DENMARK'S NATIONAL INVENTORY REPORT 2017

Emission Inventories 1990-2015 – 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. 231 2017

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DCE – DANISH CENTRE FOR ENVIRONMENT AND ENERGY

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Data sheet

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Abstract: This report is Denmark's National Inventory Report 2017. The report contains information on Denmark's emission inventories for all years' from 1990 to 2015 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
IGN	Department of Geosciences and Natural Resource Management, Copenhagen University
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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The work of compiling the Danish greenhouse gas inventory requires the input of many individuals, companies and institutions. The authors of this report would in particular like to thank the following for their valuable input in the work process:

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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.
- DCA - Danish Centre for Food and Agriculture, Aarhus University, for valuable input on animals feed consumption and excretion based on the Danish Normative System and Peter Lund for information and discussion on methane conversion rate from livestock and emissions particularly from sheep and lambs. Updated values on C stock in agricultural soils and discussions on C-TOOL and other agricultural issues.
- Annette Vestergaard - Knowledge Centre for Agriculture, for discussions on actual farming practice regarding acidification of manure during application to soils.
- The Danish AgriFish Agency for providing unrestricted access to all agricultural data.
- The European Environment Agency for granting permission for Denmark to use the CRF Aggregator tool for the submissions under the Kyoto Protocol and the UNFCCC.

Executive summary

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

ES.1.1 Reporting

This report is Denmark's National Inventory Report (NIR) 2017 for submission to the United Nations Framework Convention on Climate Change and the Kyoto Protocol, due April 15, 2017. The report contains detailed information about Denmark's inventories for all years from 1990 to 2015. The structure of the report is in accordance with the UNFCCC guidelines on reporting and review. The main difference between Denmark's NIR 2017 report to the European Commission, due March 15, 2017, and this report to UNFCCC is reporting of territories. The NIR 2017 to the EU Commission was for Denmark, while this NIR 2017 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 2015, in order to ensure transparency.

The annual emission inventories for the years from 1990 to 2015 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
- Nitrogen trifluoride NF_3

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 9 and 130 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).

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 are aggregated into six main sectors. The greenhouse gases include CO_2, CH_4, N_2O, HFCs, PFCs, SF_6 and NF_3, although NF_3 is not occurring in Denmark. Figure ES.1 shows the estimated total greenhouse gas emissions in CO_2 equivalents from 1990 to 2015. The emissions are not corrected for electricity trade or temperature variations. CO_2 is the most important greenhouse gas contributing in 2015 to the national total in CO_2 equivalents excluding LULUCF (Land Use and Land Use Change and Forestry) with 73.2 % followed by N_2O with 11.0 %, CH_4 14.3 % and F-gases (HFCs, PFCs and SF_6) with 1.5 %. Seen over the time-series from 1990 to 2015 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 2015 is 8.7 % 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 30.7 % from 1990 to 2015 and decreased 29.7 % including LULUCF. From 2014 to 2015 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 production of wind power and other renewable energy. Comments on the overall trends etc. seen in Figure ES.1 are given in the sections below on the individual greenhouse gases.

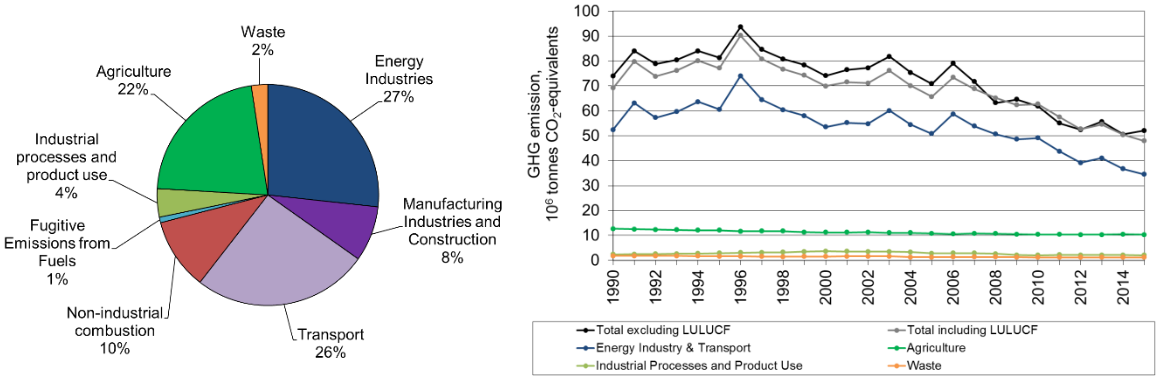


Figure ES.1 Greenhouse gas emissions in CO_2 equivalents distributed on main sectors for 2015 (excluding LULUCF and indirect CO_2) and time series for 1990 to 2015.

ES.2.2 KP-LULUCF activities

Table ES.1 contains information on emissions/removals of greenhouse gases in 2015.

Table ES.1 Emissions and removals in 2015 for activities relating to Article 3.3 and Article 3.4.

	Net CO_2 emissions/ removals	CH_4	N_2O	Net CO_2 equivalents emissions/ removals
		kt		
A. Article 3.3 activities				-354.86
A.1. Afforestation and Reforestation	-615.46	0.04	0.02	-607.62
A.2. Deforestation	244.94	0.01	0.03	252.76
B. Article 3.4 activities				4493.61
B.1. Forest Management	622.56	1.12	0.06	667.73
B.2. Cropland Management	2534.83	0.22	0.01	2542.28
B.3. Grazing Land Management	1269.01	0.54	0.00	1283.59
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 emission of CO_2 from Energy Industries has decreased by 51.6 % from 1990 to 2015. The relatively large fluctuation in the emission is due to international 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 2011-2014 are due to a large import of electricity. The main reason for the decrease in emissions owe to decreasing fuel consumption, mainly for coal and natural gas. This decrease is mainly due 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 2015 due to the liberalisation of the electricity market. The CO_2 emission from the transport sector has increased by 15.3 % from 1990 to 2015, which is mainly due to increasing road traffic.

Industrial processes and product use

The GHG emissions from industrial processes and product use, i.e. emissions from chemical processes other than fuel combustion, amount in 2015 to 4.2 % 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 2015 with 1.9 % of the national total – increased by 5.6 % from 1990 to 2015. 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 115.4 % from 1995 until 2015, 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 85.4 % in 2015. 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 in mobile systems.

Agriculture

The agricultural sector contributes in 2015 with 21.5 % 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 2015, the contribution of N_2O and CH_4 to the total emission of these gases was 88.7 % and 80.6 %, respectively. The N_2O emission from the agricultural sector decreased by 28.5 % from 1990 to 2015. 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 2015, 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 increased by 1.1 % from 1990 to 2015.

Land Use and Land Use Change and Forestry (LULUCF)

Emissions/removals from the forest sector fluctuate based on specific conditions in the given year. The total sector has been estimated to be a net sink of 1.0 % of the total Danish emission incl. LULUCF (average 2011-2015). Forest land has shown to be a large sink for the last five years. The sink has been estimated to 6.0 % of the total Danish emission incl. LULUCF over the period 2011-2015. Cropland has been estimated to be a net source of 4.8% of the total Danish emission incl. LULUCF. This is mainly due to a large area with cultivated organic soils. Grassland is a net source contributing with 2.1 % of the total Danish emission. This is also due to a large area with drained organic soils. Emissions from Cropland have shown a continuous decrease since 1990 with 41 % whereas the emission from Grassland has increased due to conversion of Cropland to Grassland.

Waste

The waste sector contributes in 2015 with 2.4 % to the national total of greenhouse gas emissions (excl. LULUCF), 14.0 % of the total CH_4 emission and 3.4 % 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 34.6 % from 1990 to 2015. This decrease is a result of a decrease in the CH_4 emission from solid waste disposal sites (SWDS) by 57.3 % due to the increasing use of waste for power and heat production, an increase in emission of N_2O from wastewater (WW) handling systems of 2.0 % due to upgrading of WW treatment plants, and an increase in CH_4 from WW of 14.2 % due to increasing industrial load to WW systems. In 2015 the contribution of CH_4 from SWDS was 9.5 % of the total CH_4 emission. The CH_4 emission from WW amounts in 2015 to 1.6 % of the total CH_4 emissions. The emission of N_2O from WW in 2015 is 1.2 % 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

A more detailed description is given in Chapter 10.

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

Recalculations and improvements are continuously made to the inventory. The sector-specific recalculations and improvements are documented in the sectoral chapters of this report (Chapter 3-7) and a general overview is provided in Chapter 9.

Sammenfatning

S.1 Baggrund for opgørelse af drivhusgasemissioner og klimaændringer

S.1.1 Rapporteringen

Denne rapport er Danmarks årlige rapport – den såkaldte Nationale Inventory Report (NIR) for 2017. Rapporten beskriver drivhusgasopgørelsen som blev fremsendt til FN's konvention om klimaændringer (UNFCCC) og Kyotoprotokollen den 15. april 2017. Rapporten indeholder detaljerede informationer om Danmarks drivhusgasudslip for alle år fra 1990 til 2015. Rapportens struktur er i overensstemmelse med UNFCCC's retningslinjer for rapportering. Forskellen mellem Danmarks NIR 2017 som blev fremsendt til EU-Kommissionen den 15. marts 2017 og denne rapport til UNFCCC, vedrører det territorium rapporteringen omfatter. NIR 2017 til EU-Kommissionen omfatter Danmark, mens NIR 2017 til UNFCCC omfatter Danmark, Grønland og Færøerne. For at sikre at opgørelserne er sammenhængende og gennemskuelig, indeholder rapporten detaljerede oplysninger om opgørelsesmetoder og baggrundsdata for alle årene fra 1990 og til 2015.

Denne emissionsopgørelse for årene 1990 til 2015, 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
- Nitrogentrifluorid NF_3

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. 9 år og for N_2O ca. 130 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).

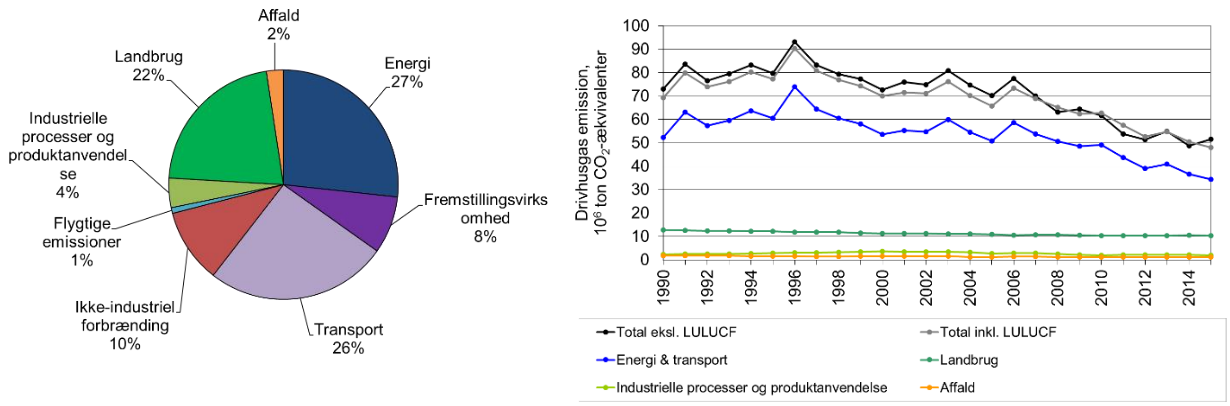
S.2 Udviklingen i drivhusgasemissioner og optag

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. Opgørelserne er opdelt i seks overordnede sektorer, 1. energi, 2. industrielle processer og produktanvendelse, 3. landbrug, 4. arealanvendelse (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 2015. 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 2015 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.

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 2015 med 73,2 % af den nationale totale udledning uden LULUCF-sektoren, efterfulgt af CH_4 med 14,3 % og N_2O med 11,0 %, mens HFC'er, PFC'er og SF_6 kun udgør 1,5 % af de totale emissioner uden LULUCF-sektoren. Set over perioden 1990-2015 så har disse procenter været stigende for CH_4 og F-gasser og svagt faldende for N_2O. For CO_2 har procenterne fluktueret mere gennem perioden. Netto CO_2-emissionen fra LULUCF er i 2015 8,0 % 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 2015 (Figur S.1). De nationale totale drivhusgasemissioner i CO_2-ækvivalenter er faldet med 30,7 % fra 1990 til 2015, hvis nettobidraget fra skovenes og jordernes udledninger og optag af CO2 (LULUCF) ikke indregnes, og faldet med 29,7 % hvis LULUCF indregnes.



Figur S.1 Danske drivhusgasemissioner. Bidrag til total emission fra hovedsektorer for 2015 og tidsserier i CO_2-ækvivalenter for 1990-2015, hvor data er angivet med og uden LULUCF.

S.2.2 KP-LULUCF-aktiviteter

Tabel S.1 viser emissioner/optag fra LULUCF i 2015.

Tabel S.1 Emissioner og optag i 2015 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				-354.86
A.1. Skovrejsning	-615.46	0.04	0.02	-607.62
A.2. Skovrydning	244.94	0.01	0.03	252.76
B. Aktiviteter under artikel 3.4				4493.61
B.1. Forvaltning af skov plantet før 1990	622.56	1.12	0.06	667.73
B.2. Forvaltning af landbrugsarealer	2534.83	0.22	0.01	2542.28
B.3. Forvaltning af permanente græsarealer	1269.01	0.54	0.00	1283.59
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

CO_2-emissionen fra energisektoren faldt med 51,6 % fra 1990 til 2015. 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 2011-2014 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 15,3 % 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 2015 4,2 % af de totale danske drivhusgasemissioner. De vigtigste kilder er cementproduktion, kølesystemer, opskumning og kalcinering af kalksten. CO_2-emissionen fra cementproduktion - som er den største kilde - bidrager med 1,9 % af den totale emission i 2015. Emissionen fra cementproduktion er steget med 5,6 % fra 1990 til 2015. 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 2015 steget med 115,4 %, 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 85,4 % i 2015. 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 2015 med 21,5 % til den totale drivhusgasemission i CO_2-ækvivalenter og er den vigtigste sektor hvad angår emissioner af N_2O og CH_4. I 2015 var landbrugets bidrag til de totale emissioner af N_2O og CH_4 henholdsvis 88,7 % og 80,6 %. Fra 1990 til 2015 ses et fald på 28.5 % 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 2015 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 steget med 1,1 % siden 1990.

Arealanvendelse - skove og jorder (LULUCF)

LULUCF-sektoren skifter mellem at udgøre et nettooptag og en nettoudledning. Gennemsnitligt for perioden 2011-2015 udgør LULUCF et nettoudledning svarende til 1,0 % af den samlede drivhusgasudledning, inklusiv LULUCF. Skov har været et stort optag gennem de seneste fem år. Optaget har over perioden 2011-2015 svaret til 6,0 % af den samlede danske emission inklusiv LULUCF. Landbrugsjorde er estimeret til gennemsnitligt over perioden 2011-2015, at udgøre en emission på 4,8 % af den samlede emission. Dette skyldes hovedsageligt det dyrkede areal på organiske jorde. Græsmarker er en kilde svarende til 2,1 % af den samlede emission. Dette skyldes også hovedsageligt de organiske jorde. Emissionen fra landbrugsjorde er faldet støt siden 1990 samlet med 41 %, men emissionen fra græsmarker er steget pga. arealovergange fra landbrugsjord til græs.

Affald

Affaldssektoren udgør i 2015 2,4 % af den danske totalemission, 14,0 % af den totale CH_4-emission og 3,4 % 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 34,6 % fra 1990 til 2015. Reduktionen skyldes især et fald i CH_4-emissionen fra lossepladser på 57,3 % pga. reducerede mængder affald, der går til deponi, en stigning i N_2O-emissionen fra spildevandshåndtering på 2,0 % pga. fornyelse af spildvandsanlæggene og en stigning i CH_4-emissionen fra spildevandshåndtering på 14,2 % pga. en stigning i det industrielle spildevand. I 2015 bidrog lossepladser med 9,5 % af den totale nationale CH_4-emission. CH_4-emissionen fra spildevandshåndtering udgør i 2015 1,6 % af den totale nationale CH_4-emission. Emissionen af N_2O fra spildevandshåndtering udgør i 2015 1,2 % 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

En mere detaljeret redegørelse findes i kapitel 10.

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 inden for 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

Genberegninger og forbedringer bliver løbende udført i forbindelse med emissionsopgørelserne. De sektorspecifikke genberegninger og forbedringer er beskrevet i sektorafsnittene i denne rapport (Kapitel 3-7). Et generelt overblik er inkluderet i Kapitel 9.

1 Introduction

1.1 Background information on greenhouse gas inventories and climate change

1.1.1 Annual report

This report is Denmark's National Inventory Report (NIR) 2017 for submission to the United Nations Framework Convention on Climate Change due April 15, 2017. The report contains detailed information about Denmark's inventories for all years from 1990 to 2015. The structure of the report is in accordance with the UNFCCC reporting guidelines (UNFCCC, 2013). The main difference between Denmark's NIR 2017 report to the European Commission, due March 15, 2017, and this report to UNFCCC is reporting of territories. The NIR 2017 to the EU Commission was for Denmark, while this NIR 2017 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 2015, in order to ensure transparency.

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.

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 2015 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 for Greenland will be made in the ratification of the Doha Amendment.

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 about 390 ppm in 2010 (an increase of about 38 %)(IPCC, Fifth Assessment Report, 2013), and exceeds the natural range of 180-300 ppm over the last 650 000 years as determined by ice cores. 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 722 ppb to 1803 ppb in 2011 (an increase of about 150 %) and N_2O has increased from a pre-industrial atmospheric concentration of about 270 ppb to 324 ppb in 2011 (an increase of about 20 %) (IPCC, Fifth Assessment Report, 2013). 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. 9 and 130 years approximately for CH_4 and N_2O, respectively. Therefore, 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 (IPCC, 2007), which UNFCCC (UNFCCC, 2013) 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 28 EU Member States. For the commitment in the second commitment period, the EU has entered into an agreement with Iceland on joint fulfilment.

The EU imposes some additional guidelines and obligations to these EU Member States through Regulation No. 525/2013/EU concerning a mechanism for monitoring and reporting greenhouse gas emissions and for implementing the Kyoto Protocol (EU monitoring mechanism). The Implementing Regulation detailing the reporting requirements was decided in

2014 (749/2014/EU). 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 Environment and Food and the Ministry of Energy, Utilities and Climate, 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 (Single National Entity) designated with overall responsibility for the national inventory under the Kyoto Protocol.

