO		
Other cancellation accounts	161 400	81 076	NO	27 068	NO	NO
Retirement account	131 237 240	2 284 518	288 245	2 558 075	NO	NO
tCER replacement account for expiry	NO	NO	NO	NO	NO	
lCER replacement account for expiry	NO	NO	NO	NO		
lCER replacement account for reversal of storage	NO	NO	NO	NO		NO
lCER replacement account for non-submission of certification report	NO	NO	NO	NO		NO
Total	267 544 288	15 206 691	8 920 413	10 359 977	NO	NO

Table A6.5 (a). Summary information on additions and subtractions.

	Additions - Unit type						Subtractions – Unit type					
Starting values	AAUs	ERUs	RMUs	CERs	tCERs	lCERs	AAUs	ERUs	RMUs	CERs	tCERs	lCERs
Issuance pursuant to Article 3.7 and 3.8	276 838 955											
Non-compliance cancellation							NO	NO	NO	NO		
Carry-over	NO	NO		NO								
Sub-total	276 838 955	NO		NO			NO	NO	NO	NO		
Annual transactions												
Year 0 (2007)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Year 1 (2008)	191 772 275	NO	NO	27 439 229	NO	NO	174 391 031	NO	NO	23 971 973	NO	NO
Year 2 (2009)	881 590 260	524 201	NO	32 057 896	NO	NO	874 991 940	185 735	NO	33 349 553	NO	NO
Year 3 (2010)	233 649 660	5 344 875	NO	28 111 141	NO	NO	252 411 415	1 389 977	NO	28 008 871	NO	NO
Year 4 (2011)	8 593 901	2 249 840	624 109	3 022 739	NO	NO	6 160 750	NO	335 864	86 669	NO	NO
Year 5 (2012)	1 255 753	4 939 318	3 531 167	3 728 306	NO	NO	2 385 957	2 152 432	NO	3 525 345	NO	NO
Year 6 (2013)	NO	6 215 073	2 787 447	6 925 616	NO	NO	16 021 922	282 197	216 331	2 503 638	NO	NO
Year 7 (2014)	NO	198 466	1 977 690	782 307	NO	NO	NO	335 817	1 037 948	288 276	NO	NO
Year 8 (2015)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Sub-total	1 316 861 849	19 471 773	8 920 413	102 067 234	NO	NO	1 326 363 015	4 346 158	1 590 143	91 734 325	NO	NO
Total	1 593 700 804	19 471 773	8 920 413	102 067 234	NO	NO	1 326 363 015	4 346 158	1 590 143	91 734 325	NO	NO

Table A6.5 (b). Summary information on replacement.

	Requirement for Replacement – Unit type		Replacement – Unit type					
	tCERs	lCERs	AAUs	ERUs	RMUs	CERs	tCERs	lCERs
Previous CPs			NO	NO	NO	NO	NO	NO
Year 1 (2008)		NO	NO	NO	NO	NO	NO	NO
Year 2 (2009)		NO	NO	NO	NO	NO	NO	NO
Year 3 (2010)		NO	NO	NO	NO	NO	NO	NO
Year 4 (2011)		NO	NO	NO	NO	NO	NO	NO
Year 5 (2012)	NO	NO	NO	NO	NO	NO	NO	NO
Year 6 (2013)	NO	NO	NO	NO	NO	NO	NO	NO
Year 7 (2014)	NO	NO	NO	NO	NO	NO	NO	NO
Year 8 (2015)	NO	NO	NO	NO	NO	NO	NO	NO
Total	NO	NO	NO	NO	NO	NO	NO	NO

Table A6.5 (c). Summary information on retirement.

	Retirement – Unit type					
Year	AAUs	ERUs	RMUs	CERs	tCERs	lCERs
Year 1 (2008)	NO	NO	NO	NO	NO	NO
Year 2 (2009)	26 171 207	NO	NO	375 230	NO	NO
Year 3 (2010)	25 322 171	NO	NO	162 743	NO	NO
Year 4 (2011)	24 446 840	1766	NO	822 623	NO	NO
Year 5 (2012)	55 297 022	2 282 752	288 245	1 197 479	NO	NO
Year 6 (2013)	NO	NO	NO	NO	NO	NO
Year 7 (2014)	NO	NO	NO	NO	NO	NO
Year 8 (2015)	NO	NO	NO	NO	NO	NO
Total	131 237 240	2 284 518	288 245	2 558 075	NO	NO

Table A.6.6 List of discrepancies.

DES Response Code	Average number of occurrences per transaction (x 100.000)		Transaction Number	Proposal Date Time	Transaction Type	Final State	Explanation	Units Involved abbreviated		
	Reported Year	Prior to the Reported Year						Serial Number	Unit Type	Quantity

Annex 7 - Methodology applied for the greenhouse gas inventory for the Faroe Islands

Introduction

This report covers the Faroese part of the National Inventory Report for the Kingdom of Denmark.

The report is made by Umhvørvisstovan, the Faroese Environment Agency (FEA) www.us.fo.

Background information on greenhouse gas inventories and climate change

Each year the Faroe Islands is obligated to report its emission of greenhouse gases (GHG), according to the requirements of the United Nations Framework Convention on Climate Change (UNFCCC). The Kingdom of Denmark (which includes Denmark, Greenland and the Faroe Islands as geographical areas) has signed the UNFCCC. The Faroese emission figures are part of the emission total for the Kingdom of Denmark.

When Denmark ratified the Kyoto Protocol, it was with territorial reservation for the Faroe Islands. Since the reservation has not been lifted, the requirements for reporting are only those related to the Convention.

The first emission inventories for the Faroe Islands were made using an average method based upon the total use of fossil fuels in the Faroe Islands and consequently the inventories have only included total estimates of CO_2 emissions. Later, the inventories were done according to IPCC guidelines. The FEA has since 2008 yearly reported GHG emissions to Danish Centre for Environment and Energy (DCE), Dep. of Environmental Science (ENVS).

The GHGs reported are:

- Carbon dioxide CO_2
- Methane CH_4
- Nitrous Oxide N_2O
- Hydrofluorocarbons HFCs
- Perfluorocarbons PFCs
- Sulphur hexaflouride SF_6
- Nitrogen triflouride NF_3

A description of the institutional arrangement for inventory preparation

FEA, an agency under the Ministry of Health and the Interior (www.himr.fo), is responsible for the annual preparation and submission to the UNFCCC of the Faroe Islands' contribution to the Kingdom of Denmark's National Inventory Report and the GHG inventories in the Common Reporting Format in accordance with the UNFCCC

Guidelines. The inventory is done with guidance from and in co-operation with DCE.

The work concerning the annual greenhouse gas emission inventory is carried out in co-operation with other Faroese ministries, research institutes, organisations and companies:

- *Statistics Faroe Islands (Ministry of Finance)* www.hagstova.fo Annual statistics on liquid fuel sale, fuel usage for electricity and heat production, and statistics on livestock (sheep and cows).
- *Municipal Waste Plants* Data on amount of incinerated waste.
- *Electricity producing company* www.sev.fo Data on import of F-gases (SF_6).
- *Airline Company* www.atlantic.fo Data for fuel bunkers for domestic flights and international flights to and from the Faroe Islands.
- *Refrigeration companies* Data on import of F-gases (HFCs).
- *Oil companies – license holders* Data on use of fuel oil in connection with exploration (deep water) drilling in Faroese territorial waters.

In January 2010, DCE and FEA made a formal agreement about data delivery.

Brief description of the process of inventory preparation. Data collection and processing, data storage and archiving

The activity data for fuel sale and for fuel usage by combustion plants, as well as for the number of livestock (sheep and cows) are collected and stored at Statistics Faroe Islands. Each year, FEA receives new data for fuel sale and fuel usage for the previous year. Numbers of livestock and other data is accessible on the homepage of Statistics Faroe Islands.

Other activity data are delivered by plants owned by municipalities or private companies.

After receiving the data, the material is placed on servers at FEA. The servers are subject to routine backup services. Material that has been backed up is archived safely. All collected data is also archived in the electronic journal of the agency.

The emission factors are yearly received from DCE Denmark, sent by email to the FEA as Excel files. In addition to copying the factors to spread sheet files, the e-mails are archived in the electronic journal.

Since the 2008 submission, all subsequent submissions have been reported in the Common Reporting Format of UNFCCC (CRF). The new format has meant improvements, higher data security and limited the potential for errors in the reporting.

Brief general description of methodologies and data sources used

The GHG inventory for the Faroe Islands includes the following sectors:

- Energy (CRF sector 1)
- Industrial Processes and Product Use (CRF sector 2)
- Agriculture (CRF sector 3)

- Waste (CRF sector 5)

Since the emissions in the Waste sector all are allocated to the Energy sector, table 1 also includes methods applied and emission factors for calculating GHG emissions related to the Waste sector.

The applied methodologies follow the IPCC Guidelines and IPCC Good Practice Guidance, and the Tier 1 method is always applied.

The methods and the emission factors used in the inventory are shown in Table 1 (emission factors for CO_2, CH_4 and N_2O in the Energy and Agriculture sector) and in Table 2 (emission factors for HFCs and SF_6 in the sector for Industrial Processes and Product Use). A brief general description of methodologies is included below for the different sectors.

Table 1 Methods applied and emission factors used for calculating CO_2, CH_4 and N_2O emissions in the Energy and Agriculture sectors.

	CO_2		CH_4		N_2O	
GHG CATEGORIES	Method applied	Emission factor	Method applied	Emission factor	Method applied	Emission factor
1. Energy	T1	CS	T1	CS	T1	CS
A. Fuel Combustion	T1	CS	T1	CS	T1	CS
1. Energy Industries	T1	CS	T1	CS	T1	CS
2. Manufacturing Industries and Construction	T1	CS	T1	CS	T1	CS
3. Transport	T1	CS	T1	CS	T1	CS
4. Other Sectors	T1	CS	T1	CS	T1	CS
3. Agriculture			T1	D	T1	D
A. Enteric Fermentation			T1	D		
B. Manure Management			T1	D	T1	D

Table 2 Methods and Emission factors used for calculating HFCs and SF_6 emissions in the Industrial Processes sector.

	HFCs		SF_6	
GHG CATEGORIES	Method applied	Emission factor	Method applied	Emission factor
2. Industrial Processes and Product Use	T1	D	T1	D
F. Product Uses as Substitutes of ODS	T1	D	T1	D

Energy sector

All emissions in the Energy sector are from Fuel combustion (1.AA), and in these categories:

- 1.A.1 Energy Industries
  - 1A1a Public Electricity and Heat Production (incl. Waste)
  - 1A1c Manufacture of Solid fuels and Other Energy Industries
- 1.A.2 Manufacturing Industry and Construction
- 1.A.3 Transport
  - 1.A.3.a Domestic Aviation
  - 1.A.3.b Road Transportation
  - 1.A.3.d Domestic Navigation
- 1.A.4 Other Sectors
  - 1.A.4.a Commercial/Institutional
  - 1.A.4.b Residential

- 1.A.4.c Agriculture/Forestry/Fishing
    - iii Fishing

Statistics Faroe Islands provides the information on fuel sales by fuel type (in m^3) and divided into eight main groups (original titles: Fishing vessels, Other ships, Transportation, Industry, Trading and Service, Residential and Communities, Institutions and Public Power), each group again divided into subgroups.

The fuel data delivered by Statistics Faroe Islands originate from several sources. The main data sources are the two main oil companies in the Faroe Islands. Fuel data not included in sales information from the oil companies are delivered by the industry to FEA.

Since the delivered data on fuel sale are not fully arranged according to IPCC guidelines, the FEA rearranges the data to comply with the guidelines.

Emission factors

Emissions from fuel combustion can be divided into two main sources: stationary and mobile combustion. Stationary combustion means fuel combustion related to e.g. industry on land, house heating and oil exploration. Mobile combustion includes the combustion in engines used for propulsion in the various modes of transport such as road transport, marine activities and aviation. The emission factors used for stationary, transport, waste and aviation are country specific and provided by DCE. All emissions factors used in the inventory are found in Annex 2 and 3.

Emissions are calculated by multiplying fuel consumption data with an emission factor (e.g. in tonnes emission per GJ fuel).

Public Electricity and Heat Production (1A1a)

The activity data used for calculations of emissions of GHG from for Public Electricity and Heat Production are data for usage of residual oil and diesel oil at electricity producing plant on the Faroe Islands. The emission factors are calculated and delivered by DCE, see Table 10 in Annex 2.

Manufacture of Solid fuels and Other Energy Industries (1A1c)

This category only covers the emissions of GHG from activity related to exploration drilling in Faroese territory. The activity data (usage of diesel on the rigs) are delivered by the operators. The emission factors are calculated and delivered by DCE, see Table 10 in Annex 2.

Manufacturing Industry and Construction (1A2)

The activity data for oil usage are delivered by Statistics Faroe Islands. The emission factors are calculated and delivered by DCE, see Table 10 in Annex 2.

Domestic aviation (1A3a)

The Faroese airline company, Atlantic Airways, www.atlantic.fo delivers data for jet fuel bunkered in the Faroe Islands. As the Faroe Islands has accepted the United Nations Framework Convention on Climate Change as a part of the Kingdom of Denmark, aviation between Denmark and the Faroe Islands is to be reported as domestic aviation. The data is thus divided by destination: flights to destinations inside the Kingdom of Denmark, i.e., Denmark and Greenland (Domestic Aviation), and outside the Danish Kingdom, e.g., Iceland, Norway and Great Britain (International Aviation). Fuel refuelled outside the Faroe Islands is not included in the Faroese inventory.

The emission factors for aviation are made by DCE, see Table 12 in Annex 3.

Road transport (1A3b)

The activity data for road transport is data for sale of gasoline and diesel to all types of vehicle at all filling stations in the Faroe Islands. The data is delivered by the Statistics Faroe Islands. The emission factors for road traffic are calculated by DCE. The Danish results are modified for Faroese traffic conditions such as other gross vehicle weights for heavy-duty vehicles and no highway driving conditions. The emissions factors are also modified because biofuel is not used in the Faroe Islands, unlike in Denmark. The emission factors are shown in Table 12 in Annex 3.

Domestic Navigation (1A3d)

The activity data for oil usage used in navigation are delivered by Statistics Faroe Islands. The emission factors are calculated and delivered by DCE, see Table 13 in Annex 3.

Commercial and Institutional (1A4a) and Residential (1A4b)

The activity data for oil usage used to calculate the GHG emissions from the Commercial and Institutional and Residential categories are delivered by Statistics Faroe Islands. The emission factors are calculated and delivered by DCE, and found in Table 10 in Annex 2

Fishing (1A4ciii)

The activity data (sale of oil to fishing vessels) is delivered by Statistics Faroe Islands. The emission factors are calculated and delivered by DCE, and found in Annex 3.

Until last year's delivery of data, in some few cases, it has not been possible to rearrange the data from Statistics Faroe Islands to fully comply with the IPCC guidelines. This was the case for foreign fishing vessels. According to the guidelines all emissions resulting from fuel used in coastal and deep sea fishing should be allocated to the country delivering the fuel. When oil is sold to foreign vessels, the oil companies do not always, or have not always, registered whether the ship is a fishing vessel or another type of vessel. Even though most foreign vessels today bunkering in the Faroe Islands are fishing vessels, the emission from foreign vessels have been allocated to International Bunkers. This means that the emission from fishing vessels in reality were higher than in the inventory and emission from International bunkering were lower. This is not so anymore, since it was changed in the last delivery. Through direct communication with the oil companies, the Environmental Agency has received more detailed information about sale of oil to foreign fishing vessels, enough to make a fairly good estimation of the amount of oil sold to foreign fishing vessels in the years 2001-2011. This has resulted in higher emissions from fishing vessels and lower emissions in International Bunkers for the year 2001-2011. The same new estimations for the years 1990-2000 remains to be done.

The inventory includes all oil bunkered on Faroese territory, excluding oil bunkered at open sea, or on other more near-coast sites, by international companies, i.e., from foreign supplier to foreign customer.

Industrial Processes and Product Use

Emissions from Industrial processes and Product Use are allocated to these categories:

- 2.F Product Uses as Substitutes for ODS
    - 2.F.1 Refrigeration and Air Conditioning
- 2.G Other Product Manufacture and Use
    - 2.G.1 Electrical Equipment

The inventory follows the principles in the IPCC Guidelines and the IPCC Good Practice Guidance, with a Tier 1 methodology. The emissions factors are IPPC default.

The activity data origin from FEA surveys on the consumption (import) of HFCs and SF_6 which have been conducted annually since 2003. An estimate of the consumption has been done for the years 1990-2002.

There has been no consumption of PFCs nor NF_3 in the Faroe Islands.

Solvent and other product use

Since no data are available, emissions from solvent and other product use are not calculated.

Agriculture

GHG emissions from agriculture are calculated for following categories:

- 3.1 Livestock
    - 3.A Enteric fermentation
    - 3.B Manure management
- 3.D Agricultural Soil

The inventory follows the principles in the IPCC Guidelines and the IPCC Good Practice Guidance. Tier 1 method is always used. All emission factors used for agriculture are IPCC standard values. The emissions are calculated with support from DCE. Activity data is accessible on the homepage of Statistics Faroe Islands.

Waste

The GHG emission from waste incineration is calculated IPCC default values. All emissions in the Waste sector have been allocated to the Energy sector. Emission factors relative to emissions of CO_2, N_2O and CH_4 from waste incineration in 1990-2013 are listed in Table 11 in Annex 2. Heating values for waste incineration are listed in Table 3.

Table 3 Heating values (GJ pr t) for waste.

Year	Heating values GJ pr t
1990-91	8,2
1992	9,0
1993-94	9,4
1995	10,0
1996-2013	10,5

Brief description of key categories

No key category analysis (KCA) has been carried out for the Faroe Islands inventory.

Information on QA/QC plan including verification and treatment of confidential issues where relevant

A number of measures are in place to ensure the quality of the greenhouse gas inventory for the Faroe Islands.

The general QC activities include:

- Check that data from Statistics Faroe Islands and other data deliverers are correctly transferred to emissions spread sheets.
- Check that data are correctly moved between data processing steps, e.g., it is ensured that the data are imported correctly from the emission spread sheets /databases to the CRF Reporter.
- The time series are analysed. Any large fluctuations are investigated and explained /corrected.
- The completeness of the inventory is checked utilising the completeness checker incorporated in the CRF Reporter.

These types of QC checks are recommended as Tier 1 QC checks in the IPCC Good Practice Guidance (IPCC, 2000).

No confidential issues are relevant.

General uncertainty evaluation, including data on the overall uncertainty for the inventory totals

No uncertainty evaluation has been made for the Faroese inventory.

General assessment of the completeness

In general, the inventory is complete.

References

Lastein, L. & Winther, M. 2003: Emissions of greenhouse gases and long-range transboundary air pollutants in the Faroe Islands 1990-2001. National Environmental Research Institute, Denmark. 62 p. NERI Technical Report no. 477. http://www2.dmu.dk/1_viden/2_Publikationer/3_fagrapporter/rapporter/FR477.pdf

Winther, M. 2001: 1998 Fuel Use and Emissions for Danish IFR Flights. Environmental Project no. 628, 2001. 112 p. Danish EPA. Prepared by the National Environmental Research Institute (NERI), Denmark. Electronic report at homepage of Danish EPA. Available at :

http://www.statensnet.dk/pligtarkiv/fremvis.pl?vaerkid=14268&reprid=0

Trends in Greenhouse Gas Emissions

The trends present in this Chapter cover the emissions from the Faroe Islands.

The emission trend tables 1990, 2000, 2010, 2011, 2012 and 2013 for GHG CO_2 eq, CO_2, CH_4, N_2O and F-gases (CRF: Table 10) and emission trend summary table 1990, 2000, 2010, 2011, 2012 and 2013 are presented in Annex 1.

Description and interpretation of emission trends for aggregated greenhouse gas emissions

The greenhouse gas emissions are estimated according to the IPCC guidelines and are aggregated into four main sectors: Energy, Industrial Processes and Product Use, Agriculture and Waste. All emissions from the Waste sector are allocated to the Energy sector. The main part, 94 %, of the emissions is from the fuel consumption in the energy sector. Figure 1 shows the estimated total greenhouse gas emissions in CO_2 equivalents from 1990 to 2013. The total greenhouse gas emission in CO_2 equivalents has increased by 3.9 % from 1990 to 2013. Comments on the overall trends etc. are given in the sections below.

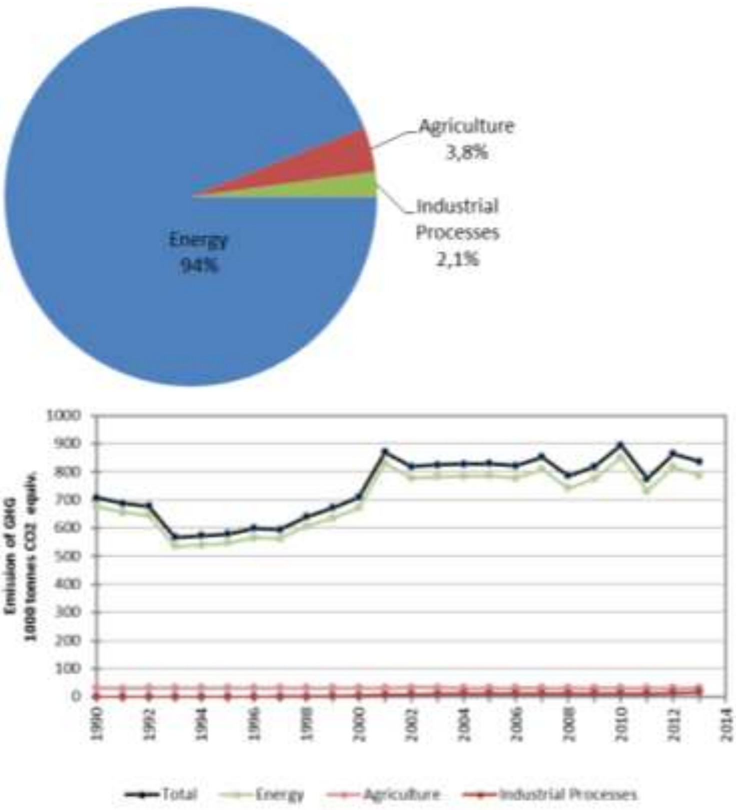

Figure 1 Greenhouse gas emissions in CO_2 equivalents distributed on main sectors for 2013 and time series for 1990 to 2013.