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 the 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	Industrial processes	Katja Hjelgaard
product use	Product use	Patrik Fauser
Agriculture		Mette Hjorth Mikkelsen
		Rikke Albrektsen
LULUCF	Forestry	Vivian Kvist Johannsen,
		Thomas Nord-Larsen,
		Ingeborg Callesen
		Lars Vesterdal
	Harvested wood products	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 archive for DCE. In this archiving 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 Compiler and Importer2CRF(xml) and IDAtoCRF(xml)
3 process	NRF Report N8 Process	Helptool	U:\ST_ENVS-Luft-Emi\Inventory\AllYears\8_AllSectors\Level_3b_Processes\NFR	Excel	NERIRep and Report Template (xls)
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

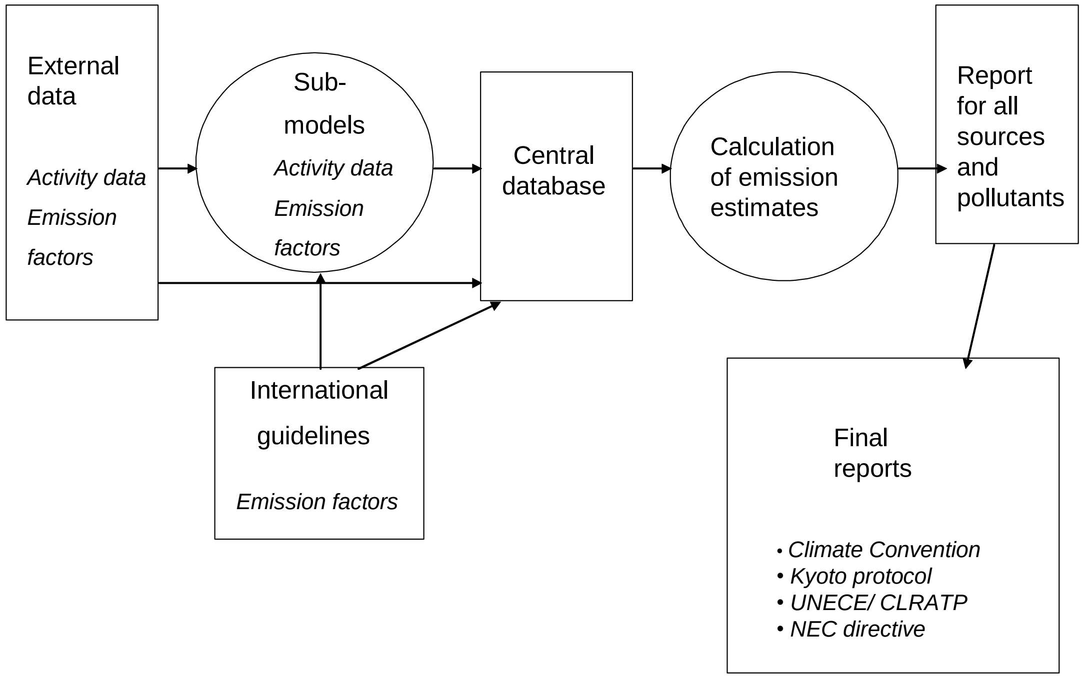


Figure 1.1 Schematic diagram of the process of inventory preparation.

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 under the first commitment period and only Denmark for the reporting under the second commitment period. 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 different versions of the CRF Reporter.

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. Under the Kyoto Protocol, Denmark now reports two submissions: one following the definition in the first commitment period and one following the definition for the second commitment period.

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 2006 IPCC Guidelines 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 as 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.

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 (EEA, 2016) 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 (EEA, 2016). 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 it 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 (EEA, 2016).

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 "Provice". Their yearly report (DEPA, 2017) documents the inventory data up to the year 2015. The methodology is implemented for the whole time series 1990-2015, 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, 2006). Activity data for livestock is on a one-year average basis from the agricultural statistics published by Statistics Denmark (2016). 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 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 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 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 corresponding to an IPCC tier 2/3 approach (IPCC, 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, 2016). 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 wastewater 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). The guidelines were updated in 2007 and 2012 and are available from the EU Commission website (EU Commission, 2012).

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, 2012). 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, 2012) 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, 2012).

	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	2	2	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 the principles are described in Article 42 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 a 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 217 emission source categories including 33 LULUCF source categories.

The 12 different KCA for Denmark point out 26-53 key source categories each and a total of 75 different key source categories. The number of key categories in each of the main sectors are: energy 38, IPPU 5, agriculture 13, LULUCF 15 and waste 4.

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 73 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	Key categories with number according to ranking in analysis Identification criteria					
			Level Approach 1 1990	Level Approach 1 2015	Trend Approach 1 1990-2015	Level Approach 2 1990	Level Approach 2 2015	Trend Approach 2 1990-2015
Energy	1A Stationary combustion, Coal, ETS data	CO_2		2	2			49
Energy	1A Stationary combustion, Coal, no ETS data	CO_2	1	12	1	17		9
Energy	1A Stationary combustion, Fossil waste, ETS data	CO_2		10	9		46	34
Energy	1A Stationary combustion, Fossil waste, no ETS data	CO_2	23	22	31		40	
Energy	1A Stationary combustion, Petroleum coke, ETS data	CO_2		24	15			
Energy	1A Stationary combustion, Petroleum coke, no ETS data	CO_2	29		26			
Energy	1A Stationary combustion, Residual oil, ETS data	CO_2		34	24			
Energy	1A Stationary combustion, Residual oil, no ETS data	CO_2	7		7			42
Energy	1A Stationary combustion, Gas oil	CO_2	3	19	5	27		24
Energy	1A Stationary combustion, Kerosene	CO_2	30		28			
Energy	1A1b Stationary combustion, Petroleum refining, Refinery gas	CO_2	16	16	22			
Energy	1A Stationary combustion, Natural gas, onshore	CO_2	6	3	4		35	47
Energy	1A1c_ii Stationary combustion, Oil and gas extraction, Off shore gas turbines, Natural gas	CO_2	28	9	10			
Energy	1A4b_i Stationary combustion, Residential wood combus-tion	CH_4				29	27	36
Energy	1A4b_i/1A4c_i Stationary Combustion, Residential and agricultural straw combustion	CH_4				32	49	
Energy	1A1 Stationary Combustion, Solid fuels	N_2O				23	38	22
Energy	1A1 Stationary Combustion, Gaseous fuels	N_2O				34	30	33
Energy	1A1 Stationary Combustion, Waste	N_2O						45
Energy	1A1 Stationary Combustion, Biomass	N_2O					24	17
Energy	1A2 Stationary Combustion, Liquid fuels	N_2O				20	41	14
Energy	1A2 Stationary Combustion, Gaseous fuels	N_2O					39	53
Energy	1A4 Stationary Combustion, Liquid fuels	N_2O				28		31
Energy	1A4 Stationary Combustion, Gaseous fuels	N_2O					34	48
Energy	1A4b_i Stationary Combustion, Residential wood combus-tion	N_2O					18	10
Energy	1.A.2.g Industry (mobile)	CO_2	21	18	29	21	16	19
Energy	1.A.3.b Road Transport	CO_2	2	1	3	12	7	7
Energy	1.A.3.c Railways	CO_2	34	35				
Energy	1.A.3.d Navigation (large vessels)	CO_2	18	33	35	33		
Energy	1.A.4.a Commercial/Institutional (mobile)	CO_2		40			45	43
Energy	1.A.4.c ii Agriculture (mobile)	CO_2	11	11	32	18	17	41
Energy	1.A.4.c iii Fisheries	CO_2	22	26				
Energy	1.A.2.g Industry (mobile)	N_2O				35	33	44
Energy	1.A.3.b Road Transport	N_2O					44	51
Energy	1.A.4.c ii Agriculture (mobile)	N_2O				26	22	40
Energy	1.B.2.c.2.ii Flaring, gas	CO_2	32	36				
Energy	1.B.2.c.2.ii Flaring, gas	N_2O				11	10	32
IPPU	2A1 Cement production	CO_2	14	15	23			
IPPU	2D2 Paraffin wax use	CO_2						50
IPPU	2B2 Nitric acid production	N_2O	13		14	22		11
IPPU	2F1 Refrigeration and air conditioning	HFCs		25	16		15	4
IPPU	2F2 Foam blowing agents	HFCs				30		35
Agriculture	3A Enteric Fermentation	CH_4	4	4	12	5	5	12
Agriculture	3B Manure Management	CH_4	9	8	13	15	12	13
Agriculture	3B Manure Management	N_2O	17	23		6	8	38
Agriculture	3B5 Atmospheric deposition	N_2O		44		24	23	
Agriculture	3Da1 Inorganic N fertilizer	N_2O	8	14	21	2	3	3
Agriculture	3Da2a Animal manure applied to soils	N_2O	12	13	25	4	2	5
Agriculture	3Da3 Urine and dung deposited by grazing animals	N_2O	33	38		19	19	52
Agriculture	3Da4 Crop Residues	N_2O	25	20	27	8	6	6
Agriculture	3Da5 Mineralization	N_2O				25		25
Agriculture	3Da6 Cultivation of organic soils	N_2O	20	28		7	9	
Agriculture	3Db1 Atmospheric deposition	N_2O	31	42		16	21	30
Agriculture	3Db2 Leaching	N_2O	27	31		10	11	
Agriculture	3G Liming	CO_2	26	41	30	9	20	8
LULUCF	4.A.1 Forest land remaining forest land, Living biomass	CO_2	19	6	8		26	23
LULUCF	4.A.1 Forest land remaining forest land, Dead organic matter	CO_2		7	6		31	18
LULUCF	4.A.1 Forest land remaining forest land, Organic soils	CO_2		45		31	37	
LULUCF	4.A.2 Land converted to forest land	CO_2		27	17		42	29
LULUCF	4.B.1 Cropland remaining cropland, Living biomass	CO_2		32	18		47	26
LULUCF	4.B.1 Cropland remaining cropland, Mineral soils	CO_2	24	29	11	13	14	1
LULUCF	4.B.1 Cropland remaining cropland, Organic soils	CO_2	5	5		1	1	

IPCC Source Categories (LULUCF included)		GHG	Key categories with number according to ranking in analysis Identification criteria					
			Level Approach 1 1990	Level Approach 1 2015	Trend Approach 1 1990-2015	Level Approach 2 1990	Level Approach 2 2015	Trend Approach 2 1990-2015
LULUCF	4.B.2 Forest land converted to cropland	CO_2		43			36	28
LULUCF	4.B.2 Other land uses converted to cropland	CO_2		37	33		32	21
LULUCF	4.C.1 Grassland remaining grassland, Living biomass	CO_2		30	20			
LULUCF	4.C.1 Grassland remaining grassland, Organic soils	CO_2	15	17	36	14	13	27
LULUCF	4.C.2 Forest land converted to grassland	CO_2						39
LULUCF	4.C.2 Other land uses converted to grassland	CO_2					48	37
LULUCF	4.E.2 Other land uses converted to settlements	CO_2						46
LULUCF	4.G Harvested wood products	CO_2		39	34		25	15
Waste	5.E Accidental fires	CO_2					43	
Waste	5.A Solid waste disposal	CH_4	10	21	19	3	4	2
Waste	5.B.1 Composting	CH_4					28	20
Waste	5.B.1 Composting	N_2O					29	16

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.

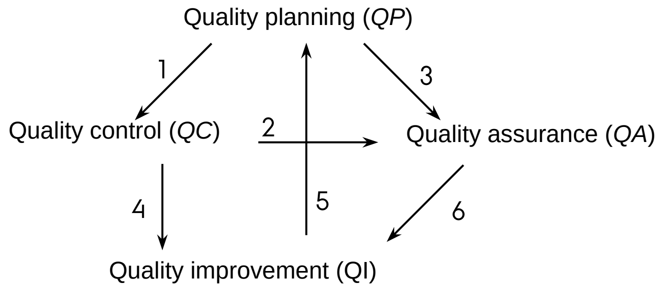


Figure 1.2 Interrelation between the activities with regard to quality. The arrows are explained in the text below this figure.

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 (2006), are to improve elements of transparency, consistency, comparability, completeness and confidence.

The objectives for the *QM* are used as *CCP*s, including the elements mentioned above. The following explanation is given by UNFCCC guidelines (UNFCCC, 2013) for each *CCP*:

Transparency means that the data sources, assumptions and methodologies used for an inventory should be clearly explained, in order to facilitate the replication and assessment of the inventory by users of the reported information. The transparency of inventories is fundamental to the success of the process for the communication and consideration of the information. The use of the common reporting format (CRF) tables and the preparation of a structured national inventory report (NIR) contribute to the transparency of the information and facilitate national and international reviews.

Consistency means that an annual GHG inventory should be internally consistent for all reported years in all its elements across sectors, categories and gases. An inventory is consistent if the same methodologies are used for the base and all subsequent years and if consistent data sets are used to estimate emissions or removals from sources or sinks. Under certain circumstances referred to in paragraphs 16 to 18 below, 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 *2006 IPCC Guidelines for National Greenhouse Gas Inventories* (hereinafter referred to as the 2006 IPCC Guidelines).

Comparability means that estimates of emissions and removals reported by Annex I Parties in their inventories should be comparable among Annex I Parties. For that purpose, Annex I Parties should use the methodologies and formats agreed by the COP for making estimations and reporting their inventories. The allocation of different source/sink categories should follow the CRF tables provided in annex II to decision 24/CP.19 at the level of the summary and sectoral tables.

Completeness means that an annual GHG inventory covers at least all sources and sinks, as well as all gases, for which methodologies are provided in the 2006 IPCC Guidelines or for which supplementary methodologies have been agreed by the COP. Completeness also means the full geographical coverage of the sources and sinks of an Annex I Party.

Accuracy means that emission and removal estimates should be accurate in the sense that they are systematically neither over nor under true emissions or removals, as far as can be judged, and that uncertainties are reduced as far as practicable. Appropriate methodologies should be used, in accordance with the 2006 IPCC Guidelines, to promote 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 IPCC (IPCC, 2006) 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 calculated either 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.

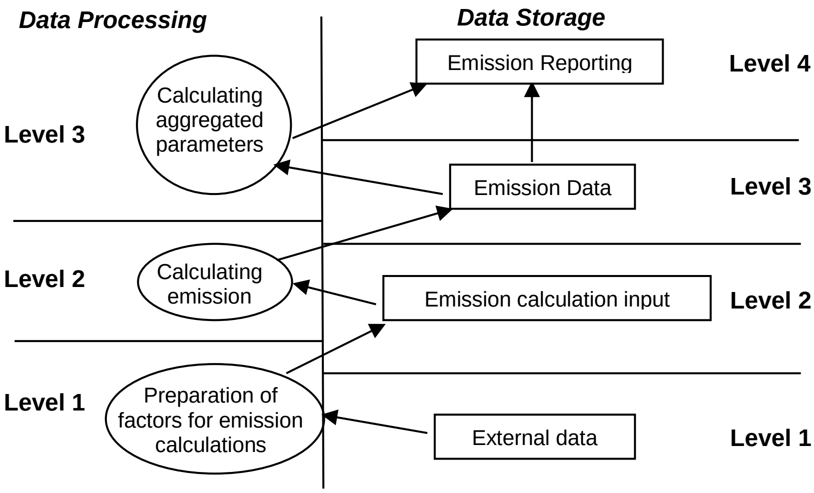


Figure 1.3 The general data structure for the emission inventory.

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 per year 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 1.4.

Table 1.4 The list of *PMs* 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
		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

Level	CCP	Id	Description	
Continued				
	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
		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

Level	CCP	Id	Description	
Continued				
		DS.4.4.3	The IEFs from the CRF are checked regarding both 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, several issues regarding the listing of priority categories exist: (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 UN-FCCC 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 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 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 reporting guidelines (UNFCCC, 2013). 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 1.5.

Table 1.5 Summary of base year and 2015 emissions in kt CO_2 eqv. and activity data and emission factor uncertainties. Calculated Approach 1 uncertainties for each emission source are given as % of the total 2015 emission. The base year for F-gases is 1995 and for all other gases, the base year is 1990.