The greenhouse gases include CO_2, CH_4, N_2O, HFCs and SF_6. Figure 2 shows the composition of greenhouse gas emissions (CO_2, N_2O, CH_4 and F-gases) in 2013, calculated in GWP values. CO_2 is the most important greenhouse gas contributing in 2013 with 93 %, followed by N_2O with 3 %, CH_4 2 % and F-gases (HFCs and SF_6) with 2 %.

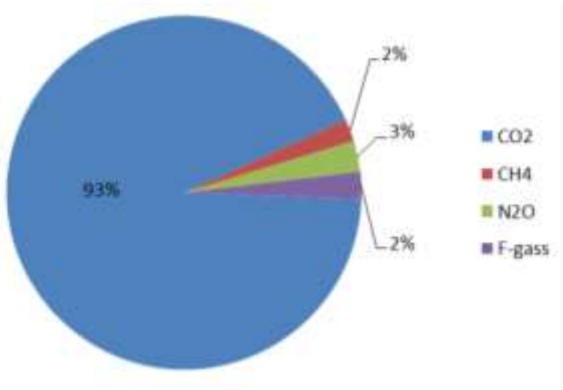

Figure 2 Emissions of GHG in CO_2 equivalents in 2013 distributed on type of gas.

Figure 3 shows the total emissions of greenhouse gases and the emission of CO_2, N_2O, CH_4 and F-gases (in CO_2 equivalents) in the time period 1990-2013. From 1990 to 1993 a decrease is observed, due to an economic crisis in the Faroe Islands, which lasts for 6-8 years. From 2001 to 2007, the emissions were rather stabile. In 2008-2011 the emissions from Faroese fishing ship were significantly lower than previous years, especially due to rising oil prices and lower prices on fish. The decrease is concealed by emissions related to new bunkering activity starting in 2009 that has led to a substantial increase in the number of foreign fishing vessels bunkering in the Faroe Island. In 2013, the emissions were 18.2 % above 1990, the base year.

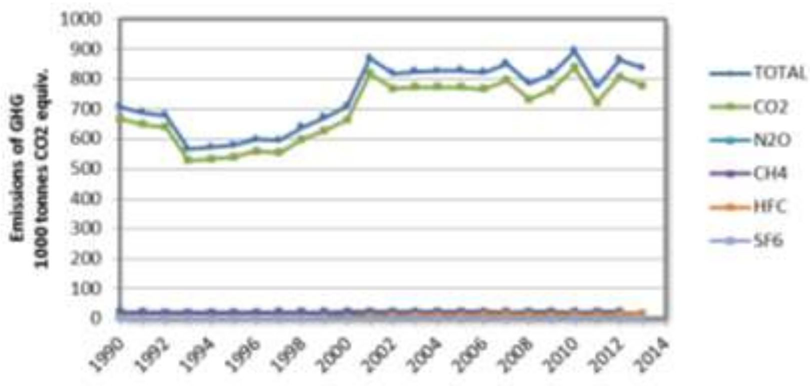

Figure 3 GHG emission in CO_2 equivalents, time series 1990-2013.

Description and interpretation of emission trends by gas

Carbon dioxide

The emission of CO_2 on the Faroe Islands is from fuel consumption only. The trend in the total emission of CO_2 (Figure 4) is nearly identical with the trend of the total emission of GHG in the Faroe Islands (Figure 3) showing the trends in CO_2 emissions in the period from 1990 to 2013. After the economic decline in the 1990s the emissions rose and were rather constant until 2007. From 2008 to 2013 the effort in the Faroese fishing fleet was significantly lower than previous years, also meaning a significant reduction in oil consumption. The reduction in the emissions for fisheries in 2009 and 2011 is not visible because a new oil bunkering activity (mostly used by foreign fishing vessels) started up in 2009, increasing the emissions.

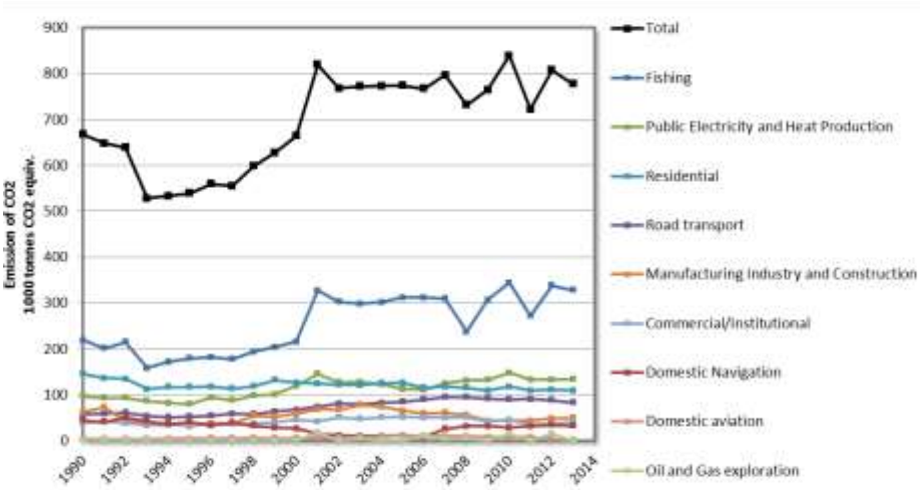

Figure 4 Total CO_2 emissions, time series for 1990-2013.

Figure 5 shows how the emissions are distributed between categories. In 2012 42 % of the CO_2 emissions came from fishing vessels. Public electricity and heat production accounted for 16 %, households for 14 % and road transport for 11 % of the total CO_2 emission.

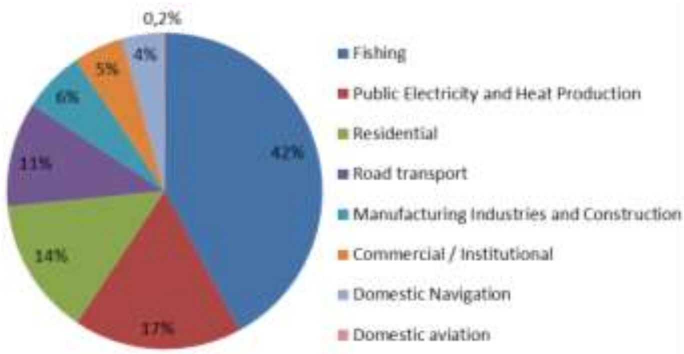

Figure 5 Emissions of CO_2 in the Energy sector, divided in fuel consumption categories, 2013.

Nitrous oxide

Figure 6 shows the emissions of nitrous oxide in the Faroe Islands 1990-2013. Most of the N_2O is from the agriculture sector, especially from animals grazing on agricultural soils.

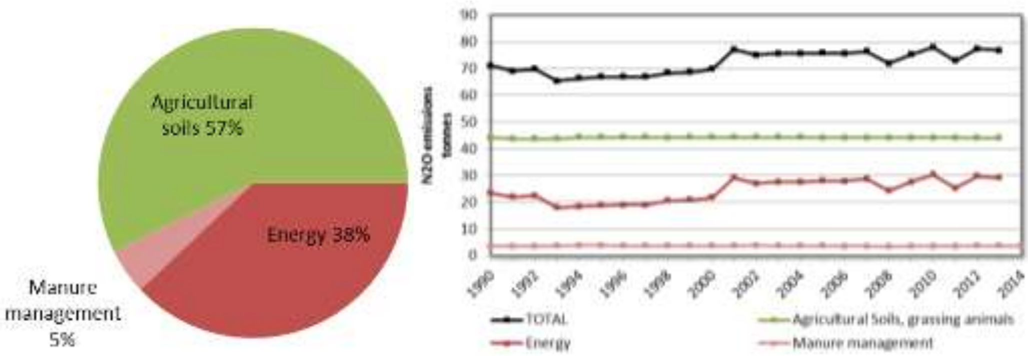

Figure 6 N_2O emissions in tonnes distributed on sector and time series for 1990-2013.

Methane

Figure 7 shows the emissions of methane in the Faroe Islands 1990-2013. Most of the methane emission is from the agriculture sector, especially from enteric fermentation (87 %). Most of the emission of CH_4 in the energy sector is due to aviation activity.

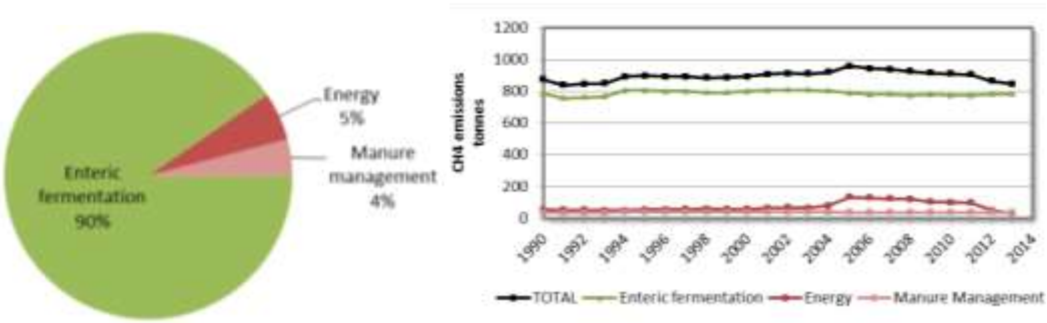

Figure 7 CH_4 emissions in tonnes distributed on sectors and time series for 1990-2013.

HFCs, PFCs, SF_6 and NF_3

Figure 8 shows the emissions of F-gases, HFCs and SF_6 respectively in the years 1990-2013. Most of the emission is HFCs, used for refrigeration purposes, as substitutes for HCFCs. After the emissions increased in the period 1996-2005, the emissions were rather stable at around 12,000 tonnes of CO_2 equivalents pr. year until 2012 and 2013, where the emissions of HFC were respectively 14,220 and 17,500 CO_2 equivalents. This is due to higher use of HFC-125 and HFC-143a, both components in the HFC-blend HFC-507a, which in recent years has been used as a substitute when phasing out HCFC-22 (ozone depleting freezing agent) on fishing vessels.

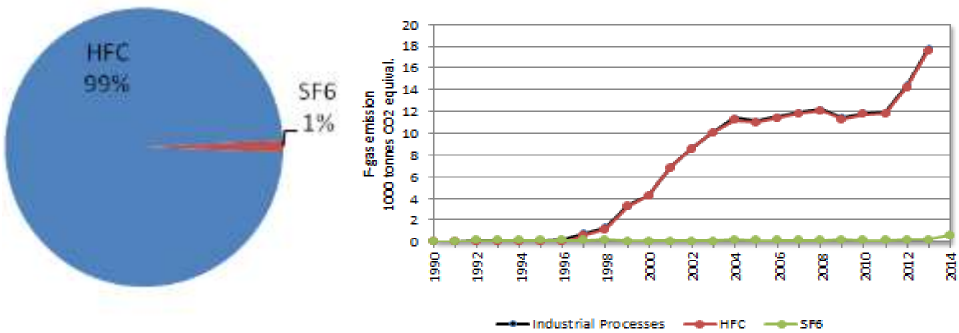

Figure 8 F-gas emissions in CO_2 equivalents, contribution from type of F-gas and time series for 1990-2013.

In 2013 the actual emission of SF_6 was 200 tonnes CO_2 equivalents.

PFC nor NF_3 have been in use in the Faroe Islands.

Description and interpretation of emission trends by source

In 2012, nearly 95 % of all GHG emissions were from the Energy sector, including waste incineration. Almost 4 % were from Agriculture and nearly 2 % from Industrial processes and Product Use, see Figure 9.

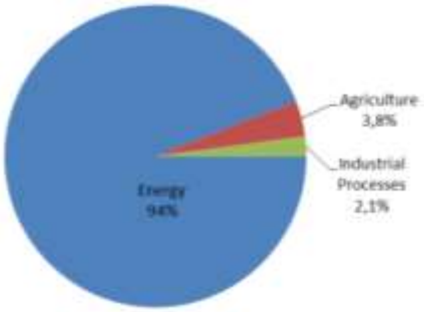

Figure 9 Emissions of GHG in CO_2 equivalents distributed by main sectors, 2013.

The fluctuations in the GHG emissions in the Energy sector are decisive for the fluctuations in the total GHG emissions, see Figure 10. The emissions from the Agriculture sector and from Industrial processes and Product Use are relative small and constant.

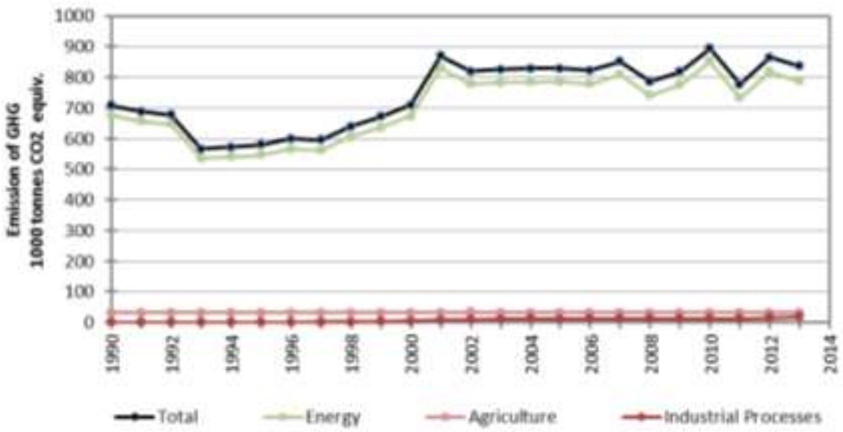

Figure 10 GHG emissions in CO_2 equivalents, main sectors, time series 1990-2013.

Description and interpretation of emission trends for indirect greenhouse gases and SO_2

Emission trends for indirect greenhouse gases and SO_2 have not been made for the Faroe Islands.

Energy (CRF sector 1)

Overview of the sector

Fuel consumption on the Faroe Islands can be seen in Figure 11. Most of the fuel is used by fishing vessels.

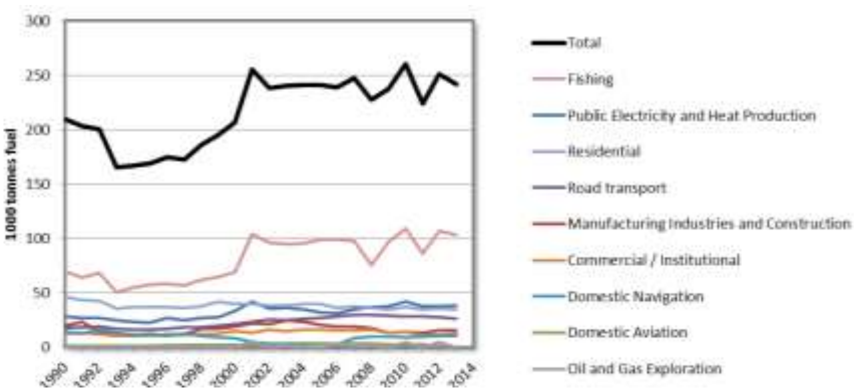

Figure 11 Fuel consumption (tonnes) in the Energy sector, including waste incineration, 1990-2013.

Figure 12 shows the GHG emissions in the Energy sector on the Faroe Islands 1990-2013. The trend in Figure 12 is just the same as in Figure 11.

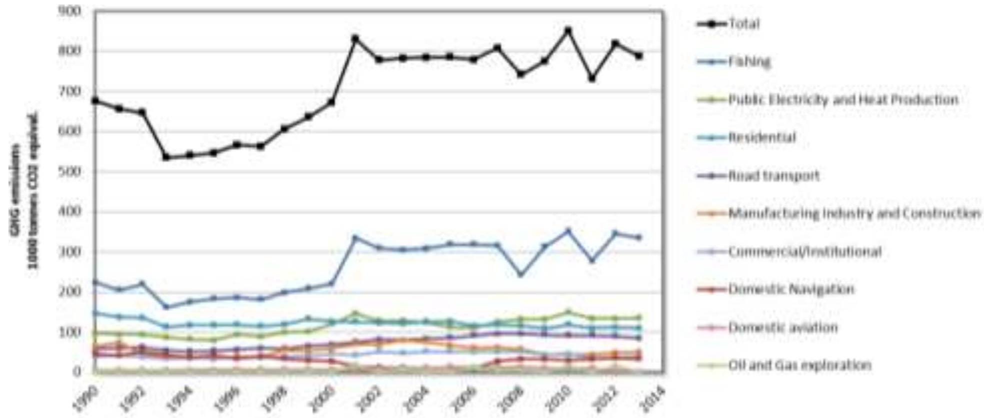

Figure 12   GHG emissions in CO_2 equivalents, categories in the Energy sector, 1990-2013.

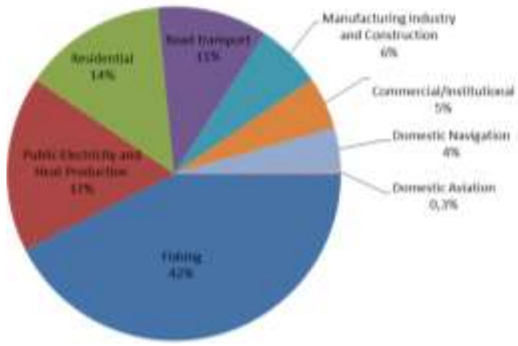

Figure 13 shows how the emission of GHG in 2013 was distributed between groups of fuel users. Fishing vessels, Electricity production, Residential and Road transport had 42, 16, 14 and 11 %, respectively, of the emissions in the Energy sector in 2013.

Waste incineration has been included under sector 1A1a (Electricity and Heat production), comprising 8% of the total emissions in the sector.

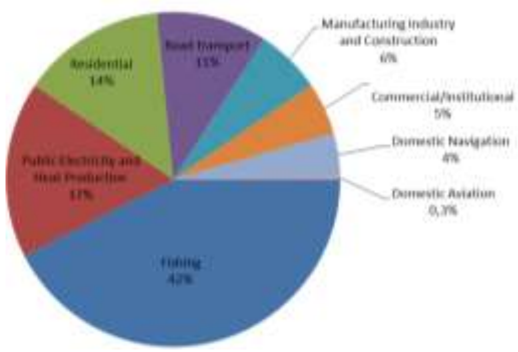

Figure 13   GHG emissions in CO_2 equivalents; Energy sector divided in categories, 2013.

Fugitive emissions (CRF sector 1B)

Fugitive emissions of GHG gases are estimated to be very limited on the Faroe Islands. These emissions have not been estimated.

Industrial Processes and Product Use (CRF Sector 2)

There is no chemical industry, no metal production, no production of F-gases and no mineral production (other than road paving with asphalt) on the Faroe Islands. The only industrial processes leading to GHG emissions on the Faroe Islands is the use of F-gases. Since no data is available on paving roads with asphalt, the emissions of GHG from road paving are not included in the inventory.

Overview of the sector

Figure 14 shows the GHG emissions from industrial processes on the Faroe Islands. The increase in emissions, starting in 1996 is due to use of HFCs in refrigeration. See Figure 8.

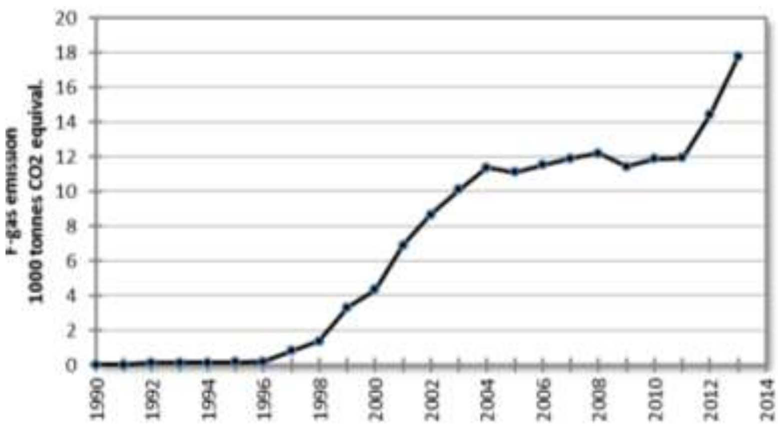

Figure 14 GHG emissions in CO_2 equivalents, Industrial processes, 1990-2013.

Mineral Industry (2A)

There is no mineral production in the Faroe Islands, other than paving roads with asphalt. No data is available for paving roads with asphalt.

Chemical Industry (2B)

No chemical industry with GHG emission is located in the Faroe Islands.

Metal Industry (2C)

No metal production industry is located in the Faroe Islands.

Production of Halocarbons and SF_6 (2E)

There is no production of halocarbons and SF_6 in the Faroe Islands.

Product Uses as Substitutes for ODS (2F) and Other Product Manufacture and Use (2G)

Of the total GHG emissions 2 % are emissions related to consumption of halocarbons and SF_6. The major part of the emission (99%) is HFC gasses, which are used for refrigeration purposes and the rest (1 % of the emission) is SF_6 used in electrical equipment. See Figure 8

Time series of the emission (tonnes) of HFCs 1990-2012, are seen in Table 4.

Table 4 Emissions of HFCs from Refrigeration and Air Conditioning, 1990, 2000, 2005-2013 (tonnes).