IPCC Source category	Gas	Base year emission kt CO_2 eqv.	2015 emission kt CO_2 eqv.	Activity data uncertainty %	Emission factor uncertainty %	Approach 1 Combined uncertainty % of total emissions
1A Stationary combustion, Coal, ETS data	CO_2	0.0	6096.7	0.5	0.3	0.005
1A Stationary combustion, Coal, no ETS data	CO_2	23833.8	1072.7	0.9	1.0	0.001
1A Stationary combustion, BKB	CO_2	11.3	0.0	2.9	5.0	0.000
1A Stationary combustion, Coke oven coke	CO_2	136.5	68.7	1.8	5.0	0.000
1A Stationary combustion, Fossil waste, ETS data	CO_2	0.0	0.0	2.0	5.0	0.000
1A Stationary combustion, Fossil waste, no ETS data	CO_2	573.5	1699.5	5.0	10.0	0.133
1A Stationary combustion, Petroleum coke, ETS data	CO_2	0.0	593.1	0.5	0.5	0.000
1A Stationary combustion, Petroleum coke, no ETS data	CO_2	414.7	23.1	1.9	5.0	0.000
1A Stationary combustion, Residual oil, ETS data	CO_2	0.0	0.0	0.5	0.5	0.000
1A Stationary combustion, Residual oil, no ETS data	CO_2	2524.5	327.2	1.6	2.0	0.000
1A Stationary combustion, Gas oil	CO_2	4721.8	699.1	2.6	1.5	0.002
1A Stationary combustion, Kerosene	CO_2	367.6	2.3	1.7	3.0	0.000
1A Stationary combustion, LPG	CO_2	186.8	87.2	2.6	4.0	0.000
1A1b Stationary combustion, Petroleum refining, Refinery gas	CO_2	816.1	928.4	1.0	2.0	0.002
1A Stationary combustion, Natural gas, onshore	CO_2	3790.5	5478.1	1.3	0.4	0.020
1A1c_ii Stationary combustion, Oil and gas extraction, Off shore gas turbines, Natural gas	CO_2	544.9	1429.1	0.5	0.5	0.000
1A1 Stationary Combustion, Solid fuels	CH_4	5.3	1.6	1	100	0.000
1A1 Stationary Combustion, Liquid fuels	CH_4	0.7	0.5	1	100	0.000
1A1 Stationary Combustion, not engines, gaseous fuels	CH_4	0.8	1.8	1	100	0.000
1A1 Stationary Combustion, Waste	CH_4	0.2	0.3	3	100	0.000
1A1 Stationary Combustion, not engines, Biomass	CH_4	3.6	10.7	3	100	0.000
1A2 Stationary Combustion, solid fuels	CH_4	3.8	1.1	2	100	0.000
1A2 Stationary Combustion, Liquid fuels	CH_4	0.9	0.6	2	100	0.000
1A2 Stationary Combustion, not engines, gaseous fuels	CH_4	0.6	0.8	2	100	0.000
1A2 Stationary Combustion, Waste	CH_4	0.0	1.9	3	100	0.000
1A2 Stationary Combustion, not engines, Biomass	CH_4	1.6	1.4	10	100	0.000
1A4 Stationary Combustion, Solid fuels	CH_4	6.2	0.2	3	100	0.000
1A4 Stationary Combustion, Liquid fuels	CH_4	3.0	0.3	3	100	0.000
1A4 Stationary Combustion, not engines, gaseous fuels	CH_4	0.6	0.9	3	100	0.000
1A4 Stationary Combustion, Waste	CH_4	0.7	0.1	3	100	0.000
1A4 Stationary Combustion, not engines, not residential wood and not residential/agricultural straw, Biomass	CH_4	0.1	0.4	10	100	0.000
1A4b_i Stationary combustion, Residential wood combustion	CH_4	71.1	86.9	20	150	0.064
1A4b_i/1A4c_i Stationary Combustion, Residential and agricultural straw combustion	CH_4	63.6	36.9	15	150	0.011
1A Stationary combustion, Natural gas fuelled engines, gaseous fuels	CH_4	5.5	51.5	1	2	0.000
1A Stationary combustion, Biogas fuelled engines, Biomass	CH_4	2.2	45.9	3	10	0.000
1A1 Stationary Combustion, Solid fuels	N_2O	57.4	17.1	1	400	0.017
1A1 Stationary Combustion, Liquid fuels	N_2O	2.8	1.5	1	1000	0.001
1A1 Stationary Combustion, Gaseous fuels	N_2O	11.8	16.2	1	750	0.054
1A1 Stationary Combustion, Waste	N_2O	5.2	13.4	3	400	0.011
1A1 Stationary Combustion, Biomass	N_2O	8.4	33.9	3	400	0.068
1A2 Stationary Combustion, Solid fuels	N_2O	6.7	9.2	2	400	0.005
1A2 Stationary Combustion, Liquid fuels	N_2O	28.7	6.6	2	1000	0.016

IPCC Source category	Gas	Base year emission kt CO_2 eqv.	2015 emission kt CO_2 eqv.	Activity data uncertainty %	Emission factor uncertainty %	Approach 1 Combined uncertainty % of total emissions
Continued						
1A2 Stationary Combustion, Gaseous fuels	N_2O	7.2	9.1	2	750	0.017
1A2 Stationary Combustion, Waste	N_2O	0.0	3.0	3	400	0.001
1A2 Stationary Combustion, Biomass	N_2O	6.9	6.0	10	400	0.002
1A4 Stationary Combustion, Solid fuels	N_2O	1.5	0.3	3	400	0.000
1A4 Stationary Combustion, Liquid fuels	N_2O	11.4	1.4	3	1000	0.001
1A4 Stationary Combustion, Gaseous fuels	N_2O	7.7	10.2	3	750	0.022
1A4 Stationary Combustion, Waste	N_2O	1.1	0.2	3	400	0.000
1A4 Stationary Combustion, not residential wood and not residential/agricultural straw, Biomass	N_2O	0.5	2.3	10	400	0.000
1A4b_i Stationary Combustion, Residential wood combustion	N_2O	10.7	44.4	20	500	0.182
1A4b_i/1A4c_i Stationary Combustion, Residential and agricultural straw combustion	N_2O	10.1	5.9	15	500	0.003
1.A.2.g Industry (mobile)	CO_2	664.5	717.7	41	5	0.324
1.A.3.a Civil aviation	CO_2	248.1	127.6	10	5	0.001
1.A.3.b Road Transport	CO_2	9283.4	11442.3	2	5	1.400
1.A.3.c Railways	CO_2	296.7	248.3	2	5	0.001
1.A.3.d Navigation (large vessels)	CO_2	748.2	373.6	11	5	0.008
1.A.4.a Commercial/Institutional (mobile)	CO_2	73.7	171.4	35	5	0.014
1.A.4.b Residential (mobile)	CO_2	39.1	61.9	35	5	0.002
1.A.4.c ii Agriculture (mobile)	CO_2	1272.3	1081.0	24	5	0.259
1.A.4.c ii Forestry (mobile)	CO_2	35.7	15.5	30	5	0.000
1.A.4.c iii Fisheries	CO_2	585.6	533.8	2	5	0.003
1.A.5.b Other (military)	CO_2	47.9	98.1	41	5	0.006
1.A.5.b Other (small boats)	CO_2	119.0	98.4	2	5	0.000
1.A.2.g Industry (mobile)	CH_4	1.5	0.7	41	100	0.000
1.A.3.a Civil aviation	CH_4	0.1	0.0	10	100	0.000
1.A.3.b Road Transport	CH_4	56.0	10.4	2	40	0.000
1.A.3.c Railways	CH_4	0.3	0.1	2	100	0.000
1.A.3.d Navigation (large vessels)	CH_4	0.4	0.4	11	100	0.000
1.A.4.a Commercial/Institutional (mobile)	CH_4	2.9	4.3	35	100	0.000
1.A.4.b Residential (mobile)	CH_4	1.3	0.9	35	100	0.000
1.A.4.c ii Agriculture (mobile)	CH_4	2.3	2.0	24	100	0.000
1.A.4.c ii Forestry (mobile)	CH_4	4.0	0.4	30	100	0.000
1.A.4.c iii Fisheries	CH_4	0.3	0.3	2	100	0.000
1.A.5.b Other (military)	CH_4	1.9	0.2	41	100	0.000
1.A.5.b Other (small boats)	CH_4	0.1	0.1	2	100	0.000
1.A.2.g Industry (mobile)	N_2O	7.8	9.6	41	1000	0.034
1.A.3.a Civil aviation	N_2O	3.0	2.1	10	1000	0.002
1.A.3.b Road Transport	N_2O	89.2	126.5	2	50	0.015
1.A.3.c Railways	N_2O	2.7	2.2	2	1000	0.002
1.A.3.d Navigation (large vessels)	N_2O	5.6	2.8	11	1000	0.003
1.A.4.a Commercial/Institutional (mobile)	N_2O	0.3	0.8	35	1000	0.000
1.A.4.b Residential (mobile)	N_2O	0.2	0.3	35	1000	0.000
1.A.4.c ii Agriculture (mobile)	N_2O	14.7	14.9	24	1000	0.082
1.A.4.c ii Forestry (mobile)	N_2O	0.2	0.2	30	1000	0.000
1.A.4.c iii Fisheries	N_2O	4.4	4.0	2	1000	0.006
1.A.5.b Other (military)	N_2O	0.4	1.0	41	1000	0.000
1.A.5.b Other (small boats)	N_2O	1.1	1.1	2	1000	0.000
1.B.2.a.1 Exploration, oil	CO_2	4.7	0.8	2	10	0.000

IPCC Source category	Gas	Base year emission kt CO_2 eqv.	2015 emission kt CO_2 eqv.	Activity data uncertainty %	Emission factor uncertainty %	Approach 1 Combined uncertainty % of total emissions
Continued						
1.B.2.a.2 Production, oil	CO_2	0.0	0.0	2	100	0.000
1.B.2.a.3 Transport, oil	CO_2	0.0	0.0	2	40	0.000
1.B.2.b.1 Exploration, gas	CO_2	8.3	0.1	2	10	0.000
1.B.2.b.2 Production, gas	CO_2	0.1	0.1	2	100	0.000
1.B.2.b.4 Transmission and storage, gas	CO_2	0.0	0.0	15	2	0.000
1.B.2.b.5 Distribution, gas	CO_2	0.0	0.0	25	10	0.000
1.B.2.c.1.ii Venting, gas	CO_2	0.0	0.0	15	2	0.000
1.B.2.c.2.i Flaring, oil	CO_2	22.9	12.8	11	2	0.000
1.B.2.c.2.ii Flaring, gas	CO_2	304.7	233.3	7.5	2	0.001
1.B.2.a.1 Exploration, oil	CH_4	0.0	0.0	2	125	0.000
1.B.2.a.2 Production, oil	CH_4	0.1	0.1	2	100	0.000
1.B.2.a.3 Transport, oil	CH_4	20.4	13.8	2	40	0.000
1.B.2.a.4 Refining/storage	CH_4	10.9	15.4	1	200	0.004
1.B.2.b.1 Exploration, gas	CH_4	0.8	0.0	2	125	0.000
1.B.2.b.2 Production, gas	CH_4	48.8	43.0	2	100	0.007
1.B.2.b.4 Transmission and storage, gas	CH_4	4.8	0.8	15	2	0.000
1.B.2.b.5 Distribution, gas	CH_4	6.4	3.9	25	10	0.000
1.B.2.c.1.ii Venting, gas	CH_4	1.5	0.8	15	2	0.000
1.B.2.c.2.i Flaring, oil	CH_4	0.2	0.1	11	15	0.000
1.B.2.c.2.ii Flaring, gas	CH_4	28.9	23.6	7.5	125	0.003
1.B.2.a.1 Exploration, oil	N_2O	0.0	0.0	2	1000	0.000
1.B.2.b.1 Exploration, gas	N_2O	1.4	0.0	2	1000	0.000
1.B.2.c.2.i Flaring, oil	N_2O	0.1	0.0	11	1000	0.000
1.B.2.c.2.ii Flaring, gas	N_2O	51.5	42.5	7.5	1000	0.666
2A1 Cement production	CO_2	882.4	931.5	1	2	0.002
2A2 Lime production	CO_2	105.4	50.6	5	4	0.000
2A3 Glass production	CO_2	20.2	8.9	1	2	0.000
2A4a Ceramics	CO_2	42.1	28.8	5	2	0.000
2A4b Other uses of soda ash	CO_2	13.8	10.1	5	2	0.000
2A4d Other process uses of carbonates	CO_2	17.5	21.8	30	2	0.000
2B10 Production of catalysts	CO_2	0.9	1.6	5	5	0.000
2C1a Steel	CO_2	30.3	0.0	5	10	0.000
2C5 Lead production	CO_2	0.2	0.2	10	50	0.000
2D1 Lubricant use	CO_2	49.7	31.7	10	20	0.000
2D2 Paraffin wax use	CO_2	21.7	72.5	15	60	0.007
Paint Application	CO_2	12.8	6.3	10	15	0.000
Degreasing, dry cleaning and electronics	CO_2	0.0	0.0	10	15	0.000
Chemical products manufacturing or processing	CO_2	19.4	11.8	10	15	0.000
Other use of solvents and related activities	CO_2	61.4	42.5	10	20	0.000
2D3 Road paving with asphalt	CO_2	0.1	0.1	20	75	0.000
2D3 Asphalt roofing	CO_2	0.0	0.0	20	75	0.000
2D3 Urea based catalysts	CO_2	0.0	7.2	5	10	0.000
2G4 Fireworks	CO_2	0.1	0.3	10	50	0.000
2D2 Paraffin wax use	CH_4	0.0	0.1	15	60	0.000
2D3 Road paving with asphalt	CH_4	0.3	0.4	20	75	0.000
2G4 Fireworks	CH_4	0.0	0.1	10	50	0.000
2G4 Tobacco	CH_4	1.0	0.6	10	50	0.000
2G4 Charcoal	CH_4	1.1	2.7	10	100	0.000
2B2 Nitric acid production	N_2O	1002.5	0.0	2	25	0.000
2D2 Paraffin wax use	N_2O	0.1	0.2	15	60	0.000

IPCC Source category	Gas	Base year emission kt CO_2 eqv.	2015 emission kt CO_2 eqv.	Activity data uncertainty %	Emission factor uncertainty %	Approach 1 Combined uncertainty % of total emissions
Continued						
2G3a Medical application of N_2O	N_2O	11.3	11.3	25	20	0.000
2G3b N_2O as propellant for pressure and aerosol products	N_2O	5.6	4.7	100	150	0.000
2G4 Fireworks	N_2O	0.7	3.3	10	50	0.000
2G4 Tobacco	N_2O	0.2	0.1	10	50	0.000
2G4 Charcoal	N_2O	0.1	0.2	10	100	0.000
2E Electronics industry	HFCs	0.0	0.0	10	50	0.000
2F1 Refrigeration and air conditioning	HFCs	41.9	590.9	10	50	0.335
2F2 Foam blowing agents	HFCs	199.5	26.2	10	50	0.001
2F4 Aerosols	HFCs	0.0	16.8	10	50	0.000
2E Electronics industry	PFCs	0.0	0.0	10	50	0.000
2F1 Refrigeration and air conditioning	PFCs	0.6	4.9	10	50	0.000
2C4 Magnesium production	SF_6	34.2	0.0	10	30	0.000
2G1 Electrical equipment	SF_6	3.7	12.2	10	50	0.000
2G2 SF6 and PFCs from other product use	SF_6	64.5	90.9	10	50	0.008
3A Enteric Fermentation	CH_4	4039.50	3667.2	2	20	2.004
3B Manure Management	CH_4	1543.62	1854.1	5	20	0.539
3F Field Burning of Agricultural Residues	CH_4	2.17	3.0	25	50	0.000
3B Manure Management	N_2O	781.10	593.9	25	100	1.382
3B5 Atmospheric deposition	N_2O	197.30	138.1	16	100	0.072
3Da1 Inorganic N fertilizer	N_2O	1875.02	952.9	3	100	3.352
3Da2a Animal manure applied to soils	N_2O	1002.65	978.8	25	100	3.754
3Da2b Sewage sludge applied to soils	N_2O	14.59	13.0	15	100	0.001
3Da2c Other organic fertilizer applied to soils	N_2O	7.16	20.9	20	100	0.002
3Da3 Urine and dung deposited by grazing animals	N_2O	297.89	177.2	10	100	0.117
3Da4 Crop Residues	N_2O	569.28	662.2	25	100	1.718
3Da5 Mineralization	N_2O	146.71	33.3	50	100	0.005
3Da6 Cultivation of organic soils	N_2O	672.08	478.4	20	100	0.878
3Db1 Atmospheric deposition	N_2O	313.21	152.1	16	100	0.087
3Db2 Leaching	N_2O	549.31	395.3	20	100	0.599
3F Field Burning of Agricultural Residues	N_2O	0.67	0.9	25	50	0.000
3G Liming	CO_2	565.49	165.6	5	100	0.101
3H Urea application	CO_2	14.67	1.4	3	100	0.000
3I Other carbon-containing fertilizers	CO_2	38.41	10.5	3	100	0.000
4.A.1 Forest land remaining forest land, Living biomass	CO_2	-737.9	-2470.7	5	2	0.065
4.A.1 Forest land remaining forest land, Dead organic matter	CO_2	-5.8	2016.6	5	2	0.043
4.A.1 Forest land remaining forest land, Mineral soils	CO_2	0.0	0.0	5	2	0.000
4.A.1 Forest land remaining forest land, Organic soils	CO_2	189.9	136.3	10	50	0.018
4.A.2 Land converted to forest land	CO_2	-30.9	493.6	10	9	0.016
4.B.1 Cropland remaining cropland, Living biomass	CO_2	-84.9	387.9	3	15	0.013
4.B.1 Cropland remaining cropland, Mineral soils	CO_2	572.4	-438.0	3	75	0.398
4.B.1 Cropland remaining cropland, Organic soils	CO_2	3929.7	2705.0	3	50	6.776
4.B.2 Forest land converted to cropland	CO_2	3.1	143.0	10	50	0.020
4.B.2 Other land uses converted to cropland	CO_2	-8.7	-200.5	10	50	0.039
4.C.1 Grassland remaining grassland, Living biomass	CO_2	64.7	406.5	3	7	0.003
4.C.1 Grassland remaining grassland, Organic soils	CO_2	838.6	734.7	3	50	0.500
4.C.2 Forest land converted to grassland	CO_2	2.0	94.0	10	50	0.008
4.C.2 Other land uses converted to grassland	CO_2	12.6	114.3	10	50	0.013
4.D.1.1 Peat extraction remaining peat extraction	CO_2	99.5	40.7	10	75	0.004

IPCC Source category	Gas	Base year emission kt CO_2 eqv.	2015 emission kt CO_2 eqv.	Activity data uncertainty %	Emission factor uncertainty %	Approach 1 Combined uncertainty % of total emissions
Continued						
4.D.1.2 Flooded land remaining flooded land	CO_2	0.0	0.0	10	75	0.000
4.D.2. Land converted to wetlands	CO_2	1.0	0.0	10	75	0.000
4.E.2 Forest land converted to settlements	CO_2	2.9	8.4	10	75	0.000
4.E.2 Other land uses converted to settlements	CO_2	9.9	58.4	10	75	0.007
4.G Harvested wood products	CO_2	-2.4	-171.5	25	75	0.068
4(II) Cropland on organic soils	CH_4	0.0	4.8	10	90	0.000
4(II) Grassland on organic soils	CH_4	13.5	12.0	10	90	0.000
4(II) A. Forest land, organic soils	CH_4	4.0	29.1	10	90	0.003
4(II) Land converted to wetlands	CH_4	0.6	14.3	10	90	0.001
4(II) Peatland	CH_4	0.2	0.1	10	90	0.000
4(V) Biomass Burning	CH_4	0.7	0.0	10	30	0.000
4(III) Mineralization/immobilization, Forest land	N_2O	0.0	0.0	10	90	0.000
4(III) Mineralization/immobilization, Cropland	N_2O	0.0	3.6	10	90	0.000
4(III) Mineralization/immobilization, Grassland	N_2O	0.0	1.9	10	90	0.000
4(III) Mineralization/immobilization, Land converted to Settlements	N_2O	0.1	4.5	10	90	0.000
4(V) Biomass burning	N_2O	0.4	0.0	10	30	0.000
4(II) Drainage and rewetting, Forest soils	N_2O	26.5	23.9	10	50	0.001
4(II) Peat extraction remaining peat extraction	N_2O	0.2	0.1	10	50	0.000
5.E Accidental fires	CO_2	17.5	21.3	10	300	0.015
5.A Solid waste disposal	CH_4	1536.3	655.4	10	118	2.218
5.B.1 Composting	CH_4	34.7	116.3	40	100	0.058
5.B.2. Anaerobic digestion at biogas facilities	CH_4	3.6	71.8	5	20	0.001
5.C.1 Incineration of corpses	CH_4	0.0	0.0	1	150	0.000
5.C.2 Incineration of carcasses	CH_4	0.0	0.0	40	150	0.000
5.D Wastewater treatment and discharge	CH_4	95.7	109.3	24	32	0.007
5.E Accidental fires	CH_4	1.9	2.4	10	500	0.001
5.B.1 Composting	N_2O	12.1	113.1	40	100	0.055
5.C.1 Incineration of corpses	N_2O	0.0	0.1	1	150	0.000
5.C.2 Incineration of carcasses	N_2O	0.2	0.2	40	150	0.000
5.D Wastewater treatment and discharge	N_2O	61.4	62.6	22	50	0.004

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 1.6. 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 ±5.4 % and the trend in net GHG emission since the base year has been estimated to be -30.0 % ± 2.0 %-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 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 2.6 % and the trend uncertainty is -34.3 % ±1.6 %-age points.