	1990	2000	2005	2006	2007	2008	2009	2010	2011	2012	2013
Domestic refrigeration											
HFC-134a	NO	0,003	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01
Commercial refrigeration											
HFC-134a	NO	0,04	0,13	0,12	0,12	0,12	0,12	0,14	0,18	0,17	0,19
HFC-32	NO	0,09	0,32	0,30	0,29	0,27	0,25	0,26	0,23	0,21	0,19
HFC-125	NO	0,15	0,50	0,49	0,50	0,56	0,58	0,72	0,80	1,28	1,75
HFC-143a	NO	0,06	0,19	0,19	0,22	0,32	0,35	0,51	0,62	1,14	1,63
Industrial refrigeration											
HFC-134a	0,00	0,16	0,45	0,40	0,37	0,36	0,36	0,38	0,39	0,30	0,30
HFC-125	0,00	0,33	0,97	1,03	1,06	1,01	0,87	0,78	0,69	0,59	0,60
HFC-143a	0,00	0,39	1,15	1,22	1,25	1,19	1,02	0,91	0,80	0,68	0,70
HFC-32	0,00	0,00	0,00	0,00	0,01	0,01	0,01	0,01	0,01	0,01	0,01
Mobile Air Conditioning											
HFC-134a	0,00	0,70	0,59	0,64	0,76	0,83	0,89	0,94	0,97	1,00	1,02

The HFC emissions are reported with the following assumptions:

- Domestic refrigeration is use in freezers and refrigerators.
- Commercial refrigeration is use in land based units.
- Industrial refrigeration is use on ships.
- Mobile air conditioning is use in cars, buses and trucks

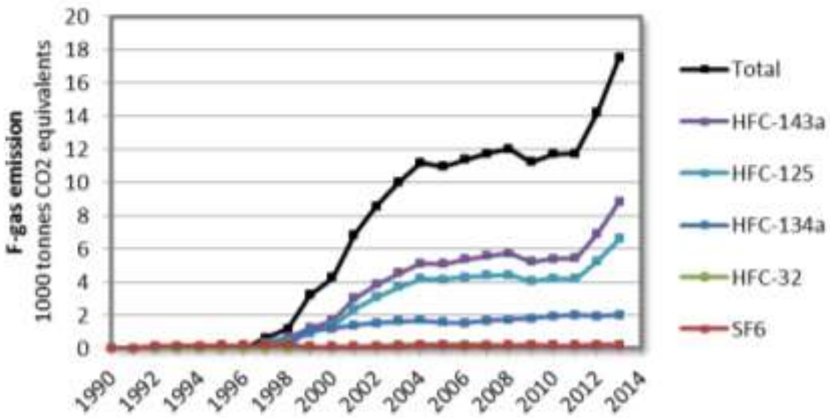

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Figure 15 shows the emissions of SF_6 and four specific HFCs.

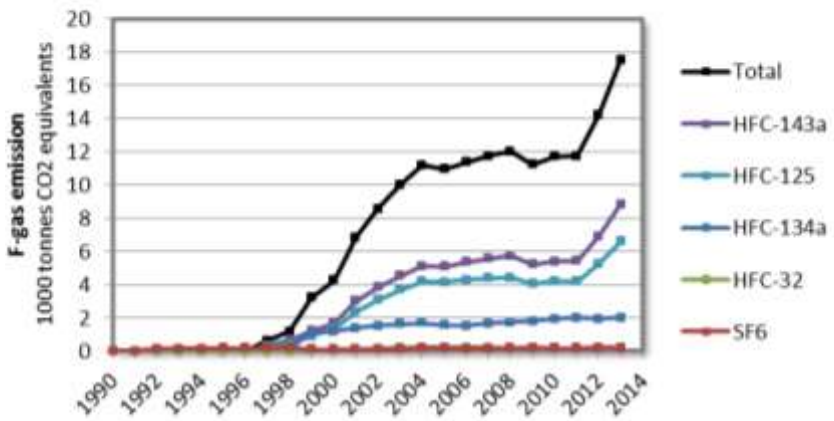

Figure 15 Emission of F-gases (HFCs and SF_6) in CO_2 equivalents, time series for 1990-2013.

Uncertainty

Estimations of the uncertainties for Industrial processes have not been done.

Agriculture (CRF Sector 3)

Overview

The emission of greenhouse gases from agricultural activities includes:

- CH_4 emission from manure management and enteric fermentation.
- N_2O emission from manure management and agricultural soil.

Nearly 4 % of the total GHG emissions on the Faroe Islands are due to agriculture. The sources are cattle and sheep.

Figure 16 shows the number of cattle in the Faroe Islands from 1990 to 2013. The number of sheep is around 78,940, which is the carrying capacity for sheep on the islands. There are no data on the exact number of sheep.

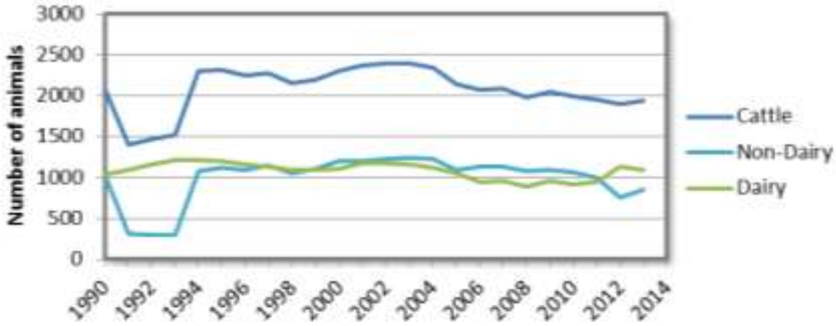

Figure 16 Number of cattle (dairy and non-dairy), time series for 1990-2013.

Figure 17 shows the total emissions from the Agriculture sector.

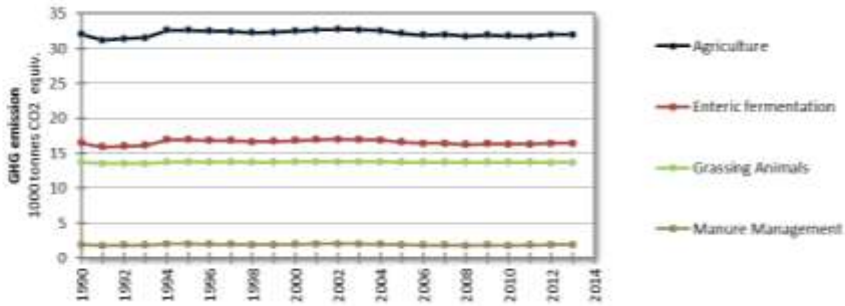

Figure 17 GHG emissions in CO_2 equivalents, in the Agriculture sector, 1990-2013.

CH_4 emission from Enteric Fermentation (CRF Sector 3A)

Figure 18 shows emissions of CH_4 from enteric fermentation in livestock on the Faroe Islands, 1990-2013. The emissions are very constant.

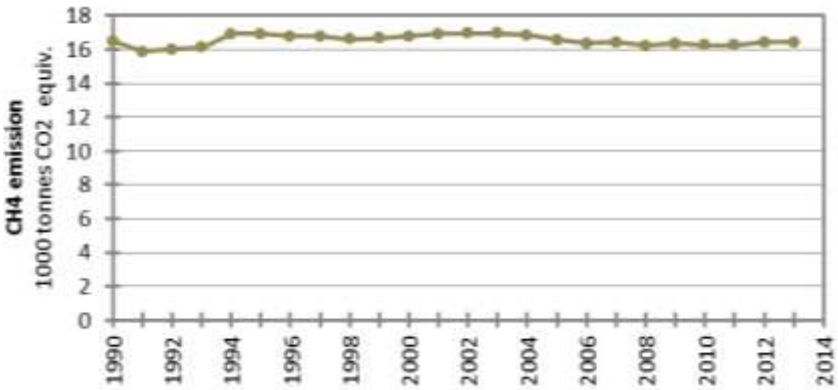

Figure 18 CH_4 emissions in CO_2 equivalents from enteric fermentation, 1990-2013.

CH_4 and N_2O emission from Manure Management (CRF Sector 3B)

Figure 19 shows emissions of N_2O and CH_4 from manure management on the Faroe Islands.

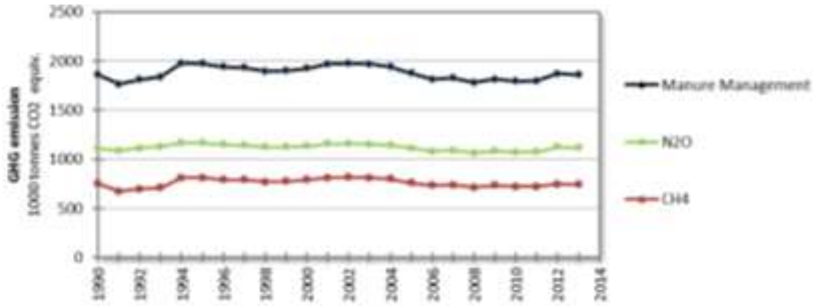

Figure 19 N_2O and CH_4 emission in CO_2 equivalents from Manure management, time series 1990-2013.

N_2O emission from Agricultural Soils (CRF Sector 3D)

The emission from sheep and cows grazing on agricultural soil is 44 tonnes N_2O per year. This corresponds to 13,700 tonnes of CO_2 equivalents.

Figure 20 shows the N_2O emissions from agricultural soil. Since the number of sheep is more or less constant over time, the emissions are also constant.

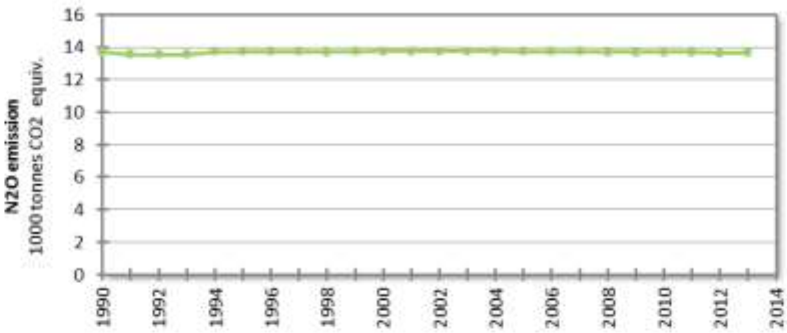

Figure 20 N_2O emissions (tonnes) from Agricultural Soils, grazing animals, time series 1990-2013.

NMVOC emission

The emission of NMVOC is not calculated.

Uncertainties

The uncertainties have not been calculated.

Recalculation

No recalculations were made in the Agriculture sector in the 2014 submission.

Planned improvements

A little project where all data from the Agricultural sector is looked at in detail is planned, including checking if emission factors other than default and methods other than Tier 1 should be used.

Include emissions from animal categories other than cattle and sheep.

Land Use, Land-Use Change and Forestry (CRF Sector 4)

No emissions are calculated for land use, land-use change and forestry.

Waste Sector (CRF Sector 5)

Overview of the Waste sector

Waste incineration is the only source in the Waste sector with significant emission. The emissions have been allocated to the energy sector in accordance with the IPCC Guidelines.

Solid Waste Disposal (CRF Source Category 5A)

A number of land-based solid waste disposals facilities are located on the Faroe Islands. The GHG emissions from these depots have not been calculated.