Table 1.6 Uncertainties 1990-2015.

	Uncertainty Base year [%]	Uncertainty 2015 [%]	Trend [%]	Uncertainty in trend [%-age points]
GHG	5.4	5.4	-30.0	± 2.0
CO_2	3.9	4.2	-32.6	± 1.8
CH_4	26.5	17.3	-12.0	± 11.4
N_2O	33.8	36.2	-33.9	± 10.4
F-gases	31.8	41.2	115.4	± 96.7
CO_2 excl. LULUCF	1.8	2.3	-34.4	± 1.5
GHG excl. LULUCF	5.0	5.0	-31.1	± 1.9

1.7.3 Tier 2 uncertainties

On the recommendation of the UNFCCC expert review team (ERT) in 2009 Denmark undertook a tier 2 uncertainty analysis. However, due to a reduction in resources, the tier 2 uncertainty analysis will no longer be carried out. For a description on the methodology and results of the tier 2 uncertainty estimation, please refer to Nielsen et al. (2016).

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 (not including aviation) for 2013-2015. As neither Greenland nor the Faroe Islands are members of the EU, the data in Table 1.7 refer to Denmark only.

Table 1.7 Share of ETS emissions.

	2013	2014	2015
National total emission without LULUCF with indirect, kt CO_2e	54 992.85	50 800.99	48 331.14
ETS emission, kt CO_2e	21 627.11	18 388.75	15 795.94
Share of ETS emission, %	39.3	36.2	32.7

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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, although NF_3 is not occurring in Denmark. Figure 2.1 shows the estimated total greenhouse gas emissions in CO_2 equivalents from 1990 to 2015. The emissions are not corrected for electricity trade or temperature variations. CO_2 is the most important greenhouse gas contributing in 2015 to the national total in CO_2 equivalents excluding LULUCF (Land Use and Land Use Change and Forestry) with 73.3 % followed by CH_4 with 14.3 % N_2O with 10.9 % and F-gases (HFCs, PFCs and SF_6) with 1.5 %. Seen over the time-series from 1990 to 2015 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 2015 is 8.5 % 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 30.7 % from 1990 to 2015 and decreased 29.7 % including LULUCF. From 2014 to 2015 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 production of wind power and other renewable energy. Comments on the overall trends etc. seen in Figure 2.1 are given in the sections below on the individual greenhouse gases.

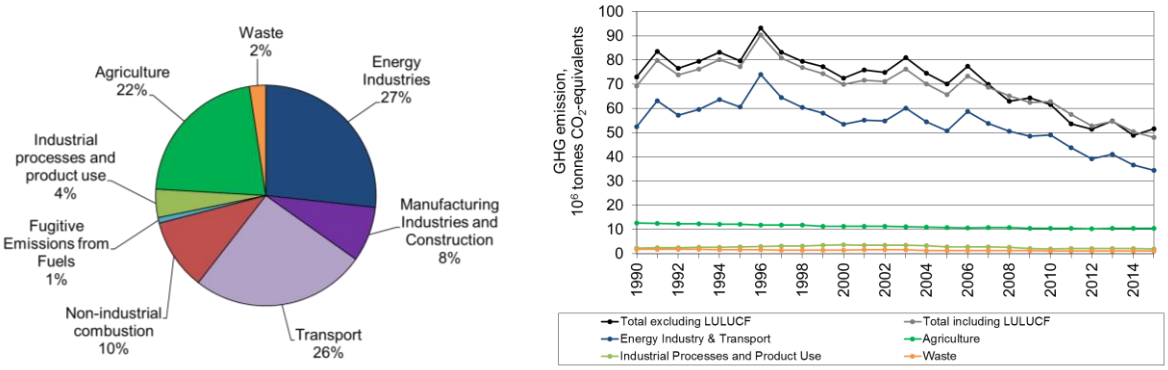


Figure 2.1 Greenhouse gas emissions in CO_2 equivalents distributed on main sectors for 2015 (excluding LULUCF and indirect CO_2) and time series for 1990 to 2015.

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 36 % of the emissions (excl. LULUCF). About 35 % come from the transport sector. The CO_2 emission (excl. LULUCF) decreased by 6.1 % from 2014 to 2015. The main reason for this decrease in emissions owe to decreasing fuel consumption, mainly for coal and natural gas. The decrease in fuel consumption owe to increasing production of wind power and other renewable energy. In 2015, the actual CO_2 emission (excl. LULUCF) was 34.4 % less than the emission in 1990.

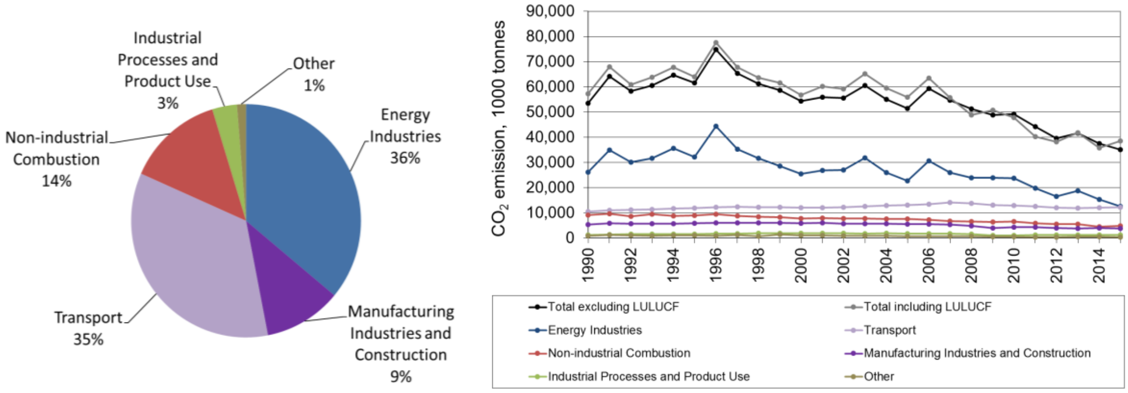


Figure 2.2 CO_2 emissions. Distribution according to the main sectors for 2015 and time series for 1990 to 2015.

2.2.2 Nitrous oxide

Agriculture is the most important N_2O emission source in 2015 contributing 88.7 % (Figure 2.3) of which N_2O from agricultural soils accounts for 74.6 %. 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 28.5 % from 1990 to 2015 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 7.5 %. The N_2O emission from transport contributed with 2.6 % in 2015. 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. However, minor emissions occur from product use, e.g. N_2O from anaesthesia.

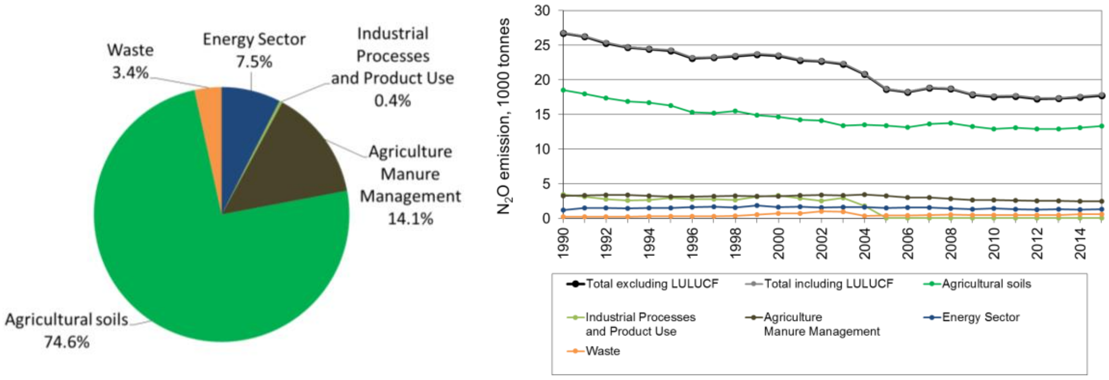


Figure 2.3 N_2O emissions. Distribution according to the main sectors for 2015 and time series for 1990 to 2015.

2.2.3 Methane

The largest sources of anthropogenic CH_4 emissions are agricultural activities contributing in 2015 with 80.6 %, waste (14.0 %), public power and energy industries (1.2 %), see Figure 2.4. The emission from agriculture derives from enteric fermentation and management of animal manure contributing with 53.5 % and 27.1 % of the national CH_4 emission excl. LULUCF in 2015. 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 2015, the emission of CH_4 from enteric fermentation has decreased 9.2 % due to the decrease in the number of cattle. However, the emission from manure management has in the same period increased 20.1 % due to a change from traditional animal housing systems (using solid manure management) towards an increase in slurry-based animal housing systems. Altogether, the emission of CH_4 from the agriculture sector has increased by 1.1 % from 1990 to 2015. The emission of CH_4 from solid waste disposal has decreased 57.3 % 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.

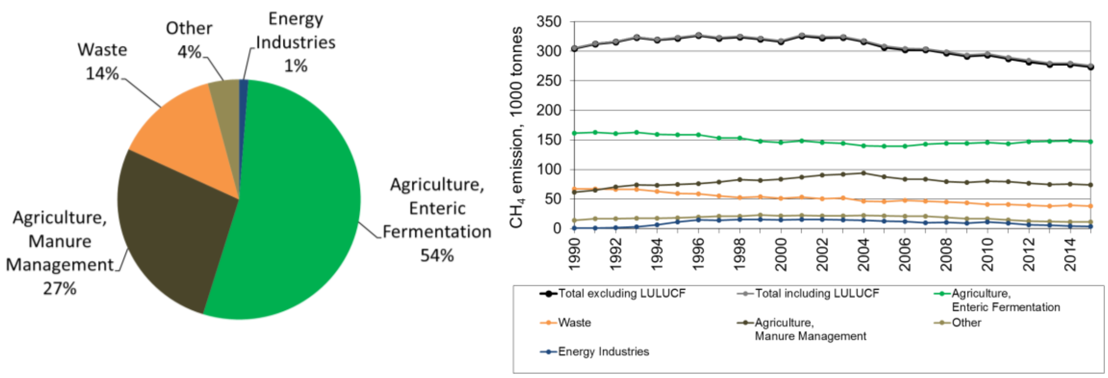


Figure 2.4 CH_4 emissions. Distribution according to the main sectors for 2015 and time series for 1990 to 2015.

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 2000-2008, the increase is lower than for the years 1995 to 2000 and after 2008 the emission has been decreasing. The overall increase from 1995 to 2015 for the total F-gas emission is 115.4 %, while emissions decreased from 2008 to 2015 by 28.7 % 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 2014 was only 15.7 %. The use of HFCs has increased several folds. HFCs have, therefore, become even more dominant, comprising 70.1 % in 1995, but 85.4 % in 2015. 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.

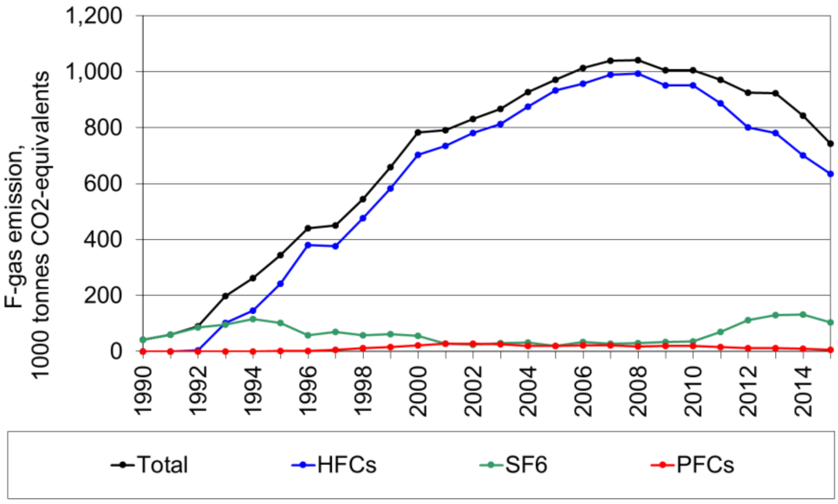


Figure 2.5 F-gas emissions. Time series for 1990 to 2015.

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 51.6 % from 1990 to 2015. The relatively large fluctuation in the emission is due to international 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 2011-2014 are due to a large import of electricity. The main reason for the decrease in emissions owe to decreasing fuel consumption, mainly for coal and natural gas. This decrease is mainly due 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 2015 due to the liberalisation of the electricity market. The CO_2 emission from the transport sector increased by 15.3 % from 1990 to 2015, 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 chemical processes other than fuel combustion, amount in 2015 to 4.2 % 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 2015 with 1.9 % of the national total – increased by 5.6 % from 1990 to 2015. 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 115.4 % from 1995 until 2015, 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 85.4 % in 2015. 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 in mobile systems.

2.3.3 Agriculture

The agricultural sector contributes in 2015 with 21.5 % 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 2015, the contribution of N_2O and CH_4 to the total emission of these gases was 88.7 % and 80.6 %, respectively. The N_2O emission from the agricultural sector decreased by 28.5 % from 1990 to 2015. 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 2015, 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 increased by 1.1 % from 1990 to 2015.

2.3.4 Land use, Land-use change and forestry

Emissions/removals from the forest sector fluctuate based on specific conditions in the given year. The total sector has been estimated to be a net sink of 1.0 % of the total Danish emission incl. LULUCF (average 2011-2015). Forest land has shown to be a large sink for the last five years. The sink has been estimated to 6.0 % of the total Danish emission incl. LULUCF over the period 2011-2015. Cropland has been estimated to be a net source of 4.8% of the total Danish emission incl. LULUCF. This is mainly due to a large area with cultivated organic soils. Grassland is a net source contributing with 2.1 % of the total Danish emission. This is also due to a large area with drained organic soils. Emissions from Cropland have shown a continuous decrease since 1990 with 41 % whereas the emission from Grassland has increased due to conversion of Cropland to Grassland.

2.3.5 Waste

The waste sector contributes in 2015 with 2.4 % to the national total of greenhouse gas emissions (excl. LULUCF), 14.0 % of the total CH_4 emission and 3.4 % 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 34.6 % from 1990 to 2015. This decrease is a result of a decrease in the CH_4 emission from solid waste disposal sites (SWDS) by 57.3 % due to the increasing use of waste for power and heat production, an increase in emission of N_2O from wastewater (WW) handling systems of 2.0 % due to upgrading of WW treatment plants, and an increase in CH_4 from WW of 14.2 % due to increasing industrial load to WW systems. In 2015 the contribution of CH_4 from SWDS was 9.5 % of the total CH_4 emission. The CH_4 emission from WW amounts in 2015 to 1.6 % of the total CH_4 emissions. The emission of N_2O from WW in 2015 is 1.2 % 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	R	R	NO	R	IE	IE	IE
Deforestation	IE	R	R	R	IE	IE	IE	IE
Article 3.4 activities								
Forest management	IE	R	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 and other mobile sources (CRF sector 1A2, 1A3, 1A4 and 1A5)
3.4 Additional information, 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	51,677	62,210	56,378	58,665	62,625	59,416	72,668	63,138	59,074	56,501
1A. Fuel Combustion (Sectoral Approach)	51,336	61,560	55,701	58,083	62,047	58,962	72,171	62,440	58,551	55,395
1A1. Energy Industries	26,150	35,020	30,093	31,668	35,667	32,160	44,468	35,338	31,682	28,591
1A2. Manufacturing Industries and Construction	5,394	5,926	5,781	5,639	5,730	5,839	5,981	6,022	6,039	6,127
1A3. Transport	10,576	10,992	11,193	11,300	11,778	11,918	12,174	12,347	12,302	12,323
1A4. Other Sectors	9,049	9,285	8,438	9,180	8,558	8,728	9,301	8,489	8,246	8,089
1A5. Other	167	338	195	295	314	318	246	245	282	265
1B. Fugitive Emissions from Fuels	341	649	677	582	578	453	498	697	523	1,106
1B1. Solid Fuels	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
1B2. 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	52,149	53,795	53,419	58,648	53,073	49,487	57,401	52,619	49,439	47,546
1A. Fuel Combustion (Sectoral Approach)	51,426	53,025	52,746	57,979	52,321	48,939	56,871	52,075	49,051	47,284
1A1. Energy Industries	25,566	26,855	27,075	31,819	25,937	22,735	30,650	26,023	23,910	23,860
1A2. Manufacturing Industries and Construction	5,922	6,027	5,734	5,702	5,763	5,458	5,582	5,299	4,802	3,992
1A3. Transport	12,124	12,116	12,213	12,665	12,987	13,102	13,468	14,078	13,775	13,053
1A4. Other Sectors	7,617	7,839	7,539	7,602	7,292	7,271	6,942	6,399	6,357	6,119
1A5. Other	197	188	184	191	343	374	228	276	208	260
1B. Fugitive Emissions from Fuels	723	770	674	669	752	548	531	543	387	261
1B1. Solid Fuels	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
1B2. Oil and Natural Gas	723	770	674	669	752	548	531	543	387	261

Continued	2010	2011	2012	2013	2014	2015
	(Gg)					
1. Energy	47,988	42,806	38,264	40,182	35,980	33,722
1A. Fuel Combustion (Sectoral Approach)	47,635	42,554	38,046	39,938	35,730	33,475
1A1. Energy Industries	23,693	19,726	16,526	18,781	15,300	12,668
1A2. Manufacturing Industries and Construction	4,350	4,271	3,969	3,866	3,902	3,830
1A3. Transport	12,992	12,644	12,012	11,813	11,989	12,192
1A4. Other Sectors	6,394	5,620	5,324	5,239	4,309	4,588
1A5. Other	206	292	214	239	230	197
1B. Fugitive Emissions from Fuels	353	252	217	244	250	247
1B1. Solid Fuels	NO	NO	NO	NO	NO	NO
1B2. Oil and Natural Gas	353	252	217	244	250	247

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	14.58	17.38	18.10	20.11	23.38	29.19	33.76	34.87	35.67	38.02
1A. Fuel Combustion (Sectoral Approach)	9.67	10.69	11.28	13.38	16.47	22.27	26.43	26.02	27.31	27.00
1A1. Energy Industries	0.63	0.97	1.37	2.99	6.08	11.42	14.59	13.91	15.30	15.40
1A2. Manufacturing Industries and Construction	0.33	0.35	0.33	0.34	0.34	0.40	0.77	0.77	0.87	0.86
1A3. Transport	2.27	2.37	2.39	2.37	2.36	2.28	2.21	2.14	2.07	1.96
1A4. Other Sectors	6.35	6.90	7.10	7.58	7.59	8.06	8.76	9.09	8.97	8.69
1A5. Other	0.08	0.10	0.09	0.09	0.10	0.10	0.10	0.10	0.10	0.10
1B. Fugitive Emissions from Fuels	4.90	6.69	6.82	6.73	6.92	6.92	7.33	8.85	8.36	11.01
1B1. Solid Fuels	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
1B2. Oil and Natural Gas	4.90	6.69	6.82	6.73	6.92	6.92	7.33	8.85	8.36	11.01

Continued	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
						(Gg)				
1. Energy	36.27	37.39	36.35	35.73	36.35	34.06	32.35	30.24	29.01	25.56
1A. Fuel Combustion (Sectoral Approach)	26.40	27.21	26.67	26.27	26.08	24.45	23.06	21.50	21.13	19.09
1A1. Energy Industries	14.69	15.57	15.14	14.40	14.08	12.44	11.53	9.60	10.12	8.84
1A2. Manufacturing Industries and Construction	1.07	1.13	1.03	1.00	1.01	0.89	0.74	0.52	0.57	0.52
1A3. Transport	1.83	1.72	1.62	1.54	1.44	1.33	1.22	1.12	0.95	0.81
1A4. Other Sectors	8.71	8.70	8.79	9.24	9.46	9.71	9.51	10.20	9.45	8.89
1A5. Other	0.09	0.09	0.09	0.08	0.08	0.07	0.06	0.05	0.04	0.03
1B. Fugitive Emissions from Fuels	9.87	10.18	9.68	9.46	10.27	9.61	9.29	8.74	7.88	6.47
1B1. Solid Fuels	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
1B2. 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**	**2014**	**2015**
			(Gg)			
1. Energy	27.66	23.46	19.03	17.44	14.99	14.60
1A. Fuel Combustion (Sectoral Approach)	21.36	18.19	14.40	13.14	10.69	10.54
1A1. Energy Industries	11.01	9.22	6.39	5.62	4.02	3.41
1A2. Manufacturing Industries and Construction	0.59	0.54	0.39	0.34	0.40	0.52
1A3. Transport	0.73	0.65	0.57	0.51	0.47	0.44
1A4. Other Sectors	9.00	7.76	7.04	6.65	5.79	6.16
1A5. Other	0.03	0.02	0.02	0.01	0.01	0.01
1B. Fugitive Emissions from Fuels	6.31	5.27	4.63	4.30	4.29	4.06
1B1. Solid Fuels	NO	NO	NO	NO	NO	NO
1B2. Oil and Natural Gas	6.31	5.27	4.63	4.30	4.29	4.06

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	1.21	1.52	1.50	1.47	1.51	1.49	1.65	1.70	1.56	1.88
1A. Fuel Combustion (Sectoral Approach)	1.03	1.16	1.13	1.15	1.19	1.25	1.38	1.31	1.28	1.26
1A1. Energy Industries	0.29	0.37	0.34	0.36	0.39	0.38	0.51	0.44	0.42	0.40
1A2. Manufacturing Industries and Construction	0.19	0.21	0.21	0.19	0.19	0.24	0.24	0.24	0.25	0.25
1A3. Transport	0.34	0.35	0.36	0.37	0.39	0.40	0.40	0.41	0.40	0.40
1A4. Other Sectors	0.21	0.22	0.21	0.22	0.22	0.22	0.23	0.22	0.21	0.21
1A5. Other	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
1B. Fugitive Emissions from Fuels	0.18	0.36	0.37	0.32	0.31	0.24	0.27	0.39	0.28	0.62
1B1. Solid Fuels	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
1B2. Oil and Natural Gas	0.18	0.36	0.37	0.32	0.31	0.24	0.27	0.39	0.28	0.62
Continued	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
						(Gg)				
1. Energy	1.62	1.67	1.60	1.65	1.65	1.49	1.57	1.56	1.45	1.33
1A. Fuel Combustion (Sectoral Approach)	1.22	1.24	1.24	1.28	1.23	1.20	1.28	1.26	1.24	1.20
1A1. Energy Industries	0.38	0.40	0.40	0.44	0.39	0.35	0.42	0.36	0.35	0.36
1A2. Manufacturing Industries and Construction	0.24	0.24	0.22	0.21	0.22	0.21	0.23	0.23	0.22	0.17
1A3. Transport	0.39	0.38	0.38	0.38	0.37	0.36	0.35	0.37	0.38	0.37
1A4. Other Sectors	0.21	0.23	0.23	0.24	0.24	0.26	0.27	0.29	0.29	0.29
1A5. Other	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
1B. Fugitive Emissions from Fuels	0.40	0.43	0.37	0.37	0.42	0.30	0.29	0.29	0.21	0.14
1B1. Solid Fuels	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
1B2. Oil and Natural Gas	0.40	0.43	0.37	0.37	0.42	0.30	0.29	0.29	0.21	0.14
Continued	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**				
			(Gg)							
1. Energy	1.45	1.32	1.26	1.31	1.27	1.31				
1A. Fuel Combustion (Sectoral Approach)	1.26	1.20	1.15	1.17	1.14	1.16				
1A1. Energy Industries	0.38	0.33	0.31	0.33	0.29	0.28				
1A2. Manufacturing Industries and Construction	0.19	0.18	0.16	0.15	0.15	0.15				
1A3. Transport	0.38	0.40	0.41	0.41	0.43	0.45				
1A4. Other Sectors	0.30	0.27	0.27	0.27	0.25	0.29				
1A5. Other	0.01	0.01	0.01	0.01	0.01	0.01				
1B. Fugitive Emissions from Fuels	0.19	0.12	0.11	0.14	0.13	0.14				
1B1. Solid Fuels	NO	NO	NO	NO	NO	NO				
1B2. Oil and Natural Gas	0.19	0.12	0.11	0.14	0.13	0.14				

3.2 Stationary combustion

Stationary combustion is the largest source of CO_2 emission in Denmark accounting for 53 % of the 2015 national total CO_2 emissions excl. LULUCF or 48 % of the CO_2 emission including LULUCF. The CO_2 emission from stationary combustion has decreased by 12 % since 2014 and decreased by 51 % 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 2015 are due to inter-country electricity trade fluctuations caused mainly by variation in hydropower generation in Norway and Sweden. The CO_2 emission in 2015 was lower than in 2014 due to a higher electricity import in 2015 than in 2014.

The methane (CH_4) emission from stationary combustion plants accounted for 3.5 % of the national CH_4 emission in 2015. The CH_4 emission from stationary combustion has increased by 43 % since 1990. The emission increased until 1996 and decreased after 2004. The time series is related to the considerable number of lean-burn gas engines installed in CHP plants in Denmark during the 1990s. The CH_4 emission from gas engines is high compared to other plant types. 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 2015 was 1 % lower than in 2014 mainly due to lower fuel consumption in gas engines.

The nitrous oxide (N_2O) emission from stationary combustion plants accounted for 3.4 % of the national N_2O emission in 2015. The N_2O emission from stationary combustion was 1 % higher than in 1990, but as for CO_2, fluctuations in emission level due to electricity import/export are considerable. The emission in 2015 was 1 % higher than in 2014 due to a higher electricity import in 2015 than in 2014.

3.2.1 Source category description

Source category definition

Stationary combustion plants are included in the emission source subcategories:

- 1A1 Energy, Fuel combustion, Energy Industries
  - 1A1a Public electricity and heat production
  - 1A1b Petroleum refining
  - 1A1c Oil and gas extraction
- 1A2 Energy, Fuel combustion, 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 combustion, Other Sectors
  - 1A4a i Commercial/institutional plants.
  - 1A4b iResidential 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 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 2015/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 [4)]	CS	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/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 2015 or trend 1990-2015.
3) Only 2.5 % of the total coal consumption is included in the non-ETS category in 2015.
4) Only 15 % of the total residual oil consumption is included in the non-ETS category in 2015.
5) Tier 3 for 2 % of the gas oil consumption in 2015.

Key Categories

Key Category Analysis (KCA) approach 1 and approach 2 for the years 1990 and 2015 and for the trend 1990-2015 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	2015	1990-2015	1990	2015	1990-2015
Energy	1A Stationary combustion, Coal, ETS data	CO_2		Level	Trend			Trend
Energy	1A Stationary combustion, Coal, no ETS data	CO_2	Level	Level	Trend	Level		Trend
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		Level	Trend		Level	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	1A Stationary combustion, LPG	CO_2						
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	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				Level	Level	Trend
Energy	1A4b_i/1A4c_i Stationary Combustion, Residential and agricultural straw combustion	CH_4				Level	Level	
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				Level	Level	Trend
Energy	1A1 Stationary Combustion, Liquid fuels	N_2O						
Energy	1A1 Stationary Combustion, Gaseous fuels	N_2O				Level	Level	Trend
Energy	1A1 Stationary Combustion, Waste	N_2O						Trend
Continued								
Energy	1A1 Stationary Combustion, Biomass	N_2O					Level	Trend
Energy	1A2 Stationary Combustion, Solid fuels	N_2O						
Energy	1A2 Stationary Combustion, Liquid fuels	N_2O				Level	Level	Trend
Energy	1A2 Stationary Combustion, Gaseous fuels	N_2O					Level	Trend
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				Level		Trend
Energy	1A4 Stationary Combustion, Gaseous fuels	N_2O					Level	Trend
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					Level	Trend
Energy	1A4b_i/1A4c_i Stationary Combustion, Residential and agricultural straw combustion	N_2O						

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

3.2.2 Fuel consumption data

In 2015, the total fuel consumption for stationary combustion plants was 387 PJ of which 253 PJ was fossil fuels and 134 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 - 52 % - 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*.

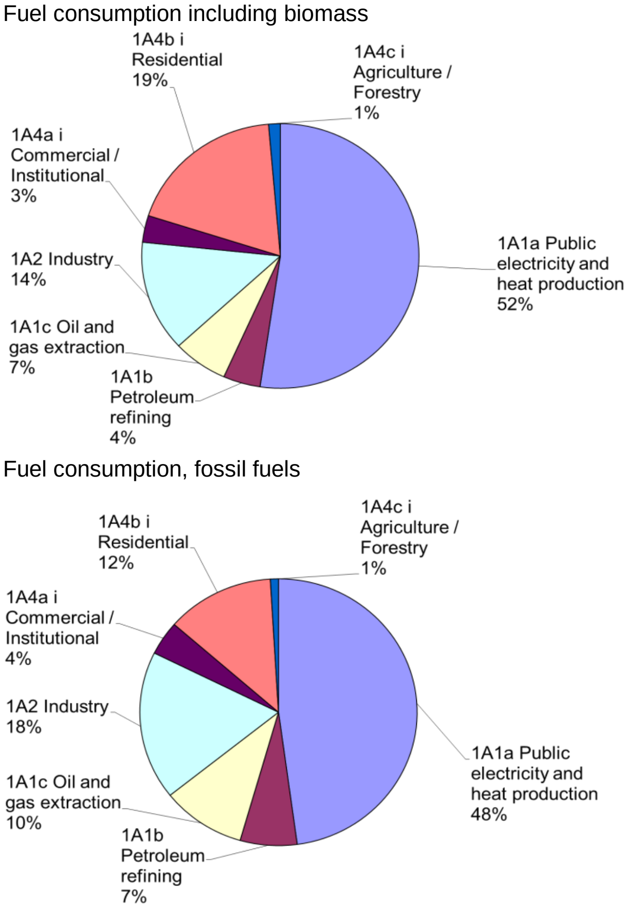


Figure 3.2.1 Fuel consumption of stationary combustion source categories, 2015. Based on DEA (2016a).

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.

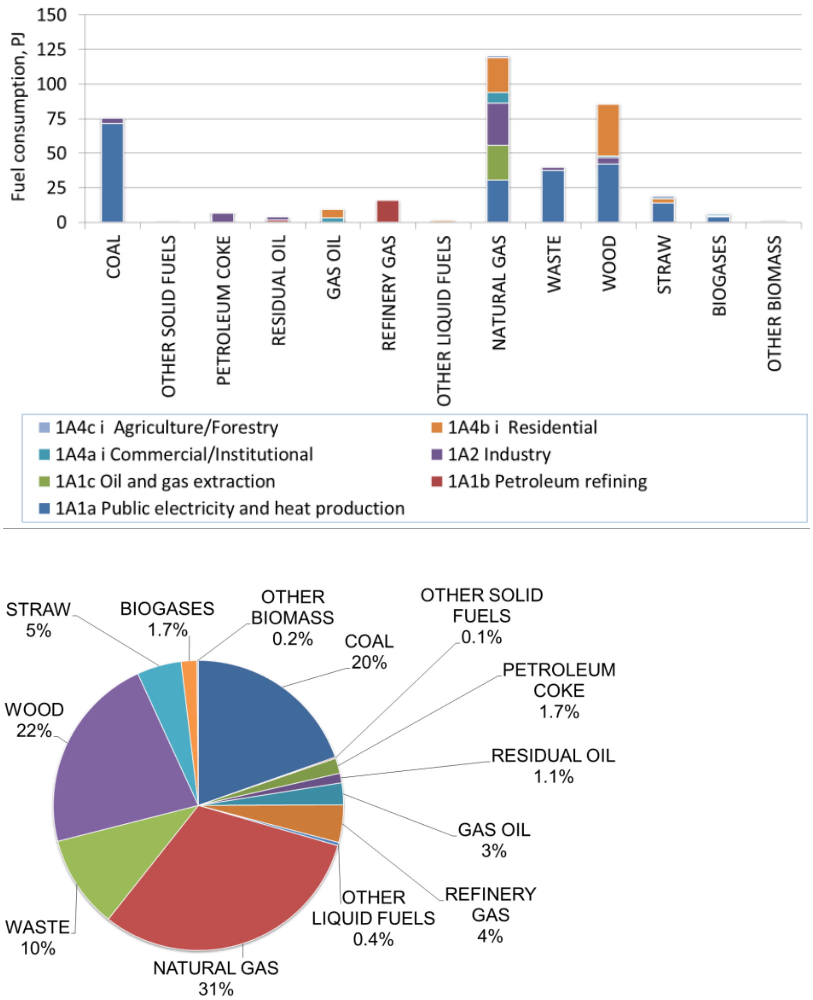
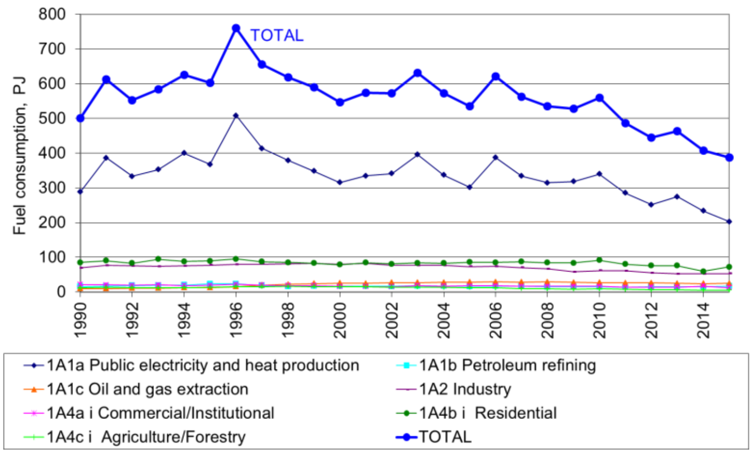


Figure 3.2.2 Fuel consumption of stationary combustion 2015, disaggregated to fuel type. Based on DEA (2016a).

Fuel consumption time series for stationary combustion plants are presented in Figure 3.2.3. The fuel consumption for stationary combustion was 23 % lower in 2015 than in 1990, while the fossil fuel consumption was 45 % lower and the biomass fuel consumption 3.3 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.



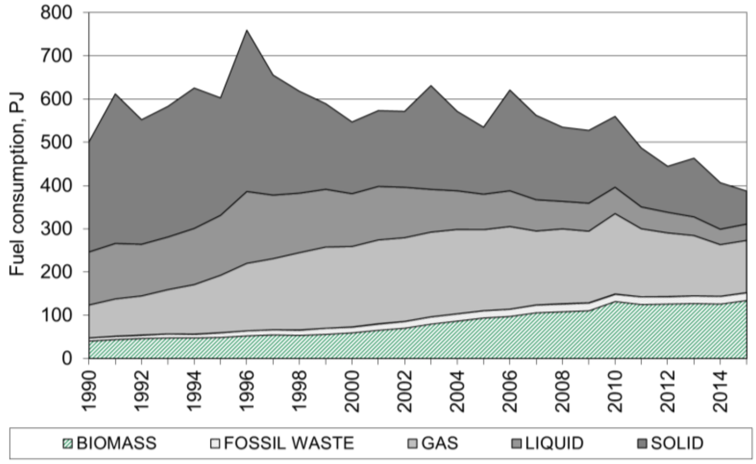


Figure 3.2.3 Fuel consumption time series, stationary combustion. Based on DEA (2016a).

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 and 2003 due to a large electricity export. In 2015, the net electricity import was 21 PJ, whereas there was a 10 PJ electricity import in 2014. 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.