Biological Treatment of Solid Waste (CRF Source Category 5B)

Composting is mostly a small scale activity in private households. There are no biogas facilities on the Faroe Island.

Incineration and Open Burning of Waste (CRF Source Category 5C)

There are two waste incineration plants on the Faroe Islands, one in Hoyvík and one in Leirvík. Both plants are considered energy recovery operations and therefore the emissions have been allocated to the energy sector (Public Electricity and Heat Production, 1A1a) in accordance with the IPCC Guidelines. Open burning of waste is prohibited.

Figure 21 shows the amounts of waste incinerated on the Faroe Islands 1990-2013.

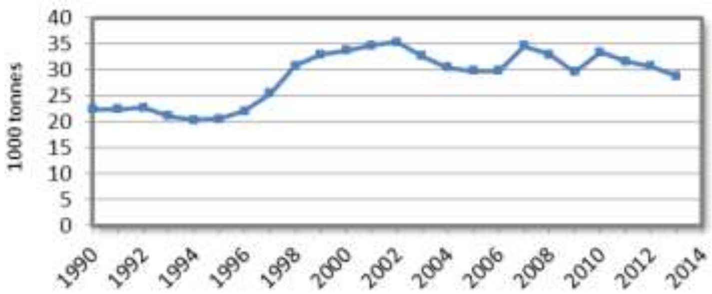

Figure 21 Incineration of municipal waste on the Faroe Islands, 1990-2013.

Wastewater Treatment and Discharge (CRF Source Category 5D)

In the Faroe Islands, most households have a septic tank (mechanical treatment). Industrial wastewater, e.g. from the fishing industry, is treated mechanically (oil/fat separation). Only a very few wastewater handling plants are treating the wastewater chemically and/or biologically.

GHG emissions from wastewater handling have not been calculated.

Waste Other (CRF Source Category 5E)

There are no activities and emissions in Waste Other.

Other (CRF sector 6)

In CRF sector 6, there are no activities and emissions or removals for the inventory of the Faroe Islands.

Recalculations and improvements

Nearly all recalculations in the 2015 submission for the Faroe Islands are due to changes in emissions factors, and in all these cases the changes are the same as in the inventory for Denmark.

Explanations and justifications for recalculations

The following recalculations and improvements to the emission inventories have been made since the reporting in 2014.

Energy

Energy Industries

Due to updates in the emissions factors for CH_4 a minor recalculation has been made for the emissions from use of heavy fuel in Public Electricity and Heat Production for 1990-2012. The emission factor was changed from 0.9 to 0.8 g/GJ. See Chapter 3.2, for a detailed explanation.

Road transport

Emission factors for road transport, diesel, CH_4 and N_2O, 1990-2012, and for gasoline, CH_4 and NO_2 have been updated. See Chapter 3.3 (road transport), for a detailed explanation

Domestic Navigation

The emission factor for diesel, CH_4, for the year 2012 has been updated. See Chapter 3.3 (Navigation) for a detailed explanation.

Waste

The emission factors for emission of CH_4 and N_2O from Waste incineration have been updated for the whole time-series 1990-2012. From using default IPCC emission factors, the emission from waste incineration is now calculated using the same country specific emission factors as used in Denmark. The emission factor for N_2O was before 4 g/GJ (IPCC default) and is now 1.2 g/GJ. The emission factor for CH_4 was changed from 6 g/GJ (earlier selected from IPCC guidelines) to 0.34-0.59 g/GJ.

In addition, errors in the heating values for waste for 2011 and 2012 have been corrected since last year's delivery.

Industrial Processes and Product Use

The emissions from use of the freezing agent R-507c (containing HFC-125 and HFC-143a) have been reallocated from commercial refrigeration to industrial refrigeration (Product used as substitute for ODS, 2.F).

Implications for emission levels

Most of the recalculations have only had small implication for the emissions levels. The exception is waste where the emission factors for CH_4 have lowered by a factor 10-18, meaning a 10-18 fold decrease in the CH_4 emissions from waste incineration. In the same way the emission of N_2O has decreased 3.3 fold.

Implications for emission trends, including time series consistency

The recalculations have only had no significant implication for the trends.

Improvements

Improvement to implement in next year's delivery:

Civil aviation

The emissions factors must be updated to follow the factors used in Denmark. This should have been done for the 2013 delivery.

Fishing vessels

Since last year's recalculation made for fishing vessels for certain reasons only could be done for the time-series 2001-2011, the time series for fishing vessels, 2001-2012, is inconsistent with the time series 1990-2000. Oil sold to foreign fishing vessels for 1990-2000 will be estimated, and the activity data will be corrected correspondently.

Paving with asphalt

Provide data for paving roads with asphalt.

Agriculture

Improvements regarding emission factors and methods are planned

Annexes

Annex 1 Emission trend tables 1990, 2000, 2010, 2011, 2102 and 2013 for GHG CO2 eq, CO_2, CH_4, N_2O, F-gases (CO_2 equivalents) and Trend tables 1990, 2000, 2010, 2011, 2012 and 2013 for Summary (all gases)

The tables are copied from the CRF 2013 spreadsheet file, Tables 10.1-10.6.

Table 5 EMISSION TRENDS GHG CO2 eq - Inventory 2013 - Submission 2015 v1 - FAROE ISLANDS.

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	1990	2000	2010	2011	2012	2013
	kt CO2 eq					
Total (net emissions)	**703,23**	**705,73**	**892,24**	**775,01**	**865,05**	**823,06**
1. Energy	**675,47**	**672,32**	**850,82**	**733,54**	**820,28**	**790,07**
A. Fuel combustion (sectoral approach)	675,47	672,32	850,82	733,54	820,28	790,07
1. Energy industries	97,11	119,55	164,47	134,64	150,52	137,37
2. Manufacturing industries and construction	62,66	59,93	43,69	43,33	48,86	49,71
3. Transport	107,21	101,64	129,34	133,65	128,18	119,29
4. Other sectors	408,50	391,21	513,32	421,92	492,72	483,70
5. Other	NE	NE	NE	NE	NE	NE
B. Fugitive emissions from fuels	NE	NE	NE	NE	NE	NE
1. Solid fuels	NE	NE	NE	NE	NE	NE
2. Oil and natural gas and other emissions from energy production	NE	NE	NE	NE	NE	NE
C. CO_2 transport and storage	NO	NO	NO	NO	NO	NO
2. Industrial Processes	**NA,NO**	**5,08**	**14,07**	**14,12**	**17,13**	**21,15**
A. Mineral Industry	NO	NO	NO	NO	NO	NO
B. Chemical Industry	NO	NO	NO	NO	NO	NO
C. Metal Industry	NE	NE	NE	NE	NE	NE
D. Non-energy products from fuels and solvent use	NE	NE	NE	NE	NE	NE
E. Electronic Industry	NE	NE	NE	NE	NE	NE
F. Product uses as ODS substitutes	NO	5,01	13,90	13,97	16,95	20,95
G. Other product manufacture and use	NA,NO	0,08	0,16	0,15	0,18	0,20
H. Other	NE	NE	NE	NE	NE	NE
3. Agriculture	**27,76**	**28,33**	**27,36**	**27,35**	**27,64**	**11,84**
A. Enteric fermentation	20,30	20,73	20,00	19,99	20,20	4,41
B. Manure management	3,19	3,27	3,11	3,12	3,20	3,19
C. Rice cultivation	NO	NO	NO	NO	NO	NO
D. Agricultural soils	4,27	4,33	4,24	4,24	4,24	4,25
E. Prescribed burning of savannas	NO	NO	NO	NO	NO	NO
F. Field burning of agricultural residues	NE	NE	NE	NE	NE	NE
G. Liming	NO	NO	NO	NO	NO	NO
H. Urea application	NO	NO	NO	NO	NO	NO
I. Other carbon-containing fertilizers	NE	NE	NE	NE	NE	NE
J. Other	NE	NE	NE	NE	NE	NE
4. Land use, land-use change and forestry	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**
A. Forest land	NE	NE	NE	NE	NE	NE
B. Cropland	NE	NE	NE	NE	NE	NE
C. Grassland	NE	NE	NE	NE	NE	NE
D. Wetlands	NE	NE	NE	NE	NE	NE
E. Settlements	NE	NE	NE	NE	NE	NE
F. Other land	NE	NE	NE	NE	NE	NE
G. Harvested wood products	NE	NE	NE	NE	NE	NE
H. Other	NE	NE	NE	NE	NE	NE
5. Waste	**IE,NE,NA**	**IE,NE,NA**	**IE,NE,NA**	**IE,NE,NA**	**IE,NE,NA**	**IE,NE,NA**
A. Solid waste disposal	NE	NE	NE	NE	NE	NE
B. Biological treatment of solid waste	NO	NO	NO	NO	NO	NO
C. Incineration and open burning of waste	IE,NA	IE,NA	IE,NA	IE,NA	IE,NA	IE,NA
D. Waste water treatment and dis charge	NE	NE	NE	NE	NE	NE
E. Other	NE	NE	NE	NE	NE	NE
6. Other	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**

Memo items:						
International bunkers	**NE,NA,NO**	**150,53**	**54,26**	**67,29**	**79,06**	**42,45**
Aviation	NA,NO	12,31	10,95	16,99	18,23	15,94
Navigation	NE,NA,NO	138,22	43,31	50,30	60,83	26,52
Multilateral operations	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**
CO_2 emissions from biomass	**15,90**	**28,18**	**27,91**	**28,93**	**30,51**	**30,92**
CO_2 captured	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**
Long-term storage of C in waste disposal sites	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**
Indirect N_2O	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**
Indirect CO_2	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**
Total CO_2 equivalent emissions without land use, land-use change and forestry	**703,23**	**705,73**	**892,24**	**775,01**	**865,05**	**823,06**
Total CO_2 equivalent emissions with land use, land-use change and forestry	**703,23**	**705,73**	**892,24**	**775,01**	**865,05**	**823,06**
Total CO_2 equivalent emissions, including indirect CO2, without land use, land-use change and forestry	**703,23**	**705,73**	**892,24**	**775,01**	**865,05**	**823,06**
Total CO_2 equivalent emissions, including indirect CO2, with land use, land-use change and forestry	**703,23**	**705,73**	**892,24**	**775,01**	**865,05**	**823,06**

Table 6 EMISSION TRENDS CO2 - Inventory 2013 - Submission 2015 v1 - FAROE ISLANDS.