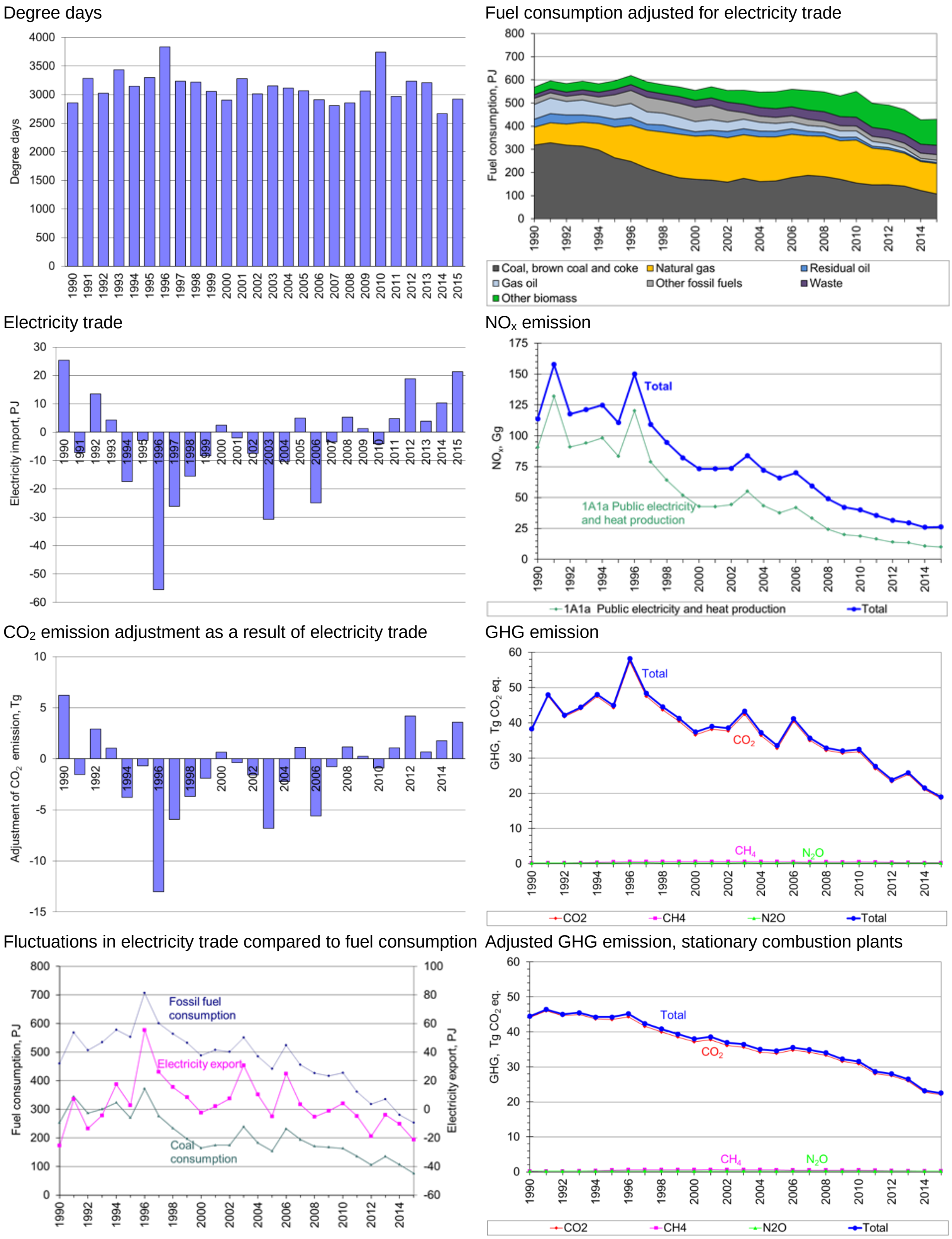


Figure 3.2.4 Comparison of time series fluctuations for electricity trade, fuel consumption, CO_2 emission and NO_x emission. Based on DEA (2016a).

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 2015 was 12 % lower than in 1990 and the fossil fuel consumption was 45 % 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 2015 added up to 82 PJ, which is 5.0 times the level in 1990 and almost the same as in 2014.

The fuel consumption in *Industry* was 24 % lower in 2015 than in 1990 (Figure 3.2.6). The fuel consumption in industrial plants decreased considerably as a result of the financial crisis. The biomass fuel consumption in *Industry* in 2015 added up to 7 PJ, which is a 13 % increase since 1990.

The fuel consumption in *Other Sectors* decreased 24 % since 1990 (Figure 3.2.7) and increased 11 % since 2014. The biomass fuel consumption in *Other sectors* in 2015 added up to 46 PJ which is 2.5 times the consumption in 1990 and 15 % decrease since 2014. Wood consumption in residential plants in 2015 was 2.5 times the consumption in year 2000.

Time series for subcategories are shown in Chapter 3.2.4.

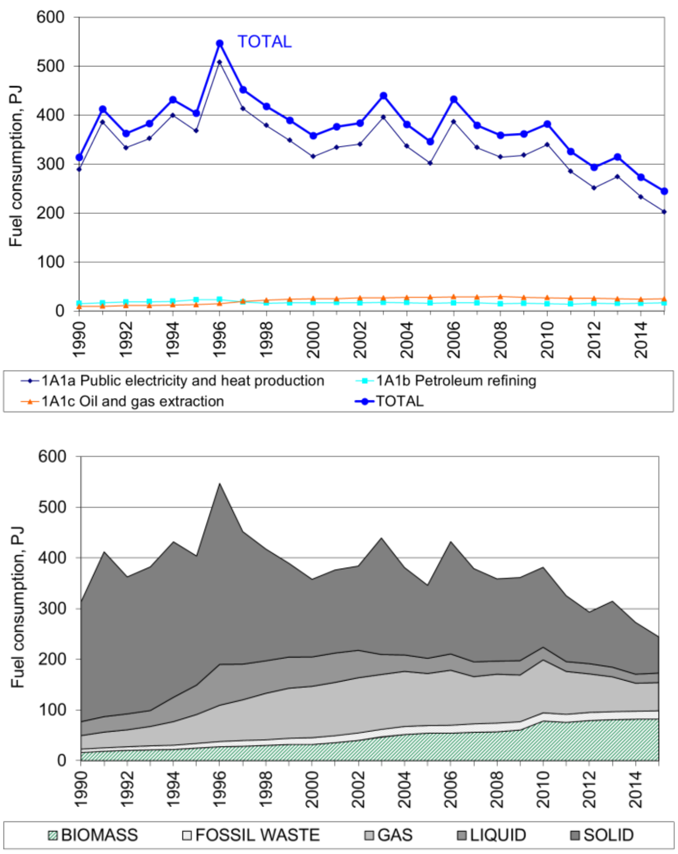


Figure 3.2.5 Fuel consumption time series for subcategories - 1A1 Energy Industries.

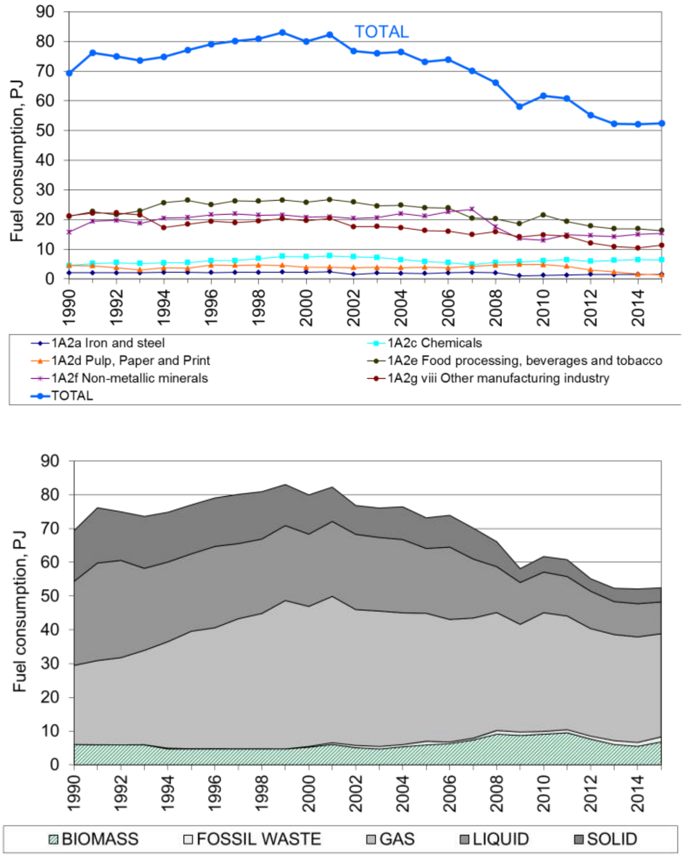


Figure 3.2.6 Fuel consumption time series for subcategories - 1A2 Industry.

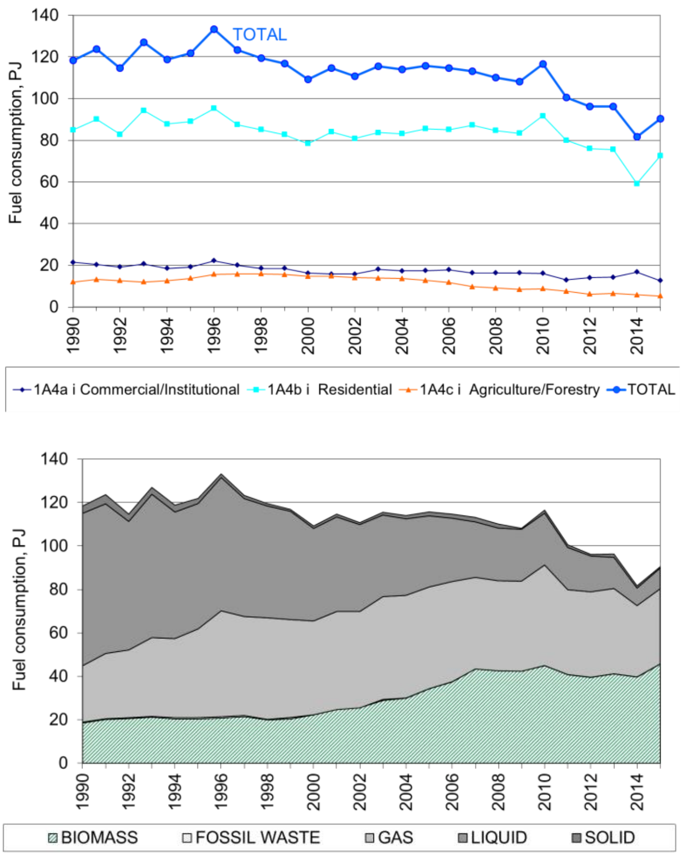


Figure 3.2.7 Fuel consumption time series for subcategories - 1A4 Other Sectors.

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 37 % of the national greenhouse gas emission (including LULUCF) in 2015.

The CO_2 emission from stationary combustion plants accounts for 48 % of the national CO_2 emission (including LULUCF). The CH_4 emission accounts for 3.5 % of the national CH_4 emission and the N_2O emission for 3.4 % of the national N_2O emission.

Table 3.2.3 Greenhouse gas emission, 2015 [1].

	CO_2	CH_4	N_2O
	Gg CO_2 equivalent		
1A1 Fuel Combustion, Energy industries	12668	85	82
1A2 Fuel Combustion, Manufacturing Industries and Construction[1]	3113	12	34
1A4 Fuel Combustion, Other sectors [1]	2725	146	65
Emission from stationary combustion plants	18505	244	181
Emission share for stationary combustion (LULUCF included)	48%	3.5%	3.4%

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

CO_2 is the most important greenhouse gas accounting for 97.8 % of the greenhouse gas emission (CO_2 eq.) from stationary combustion. CH_4 accounts for 1.3 % and N_2O for 1.0 % of the greenhouse gas emission (CO_2 eq.) from stationary combustion (Figure 3.2.8).

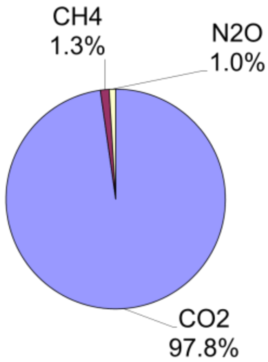


Figure 3.2.8 Greenhouse gas emission from stationary combustion (CO_2 equivalent), contribution from each pollutant.

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 2015 than in 1990, CO_2 by 51.2 % and greenhouse gas by 50.5 %. However, fluctuations in the GHG emission level are large.

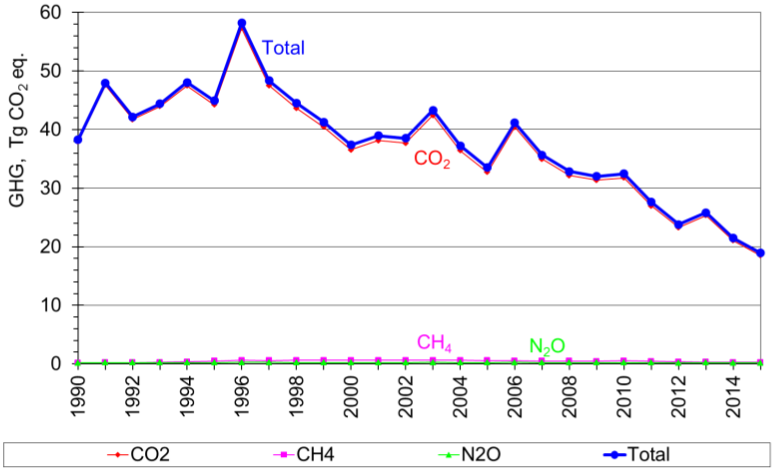


Figure 3.2.9 GHG emission time series for stationary combustion.

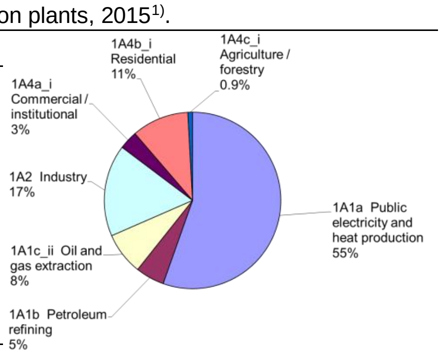
The fluctuations in the time series are largely a result of electricity import/export, but also of outdoor temperature variations from year to year. The fluctuations follow the fluctuations in fuel consumption discussed in Chapter 3.2.2. As mentioned in Chapter 3.2.2, the Danish Energy Agency estimates 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 49.4 % since 1990, and the CO_2 emission by 49.9 %. 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 48 % of the national CO_2 emission (LULUCF included). Table 3.2.4 lists the CO_2 emission inventory for stationary combustion plants for 2015. *Public electricity and heat production* accounts for 55 % of the CO_2 emission from stationary combustion. This share is somewhat higher than the fossil fuel consumption share for this category, which is 48 % (Figure 3.2.1). This is due to a large share of coal in this category. Other large CO_2 emission sources are *Industry, Residential plants* and *Oil and gas extraction*. 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, 2015[1)].

	CO_2 Gg
1A1a Public electricity and heat production	10254
1A1b Petroleum refining	978
1A1c Oil and gas extraction	1436
1A2 Industry	3113
1A4a Commercial/Institutional	632
1A4b Residential	1934
1A4c Agriculture/Forestry	159
Total	18505

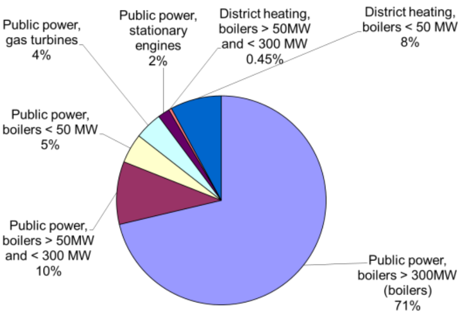


[1)] Only emission from stationary combustion plants in the categories is included.

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)	7311
010102	Combustion plants ≥ 50MW and < 300 MW (boilers)	997
010103	Combustion plants <50 MW (boilers)	468
010104	Gas turbines	435
010105	Stationary engines	188
0102	District heating plants	
010202	Combustion plants ≥ 50MW and < 300 MW (boilers)	46
010203	Combustion plants <50 MW (boilers)	810



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 2015, the CO_2 emission from biomass combustion was 15 031 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 30 % of the fossil fuel consumption and for 39 % of the CO_2 emission. Natural gas accounts for 48 % of the fossil fuel consumption but only 37 % of the CO_2 emission.

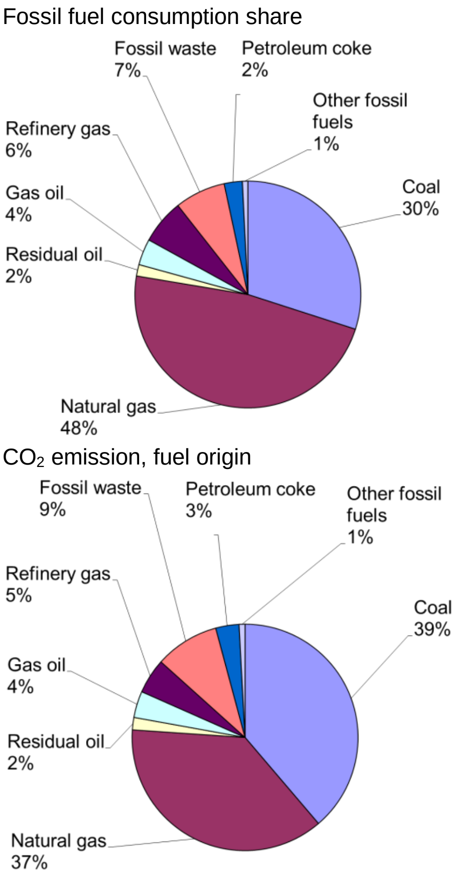


Figure 3.2.10 CO_2 emission, fuel origin.

The time series for CO_2 emission is provided in Figure 3.2.11. Despite a decrease in fuel consumption of 23 %[3] since 1990, the CO_2 emission from stationary combustion has decreased by 51 % 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.

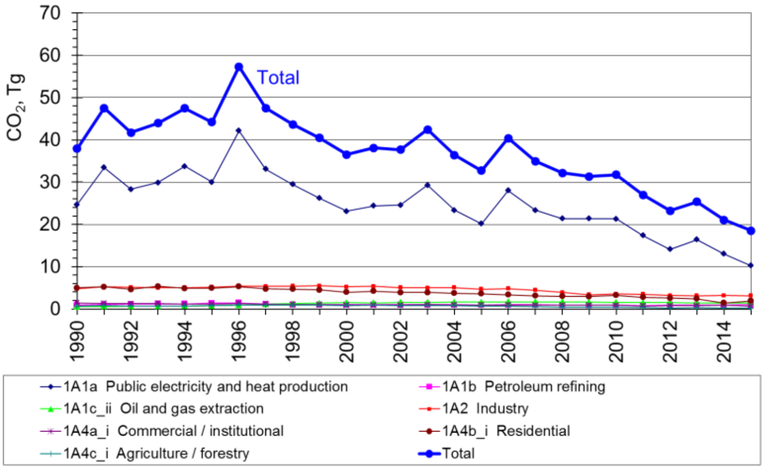


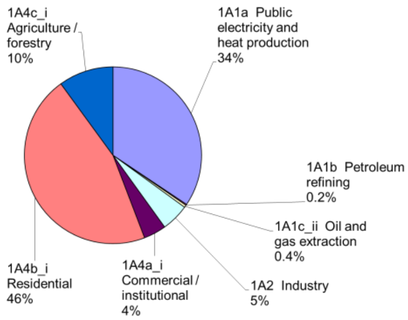
Figure 3.2.11 CO_2 emission time series for stationary combustion plants.

CH_4

The methane (CH_4) emission from stationary combustion plants accounts for 3.5 % of the national CH_4 emission. Table 3.2.6 lists the CH_4 emission inventory for stationary combustion plants in 2015. *Public electricity and heat production* accounts for 34 % of the CH_4 emission from stationary combustion. The emission from residential plants adds up to 46 % of the emission.