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	1990	2000	2010	2011	2012	2013
	Gg					
1. Energy	**667,21**	**664,33**	**839,23**	**723,53**	**810,23**	**780,64**
A. Fuel combustion (sectoral approach)	667,21	664,33	839,23	723,53	810,23	780,64
1. Energy industries	96,90	119,26	163,99	134,35	150,08	137,08
2. Manufacturing industries and construction	61,86	59,30	43,28	42,97	48,54	49,17
3. Transport	104,67	99,17	125,71	129,93	125,81	117,43
4. Other sectors	403,78	386,60	506,25	416,28	485,79	476,96
5. Other	NE	NE	NE	NE	NE	NE
B. Fugitive emissions from fuels	NE	NE	NE	NE	NE	NE
1. Solid fuels	NE	NE	NE	NE	NE	NE
2. Oil and natural gas and other emissions from energy production	NE	NE	NE	NE	NE	NE
C. CO2 transport and storage	NO	NO	NO	NO	NO	NO
2. Industrial processes	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**
A. Mineral industry	NO	NO	NO	NO	NO	NO
B. Chemical industry	NO	NO	NO	NO	NO	NO
C. Metal industry	NE	NE	NE	NE	NE	NE
D. Non-energy products from fuels and solvent use	NE	NE	NE	NE	NE	NE
E. Electronic industry						
F. Product uses as ODS substitutes						
G. Other product manufacture and use	NE	NE	NE	NE	NE	NE
H. Other	NE	NE	NE	NE	NE	NE
3. Agriculture	**NO,NE**	**NO,NE**	**NO,NE**	**NO,NE**	**NO,NE**	**NO,NE**
A. Enteric fermentation						
B. Manure management						
C. Rice cultivation						
D. Agricultural soils						
E. Prescribed burning of savannas						
F. Field burning of agricultural residues						
G. Liming	NO	NO	NO	NO	NO	NO
H. Urea application	NO	NO	NO	NO	NO	NO
I. Other carbon-containing fertilizers	NE	NE	NE	NE	NE	NE
J. Other	NE	NE	NE	NE	NE	NE
5. Waste	**IE,NA,NE**	**IE,NA,NE**	**IE,NA,NE**	**IE,NA,NE**	**IE,NA,NE**	**IE,NA,NE**
A. Solid waste disposal	NE	NE	NE	NE	NE	NE
B. Biological treatment of solid waste						
C. Incineration and open burning of waste	IE,NA	IE,NA	IE,NA	IE,NA	IE,NA	IE,NA
D. Waste water treatment and discharge						
E. Other	NE	NE	NE	NE	NE	NE
6. Other	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**
Memo items:						
International bunkers	**NE,NA,NO**	**147,74**	**53,23**	**66,01**	**77,63**	**41,71**
Aviation	NA,NO	12,16	10,74	16,66	17,97	15,70
Navigation	NE,NA,NO	135,59	42,48	49,35	59,67	26,01
Multilateral operations	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**
CO_2 emissions from biomass	**15,90**	**28,18**	**27,91**	**28,93**	**30,51**	**30,92**
CO_2 captured	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**
Long-term storage of C in waste disposal sites	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**

Table 7 EMISSION TRENDS CH_4 – Inventory 2013 - Submission 2015 v1 - FAROE ISLANDS.

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	1990	2000	2010	2011	2012	2013
	Gg					
1. Energy	**0,05**	**0,06**	**0,10**	**0,10**	**0,05**	**0,03**
A. Fuel combustion (sectoral approach)	0,05	0,06	0,10	0,10	0,05	0,03
1. Energy industries	0,00	0,00	0,00	0,00	0,00	0,00
2. Manufacturing industries and construction.	0,00	0,00	0,00	0,00	0,00	0,00
3. Transport	0,04	0,05	0,09	0,09	0,04	0,02
4. Other sectors	0,01	0,01	0,01	0,01	0,01	0,01
5. Other	NO	NO	NO	NO	NO	NO
B. Fugitive emissions from fuels	NE	NE	NE	NE	NE	NE
1. Solid fuels	NE	NE	NE	NE	NE	NE
2. Oil and natural gas and other emissions from energy production	NE	NE	NE	NE	NE	NE
C. CO_2 transport and storage						
2. Industrial processes	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**
A. Mineral industry						
B. Chemical industry	NO	NO	NO	NO	NO	NO
C. Metal industry	NO	NO	NO	NO	NO	NO
D. Non-energy products from fuels and solvent use	NO	NO	NO	NO	NO	NO
E. Electronic industry						
F. Product uses as ODS substitutes						
G. Other product manufacture and use	NO	NO	NO	NO	NO	NO
H. Other	NO	NO	NO	NO	NO	NO
3. Agriculture	**0,85**	**0,87**	**0,84**	**0,84**	**0,85**	**0,22**
A. Enteric fermentation	0,81	0,83	0,80	0,80	0,81	0,18
B. Manure management	0,04	0,05	0,04	0,04	0,04	0,04
C. Rice cultivation	NO	NO	NO	NO	NO	NO
D. Agricultural soils	NE	NE	NE	NE	NE	NE
E. Prescribed burning of savannas	NO	NO	NO	NO	NO	NO
F. Field burning of agricultural residues	NE	NE	NE	NE	NE	NE
G. Liming						
H. Urea application						
I. Other carbon-containing fertilizers						
J. Other	NE	NE	NE	NE	NE	NE
5. Waste	**IE,NE,NA**	**IE,NE,NA**	**IE,NE,NA**	**IE,NE,NA**	**IE,NE,NA**	**IE,NE,NA**
A. Solid waste disposal	NE	NE	NE	NE	NE	NE
B. Biological treatment of solid waste	NO	NO	NO	NO	NO	NO
C. Incinerat. and open burning of waste	IE,NA	IE,NA	IE,NA	IE,NA	IE,NA	IE,NA
D. Waste water treatment and discharge	NE	NE	NE	NE	NE	NE
E. Other	NE	NE	NE	NE	NE	NE
6. Other	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**
Total CH_4 emissions without CH_4 from LULUCF	**0,91**	**0,93**	**0,94**	**0,94**	**0,90**	**0,25**
Total CH_4 emissions with CH_4 from LULUCF	**0,91**	**0,93**	**0,94**	**0,94**	**0,90**	**0,25**
Memo items:						
International bunkers	**NE,NA,NO**	**0,01**	**0,01**	**0,01**	**0,01**	**0,01**
Aviation	NA,NO	0,01	0,01	0,01	0,01	0,01
Navigation	NE,NA,NO	0,00	0,00	0,00	0,00	0,00

Table 8 EMISSION TRENDS N2O - Inventory 2013 - Submission 2015 v1 - FAROE ISLANDS

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	1990	2000	2010	2011	2012	2013
	Gg					
1. Energy	**0,02**	**0,02**	**0,03**	**0,03**	**0,03**	**0,03**
A. Fuel combustion (sectoral approach)	0,02	0,02	0,03	0,03	0,03	0,03
1. Energy industries	0,00	0,00	0,00	0,00	0,00	0,00
2. Manufacturing industries and construction	0,00	0,00	0,00	0,00	0,00	0,00
3. Transport	0,00	0,00	0,00	0,01	0,00	0,00
4. Other sectors	0,02	0,01	0,02	0,02	0,02	0,02
5. Other	NE	NE	NE	NE	NE	NE
B. Fugitive emissions from fuels	NE	NE	NE	NE	NE	NE
1. Solid fuels	NE	NE	NE	NE	NE	NE
2. Oil and natural gas and other emissions from energy production	NE	NE	NE	NE	NE	NE
C. CO_2 transport and storage						
2. Industrial processes	**NO, NE**	**NO, NE**	**NO, NE**	**NO, NE**	**NO, NE**	**NO, NE**
A. Mineral industry						
B. Chemical industry	NO	NO	NO	NO	NO	NO
C. Metal industry	NE	NE	NE	NE	NE	NE
D. Non-energy products from fuels and solvent use	NE	NE	NE	NE	NE	NE
E. Electronic industry						
F. Product uses as ODS substitutes						
G. Other product manufacture and use	NE	NE	NE	NE	NE	NE
H. Other	NE	NE	NE	NE	NE	NE
3. Agriculture	**0,02**	**0,02**	**0,02**	**0,02**	**0,02**	**0,02**
A. Enteric fermentation						
B. Manure management	0,01	0,01	0,01	0,01	0,01	0,01
C. Rice cultivation						
D. Agricultural soils	0,01	0,01	0,01	0,01	0,01	0,01
E. Prescribed burning of savannas	NO	NO	NO	NO	NO	NO
F. Field burning of agricultural residues	NE	NE	NE	NE	NE	NE
G. Liming						
H. Urea application						
I. Other carbon containing fertlizers						
J. Other	NE	NE	NE	NE	NE	NE
5. Waste	**IE,NA**	**IE,NA**	**IE,NA**	**IE,NA**	**IE,NA**	**IE,NA**
A. Solid waste disposal						
B. Biological treatment of solid waste	NO	NO	NO	NO	NO	NO
C. Incineration and open burning of waste	IE,NA	IE,NA	IE,NA	IE,NA	IE,NA	IE,NA
D. Waste water treatment and discharge	NE	NE	NE	NE	NE	NE
E. Other	NE	NE	NE	NE	NE	NE
6. Other	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**
Total direct N_2O emissions without N_2O from LULUCF	**0,04**	**0,04**	**0,05**	**0,05**	**0,05**	**0,05**
Total direct N_2O emissions with N_2O from LULUCF	**0,04**	**0,04**	**0,05**	**0,05**	**0,05**	**0,05**
Memo items:						
International bunkers	**NE,NA,NO**	**0,01**	**0,00**	**0,00**	**0,00**	**0,00**
Aviation	NA,NO	0,00	0,00	0,00	0,00	0,00
Navigation	NE,NA,NO	0,01	0,00	0,00	0,00	0,00

Table 9 EMISSION TRENDS HFCs, PFCs and SF6 - Inventory 2013 - Submission 2015 v1 - FAROE ISLANDS.

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	1990	2000	2010	2011	2012	2013
	kt CO_2 equivalent					
Emissions of HFCs and PFCs	**NO**	**5,01**	**13,90**	**13,97**	**16,95**	**20,95**
Emissions of HFCs	**NO**	**5,01**	**13,90**	**13,97**	**16,95**	**20,95**
HFC-23	NO	NO	NO	NO	NO	NO
HFC-32	NO	0,00	0,00	0,00	0,00	0,00
HFC-41	NO	NO	NO	NO	NO	NO
HFC-43-10mee	NO	NO	NO	NO	NO	NO
HFC-125	NO	0,00	0,00	0,00	0,00	0,00
HFC-134	NO	NO	NO	NO	NO	NO
HFC-134a	NO	0,00	0,00	0,00	0,00	0,00
HFC-143	NO	NO	NO	NO	NO	NO
HFC-143a	NO	0,00	0,00	0,00	0,00	0,00
HFC-152	NO	NO	NO	NO	NO	NO
HFC-152a	NO	NO	NO	NO	NO	NO
HFC-161	NO	NO	NO	NO	NO	NO
HFC-227ea	NO	NO	NO	NO	NO	NO
HFC-236cb	NO	NO	NO	NO	NO	NO
HFC-236ea	NO	NO	NO	NO	NO	NO
HFC-236fa	NO	NO	NO	NO	NO	NO
HFC-245ca	NO	NO	NO	NO	NO	NO
HFC-245fa	NO	NO	NO	NO	NO	NO
HFC-365mfc	NO	NO	NO	NO	NO	NO
Unspecified mix of HFCs	NO	NO	NO	NO	NO	NO
Emissions of PFCs	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**
Unspecified mix of HFCs and PFCs	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**
Emissions of SF_6	**NA,NO**	**0,08**	**0,16**	**0,15**	**0,18**	**0,20**
SF_6	NA,NO	0,00	0,00	0,00	0,00	0,00
Emissions of NF_3	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**
NF_3	NO	NO	NO	NO	NO	NO

Table 10 EMISSION TRENDS SUMMARY - Inventory 2013 - Submission 2015 v1 - FAROE ISLANDS.