Table 3.2.6 CH_4 emission from stationary combustion plants, 2015[1)].

	CH_4, Mg
1A1a Public electricity and heat production	3352
1A1b Petroleum refining	19
1A1c Oil and gas extraction	42
1A2 Industry	494
1A4a Commercial/Institutional	401
1A4b Residential	4463
1A4c Agriculture/Forestry	976
Total	9747



[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 in 2015, these plants accounted for 40 % 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 combus-

[3] The consumption of fossil fuels has decreased 45 %.

tion is the largest emission source accounting for 36 % of the emission in 2015.

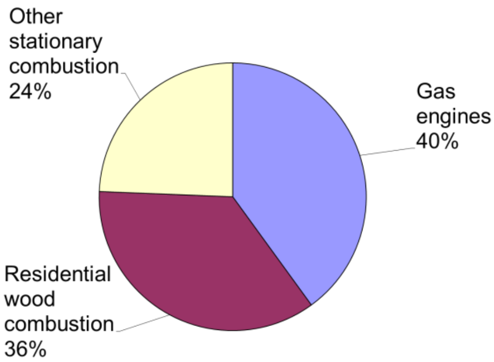


Figure 3.2.12 CH_4 emission share for gas engines and residential wood combustion, 2015.

Figure 3.2.13 shows the time series for CH_4 emission. The CH_4 emission from stationary combustion was 43 % higher in 2015 than in 1990. The emission increased until 1996 and decreased after 2004. This time series is related to 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 78 % of the CH_4 emission from residential plants in 2015.

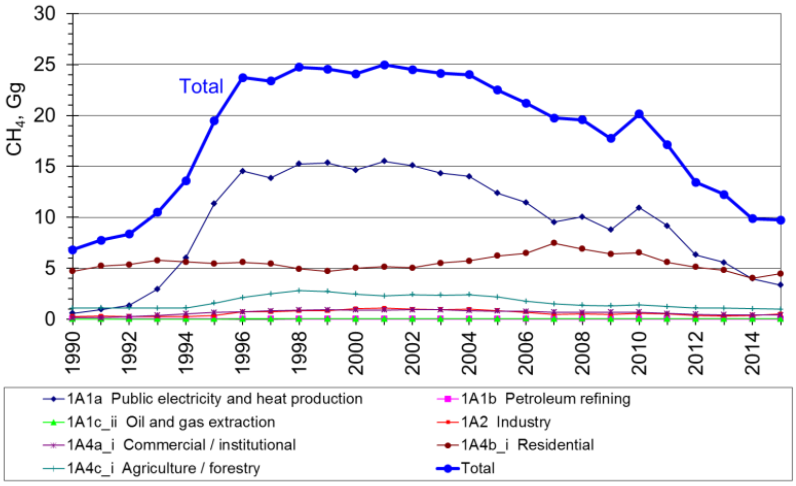


Figure 3.2.13 CH_4 emission time series for stationary combustion plants.

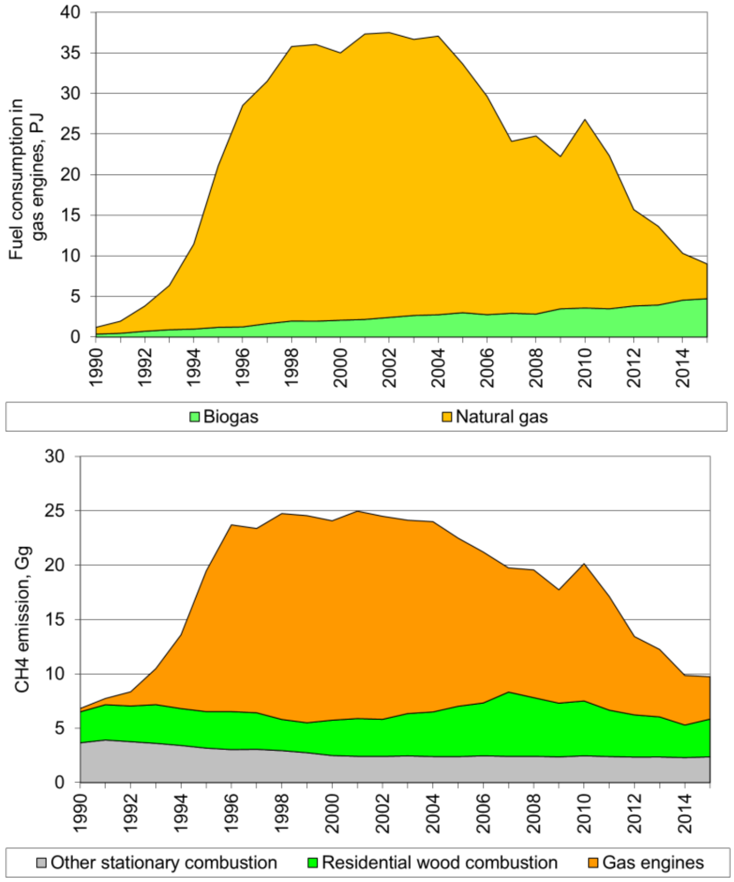


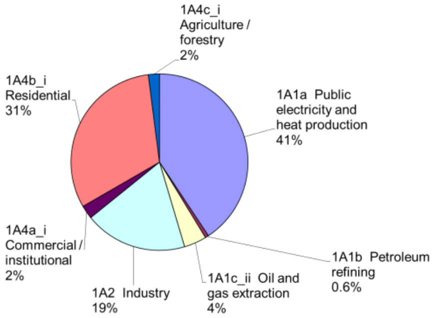
Figure 3.2.14 Time series for a) fuel consumption in gas engines and b) CH_4 emission from gas engines, residential wood combustion and other plants.

N_2O

The nitrous oxide (N_2O) emission from stationary combustion plants accounts for 3.4 % of the national N_2O emission. Table 3.2.7 lists the N_2O emission inventory for stationary combustion plants in the year 2015. *Public electricity and heat production* accounts for 41 % of the N_2O emission from stationary combustion.

Table 3.2.7 N_2O emission from stationary combustion plants, 2015[1].

		N_2O, Mg
1A1a	Public electricity and heat production	247
1A1b	Petroleum refining	4
1A1c	Oil and gas extraction	25
1A2	Industry	114
1A4a	Commercial/Institutional	15
1A4b	Residential	190
1A4c	Agriculture/Forestry	12
Total		606



[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 1 % from 1990 to 2015, but again fluctuations in emission level due to electricity import/export are considerable.

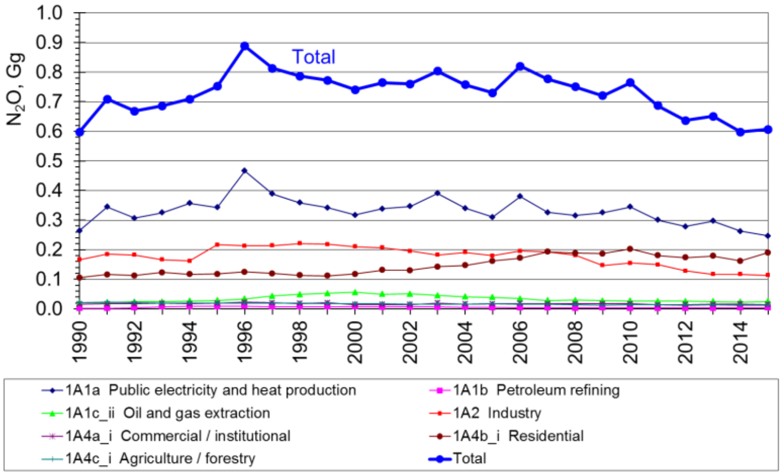


Figure 3.2.15 N_2O emission time series for stationary combustion plants.

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., 2017). 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.

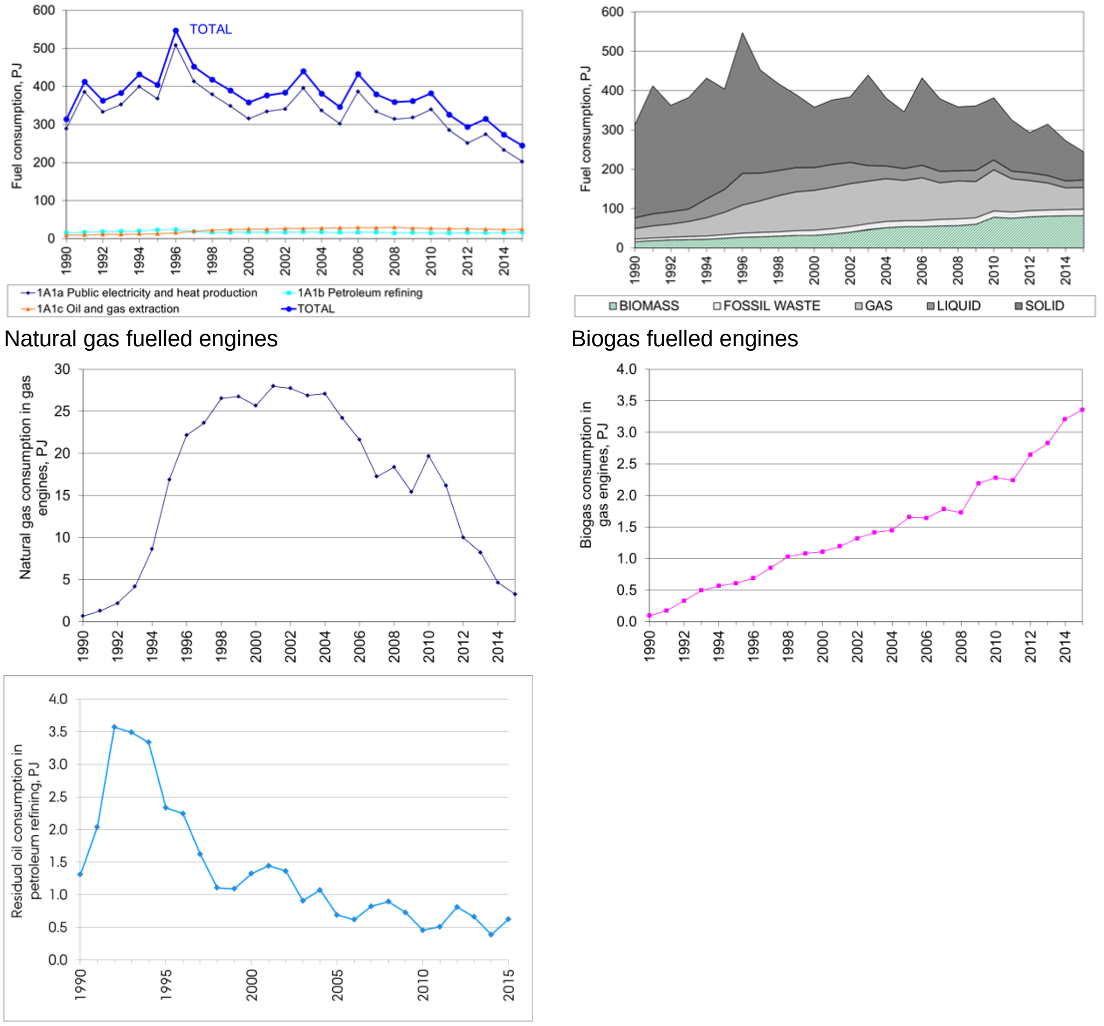


Figure 3.2.16 Time series for fuel consumption, 1A1 Energy industries.

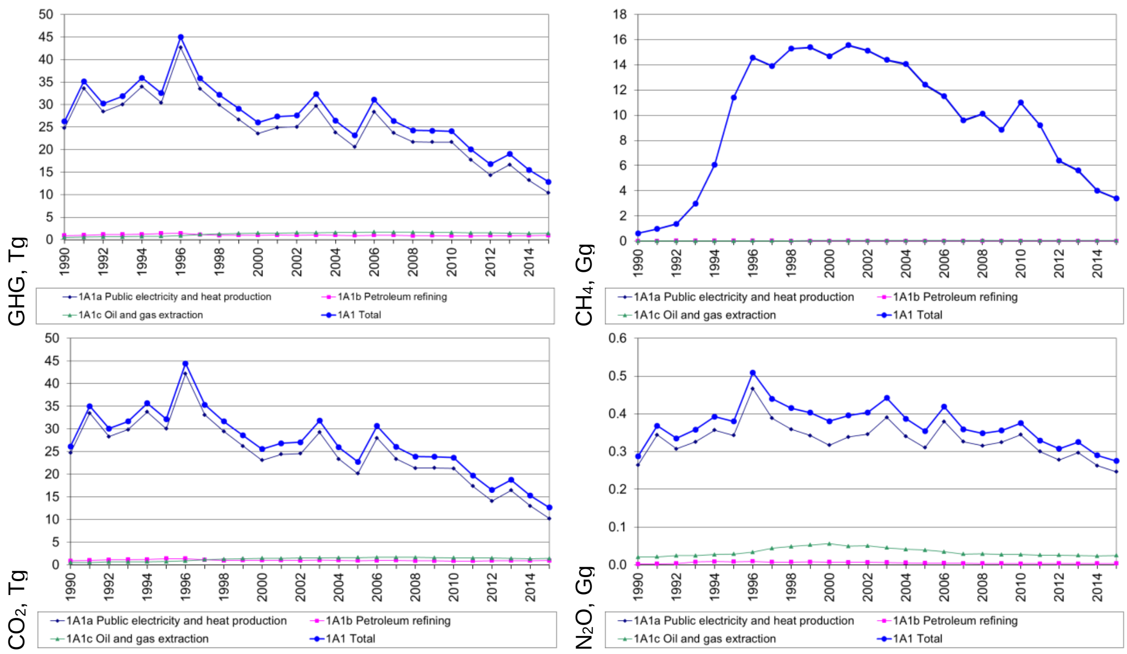


Figure 3.2.17 Time series for greenhouse gas emissions, 1A1 Energy industries.

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 30 % lower in 2015 than in 1990. The fossil fuel consumption was 56% lower than in 1990 whereas the biomass consumption was 5 times the 1990-level. In addition to the fuel type changes, the total fuel consumption is also influenced by the fact that the Danish wind power production has increased.

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 2015 was 70 % lower than in 1990. Natural gas is also an important fuel and the consumption of natural gas increased in 1990-2000 but has decreased since 2010. 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 58 % lower in 2015 than in 1990. This decrease – in spite of only a 30 % 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 after 2004 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 2015 was 5.6 times the 1990 emission level. The N_2O emission in 2015 was 7 % lower than the 1990 emission level. The emission fluctuates similar to the fuel consumption.

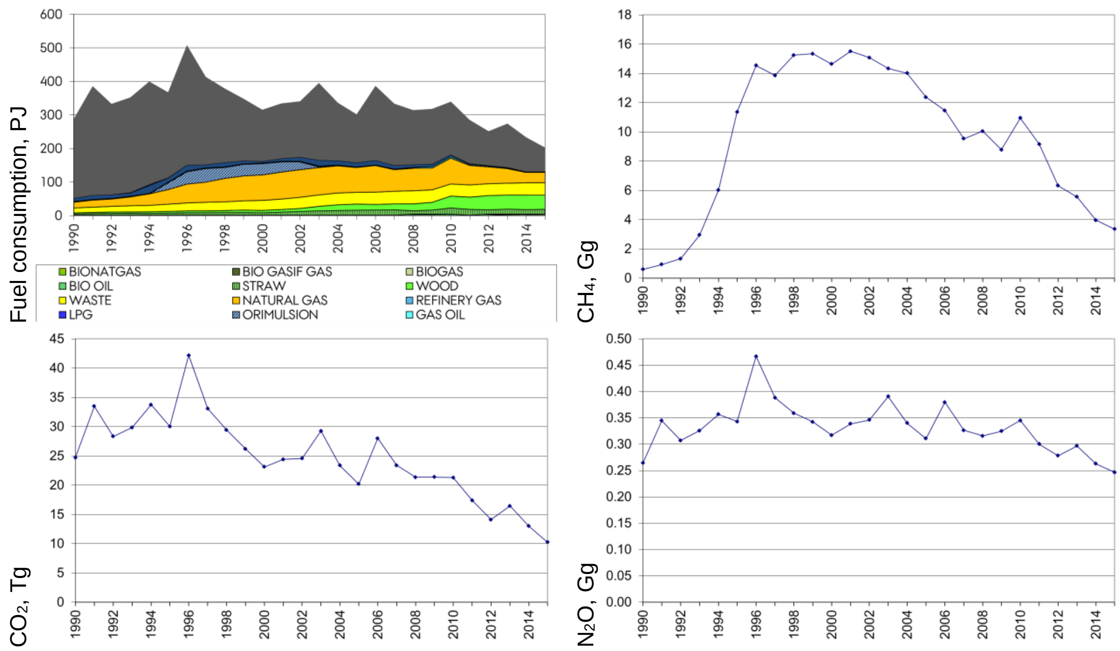


Figure 3.2.18 Time series for 1A1a Public electricity and heat production.

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 10 % since 1990 and the CO_2 emission increased 8 %.

The CH_4 emission has increased 9 % since 1990 and increased 8 % since 2014. The reduction in CH_4 emission from 1995 to 1996 is caused by the closure of a refinery.

The N_2O emission was 75 % higher in 2015 than in 1990. The emission increased in 1993 is as a result of the installation of a gas turbine in one of the refineries (DEA, 2016b).

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 2001. The time series for the emission factor cause the decreasing N_2O emission since 2001.

Emissions from refineries are further discussed in Chapter 3.5.