GREENHOUSE GAS EMISSIONS	1990	2000	2010	2011	2012	2013
	kt CO2 equivalents					
CO_2 emissions without net CO_2 from LULUCF	667,21	664,33	839,23	723,53	810,23	780,64
CO_2 emissions with net CO_2 from LULUCF	667,21	664,33	839,23	723,53	810,23	780,64
CH_4 emissions without CH_4 from LULUCF	22,68	23,26	23,52	23,45	22,47	6,24
CH_4 emissions with CH_4 from LULUCF	22,68	23,26	23,52	23,45	22,47	6,24
N_2O emissions without N_2O from LULUCF	13,33	13,06	15,43	13,90	15,22	15,03
N_2O emissions with N_2O from LULUCF	13,33	13,06	15,43	13,90	15,22	15,03
HFCs	NO	5,01	13,90	13,97	16,95	20,95
PFCs	NO	NO	NO	NO	NO	NO
Unspecified mix of HFCs and PFCs	NE	NE	NE	NE	NE	NE
SF_6	NA,NO	0,08	0,16	0,15	0,18	0,20
NF_3	NO	NO	NO	NO	NO	NO
Total (without LULUCF)	**703,23**	**705,73**	**892,24**	**775,01**	**865,05**	**823,06**
Total (with LULUCF)	**703,23**	**705,73**	**892,24**	**775,01**	**865,05**	**823,06**
Total (without LULUCF, with indirect)	**703,23**	**705,73**	**892,24**	**775,01**	**865,05**	**823,06**
Total (with LULUCF, with indirect)	**703,23**	**705,73**	**892,24**	**775,01**	**865,05**	**823,06**

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	1990	2000	2010	2011	2012	2013
	Kt CO2 eq					
1. Energy	675,47	672,32	850,82	733,54	820,28	790,07
2. Industrial processes and product use	NA,NO	5,08	14,07	14,12	17,13	21,15
3. Agriculture	27,76	28,33	27,36	27,35	27,64	11,84
4. Land use, land-use change and forestry	NE	NE	NE	NE	NE	NE
5. Waste	IE,NE,NA	IE,NE,NA	IE,NE,NA	IE,NE,NA	IE,NE,NA	IE,NE,NA
6. Other	NE	NE	NE	NE	NE	NE
Total (including LULUCF)	**703,23**	**705,73**	**892,24**	**775,01**	**865,05**	**823,06**

Annex 2a Emissions factors – stationary combustion

The emissions factors used for calculating the Faroese emission in following stationary combustion categories:

- 1A1a Public Electricity and Heat Production
- 1A2 Manufacturing Industry and Construction
- 1A4a Commercial/Institutional
- 1A4b Residential

are found in Table 11.

Table 11 Emission Factors for Stationary Combustion, 1990-2013.

Category	Fuel	Pollutant	1990-2005	2006-2013
Public Electricity and Heat Production	Gas/diesel oil	CH_4 (g/GJ)	0,9	0,9
		CO_2 (kg/GJ)	74	74
		N_2O (g/GJ)	0,4	0,4
	Heavy fuel oil	CH_4 (g/GJ)	0,9	0,9
		CO_2 (kg/GJ)	78,4	78,1-79,28
		N_2O (g/GJ)	0,3	0,3
Manufacturing Industries and Construction	Gas/diesel oil	CH_4 (g/GJ)	0,2	0,2
		CO_2 (kg/GJ)	74	74
		N_2O (g/GJ)	0,4	0,4
	Heavy fuel oil	CH_4 (g/GJ)	1,3	1,3
		CO_2 (kg/GJ)	77,4	77,4
		N_2O (g/GJ)	5	5
	Kerosene	CH_4 (g/GJ)	3	3
		CO_2 (kg/GJ)	71,9	71,9
		N_2O (g/GJ)	0,6	0,6
Commercial/Institutional	Gas/diesel oil	CH_4 (g/GJ)	0,7	0,7
		CO_2 (kg/GJ)	74	74
		N_2O (g/GJ)	0,4	0,4
	Kerosene	CH_4 (g/GJ)	10	10
		CO_2 (kg/GJ)	71,9	71,9
		N_2O (g/GJ)	0,6	0,6
Residential	Gas/diesel oil	CH_4 (g/GJ)	0,7	0,7
		CO_2 (kg/GJ)	74	74
		N_2O (g/GJ)	0,6	0,6
	Kerosene	CH_4 (g/GJ)	10	10
		CO_2 (kg/GJ)	71,9	71,9
		N_2O (g/GJ)	0,6	0,6

The emissions factors for calculating the Faroese emissions from the Waste sector are found in Table 11.

Table 11 Emission factors for Waste Incineration, 1990-2013.

Year	Fossil waste %	CO_2 EMF - fossil Kg pr GJ	CO_2 EMF - biogen Kg pr GJ	CH_4 EMF - tot g pr GJ	N_2O EMF - tot g pr GJ
1990	32,2	37	86,7	0,59	1,2
1991	32,2	37	86,7	0,59	1,2
1992	35,4	37	84,2	0,59	1,2
1993	36,9	37	83,0	0,59	1,2
1994	36,9	37	83,0	0,59	1,2
1995	39,3	37	81,1	0,59	1,2
1996-2013	41,2	37	79,6	0,59	1,2

Annex 2b Emissions factors – mobile combustion

The emissions factors used for calculating the Faroese emission in following mobile combustion categories:

- 1A3a Civil aviation
- 1A3b Road transport
- 1A3d Navigation
- 1A4c Agriculture, Forestry and Fishing

are found in Table 12, Table 13 and Table 14.

Table 12 Emission factors for aviation, 1990-2013.

	CH_4 - g pr GJ	CO_2 - Kg pr GJ	N_2O - g pr GJ
1990	485,3	72,0	2,680
1991	485,3	72,0	2,680
1992	485,3	72,0	2,680
1993	485,3	72,0	2,680
1994	485,3	72,0	2,680
1995	485,3	72,0	2,680
1996	485,3	72,0	2,680
1997	485,3	72,0	2,680
1998	485,3	72,0	2,680
1999	485,3	72,0	2,680
2000	485,3	72,0	2,680
2001	485,3	72,0	2,608
2002	493,4	72,0	2,611
2003	494,8	72,0	2,611
2004	545,1	72,0	2,624
2005	747,9	72,0	2,675
2006	746,4	72,0	2,669
2007	749,3	72,0	2,674
2008	750,2	72,0	2,677
2009	754,3	72,0	2,674
2010	750,2	72,0	2,677
2011	754,3	72,0	2,674
2012	564,7	72,0	2,621
2013	564,7	72,0	2,621

Table 13 Emission factors for road transport, 1990-2013.

	Diesel			Gasoline		
	CH_4	CO_2	N_2O	CH_4	CO_2	N_2O
1990	6,741	74	1,727	27,566	73	2,848
1991	6,688	74	1,723	27,153	73	2,872
1992	6,671	74	1,719	26,115	73	2,946
1993	6,608	74	1,673	25,296	73	3,003
1994	6,626	74	1,607	23,852	73	3,095
1995	6,695	74	1,534	22,470	73	3,174
1996	6,705	74	1,448	21,181	73	3,244
1997	6,623	74	1,389	19,857	73	3,290
1998	6,442	74	1,358	18,701	73	3,232
1999	6,204	74	1,352	17,515	73	3,202
2000	5,866	74	1,357	16,587	73	3,189
2001	5,627	74	1,368	15,600	73	3,128
2002	5,281	74	1,390	14,526	73	3,036
2003	4,934	74	1,415	13,536	73	2,917
2004	4,637	74	1,455	12,437	73	2,787
2005	4,310	74	1,498	11,481	73	2,604
2006	3,934	74	1,564	10,460	73	2,393
2007	3,250	74	1,742	9,682	73	2,216
2008	2,535	74	1,974	9,033	73	2,033
2009	2,028	74	2,157	8,527	73	1,921
2010	1,702	74	2,352	8,165	73	1,765
2011	1,419	74	2,589	7,759	73	1,636
2012	1,146	74	2,796	7,399	73	1,463
2013	0,942	74	2,971	7,032	73	1,300

Table 14 Emission factors for Navigation (diesel and residual) and Fisheries (diesel), 1990-2013.

	Navigation - diesel			Navigation and Fisheries - Residual			Fisheries - diesel		
	CH_4	CO_2	N_2O	CH_4	CO_2	N_2O	CH_4	CO_2	N_2O
1990	1,564	74	4,684	1,653	78	4,890	1,519	74	4,684
1991	1,571	74	4,684	1,645	78	4,890	1,530	74	4,684
1992	1,579	74	4,684	1,642	78	4,890	1,541	74	4,684
1993	1,582	74	4,684	1,646	78	4,890	1,553	74	4,684
1994	1,586	74	4,684	1,649	78	4,890	1,565	74	4,684
1995	1,600	74	4,684	1,651	78	4,890	1,578	74	4,684
1996	1,588	74	4,684	1,668	78	4,890	1,592	74	4,684
1997	1,502	74	4,684	1,694	78	4,890	1,606	74	4,684
1998	1,493	74	4,684	1,712	78	4,890	1,622	74	4,684
1999	1,461	74	4,684	1,724	78	4,890	1,639	74	4,684
2000	1,466	74	4,684	1,737	78	4,890	1,656	74	4,684
2001	1,486	74	4,684	1,753	78	4,890	1,673	74	4,684
2002	1,519	74	4,684	1,767	78	4,890	1,689	74	4,684
2003	1,513	74	4,684	1,820	78	4,890	1,704	74	4,684
2004	1,506	74	4,684	1,828	78	4,890	1,718	74	4,684
2005	1,510	74	4,684	1,869	78	4,890	1,731	74	4,684
2006	1,487	74	4,684	1,897	78	4,890	1,743	74	4,684
2007	1,498	74	4,684	1,906	78	4,890	1,753	74	4,684
2008	1,511	74	4,684	1,912	78	4,890	1,762	74	4,684
2009	1,515	74	4,684	1,925	78	4,890	1,770	74	4,684
2010	1,509	74	4,684	1,934	78	4,890	1,775	74	4,684
2011	1,502	74	4,684	1,943	78	4,890	1,780	74	4,684
2012	1,705	74	4,684	1,952	78	4,890	1,785	74	4,684
2013	1,815	74	4,684	1,960	78,000	4,890	1,790	74	4,684

DENMARK'S NATIONAL INVENTORY REPORT 2015

Emission Inventories1990-2013 - Submitted under the United Nations Framework Convention on Climate Change and the Kyoto Protocol

This report is Denmark's National Inventory Report 2015. The report contains information on Denmark's emission inventories for all years' from 1990 to 2012 for CO_2, CH_4, N_2O, HFCs, PFCs and SF_6, NOx, CO, NMVOC, SO_2.

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