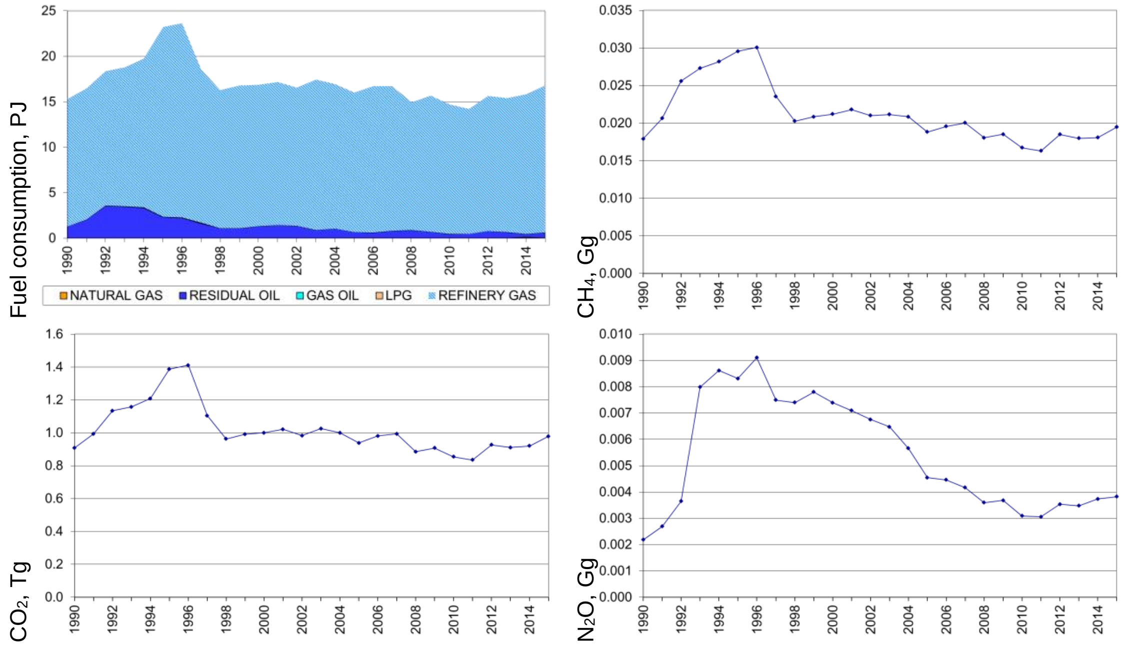


Figure 3.2.19 Time series for 1A1b Petroleum refining.

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 2015 was 2.6 times the consumption in 1990. The fuel consumption has decreased since 2008, but increased between 2014 and 2015. The CO_2 emission follows the fuel consumption and the emission in 2015 was also 2.6 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.

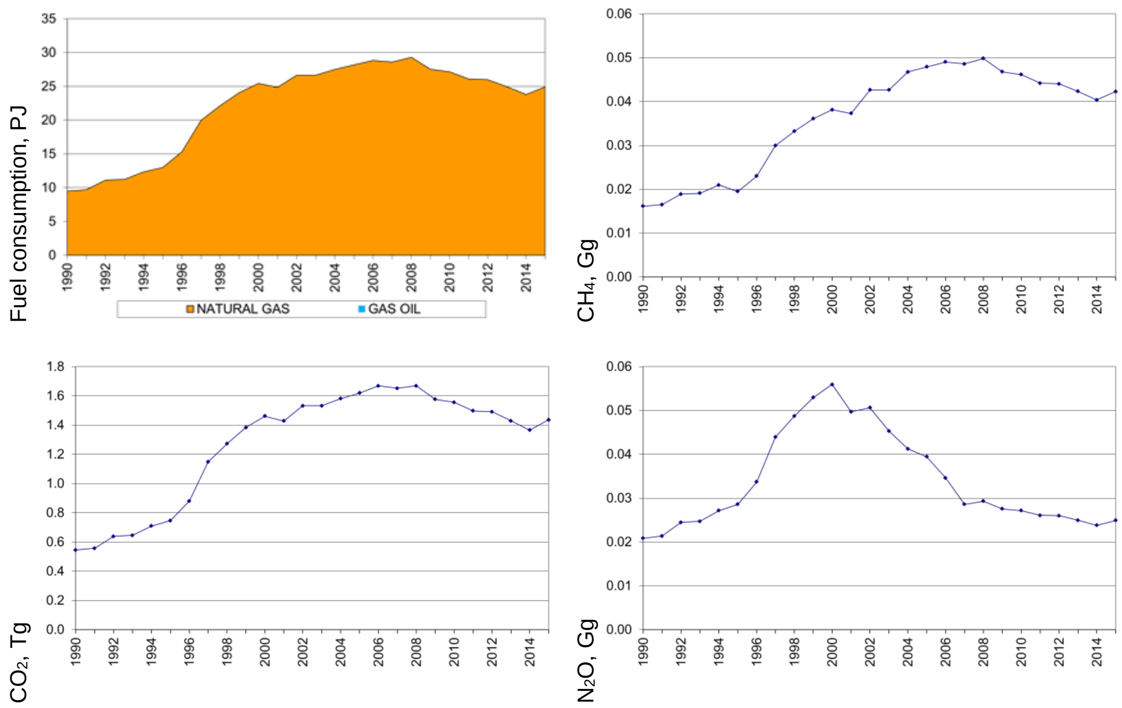


Figure 3.2.20 Time series for 1A1c Oil and gas extraction.

[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

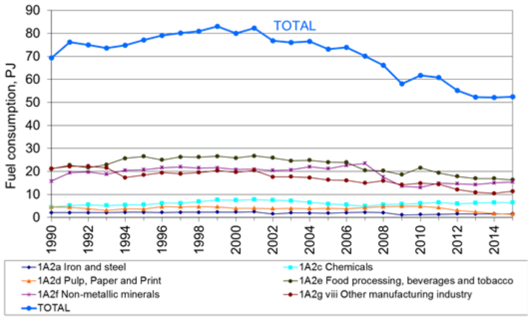
The figures 3.2.21-3.2.22 show the time series for fuel consumption and emissions. The subsectors *Non-metallic minerals*, *Other manufacturing industry* and *Food processing, beverages and tobacco* are the main subsectors for fuel consumption and emissions.

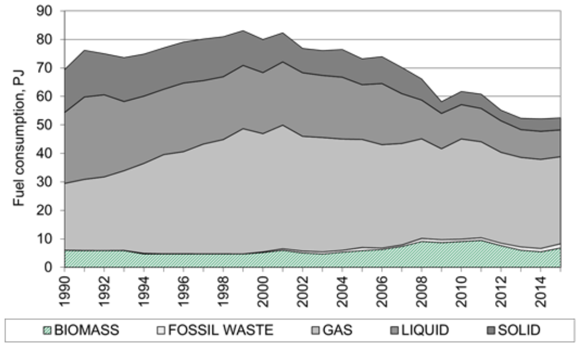
The total fuel consumption in industrial combustion was 24 % lower in 2015 than in 1990. The consumption of natural gas has increased since 1990 whereas the consumption of coal has decreased. The consumption of residual oil has decreased, but the consumption of petroleum coke increased. The biomass consumption has increased 13 % 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 34 %.

The CH_4 emission has increased from 1994-2001 and decreased again from 2001 - 2007. In 2015, the emission was 81 % 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 after 2004 is a result of the liberalisation of the electricity market.

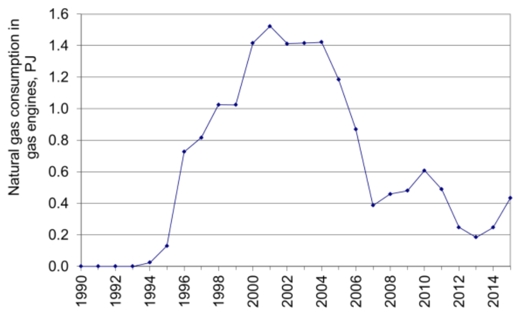
The N_2O emission has decreased 32 % since 1990, mainly due to the decreased residual oil consumption. The emission from other manufacturing industries increased from 1994 to 1995. This increase is related to combustion of coke oven coke in mineral wool production. Plant specific fuel consumption data are only available from 1995 onwards for the mineral wool production plants.





Fuel consumption in natural gas fuelled engines

Fuel consumption, residual oil and wood



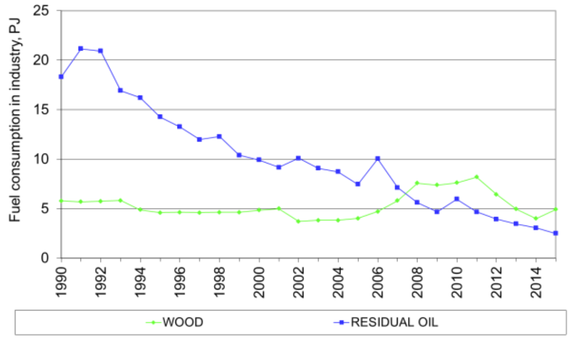


Figure 3.2.21 Time series for fuel consumption, 1A2 Industry.

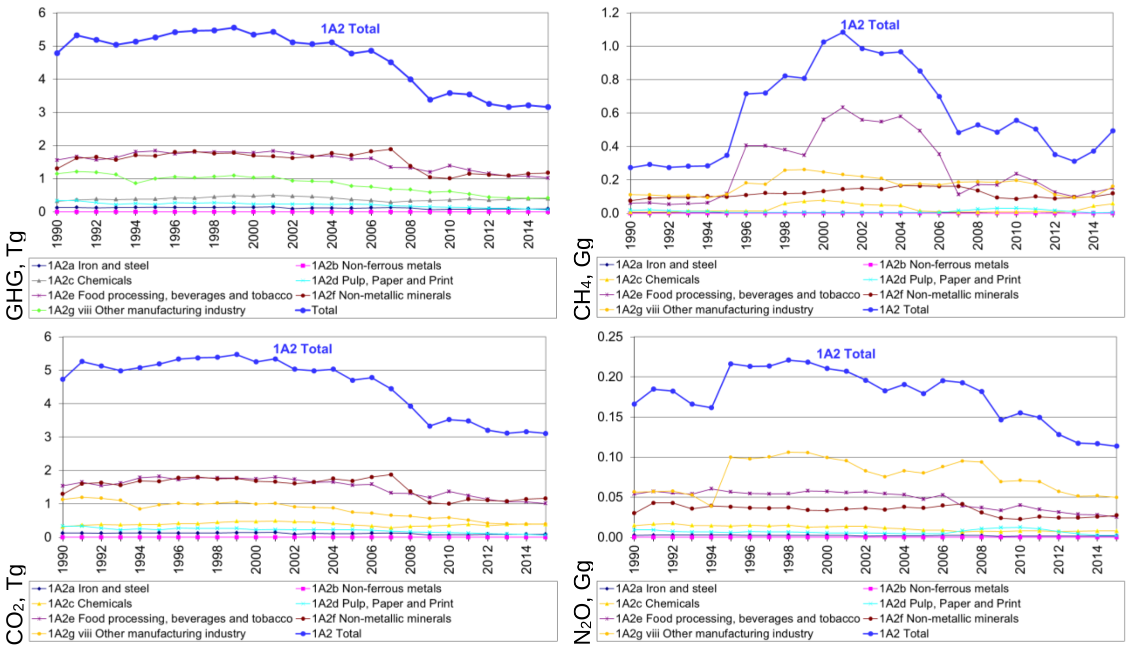


Figure 3.2.22 Time series for greenhouse gas emission, 1A2 Industry.

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.

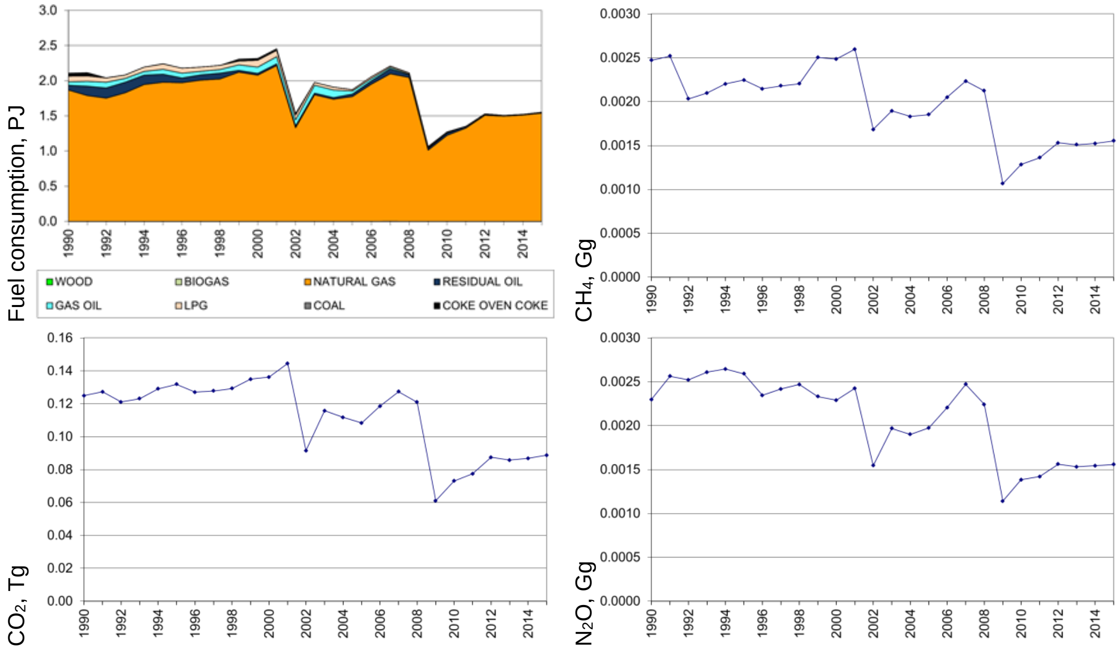


Figure 3.2.23 Time series for 1A2a Iron and steel.

1A2b Non-ferrous metals

The energy statistics have been recalculated and now no fuel consumption is reported for non-ferrous metals.

1A2c Chemicals

Chemicals is a minor emission source category. Figure 3.2.24 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 1997-2012 is related to consumption of natural gas in gas engines. The increased CH_4 emission in 2014 and 2015 is related to one biogas fuelled engine. The decreasing time series for N_2O emission is related to the decreasing consumption of residual oil.

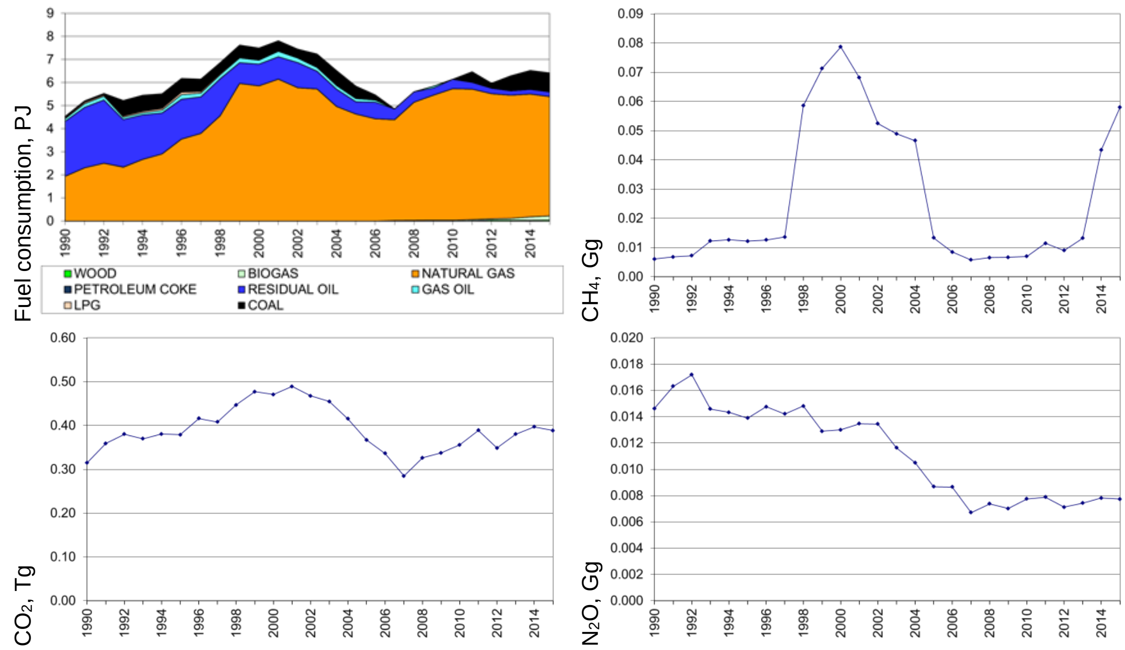


Figure 3.2.24 Time series for 1A2c Chemicals.

1A2d Pulp, paper and print

Pulp, paper and print is a minor emission source category. Figure 3.2.25 shows the time series for fuel consumption and emissions.

Natural gas - and from 2007-2013, also wood - are the main fuels in the sub-sector. The increased use of wood from 2007 is reflected in the CO_2 emission time series.

The increased consumption of wood in 2007-2013 is also reflected in the CH_4 and N_2O emission time series.

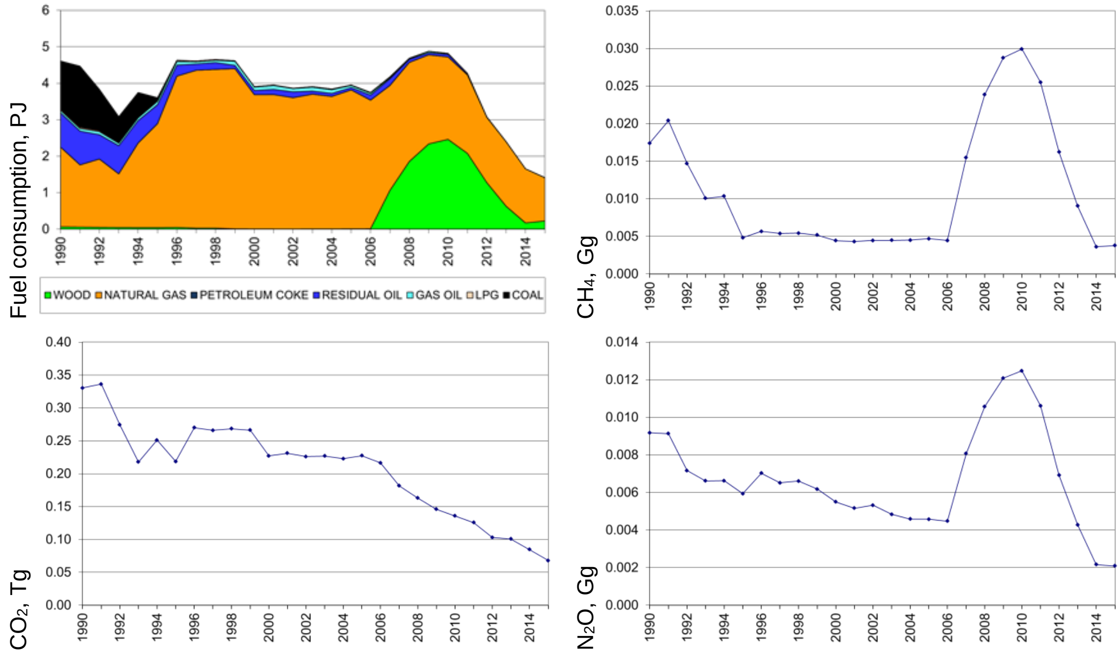


Figure 3.2.25 Time series for 1A2d Pulp, paper and print.

1A2e Food processing, beverages and tobacco

Food processing, beverages and tobacco is a considerable industrial subsector. Figure 3.2.26 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.

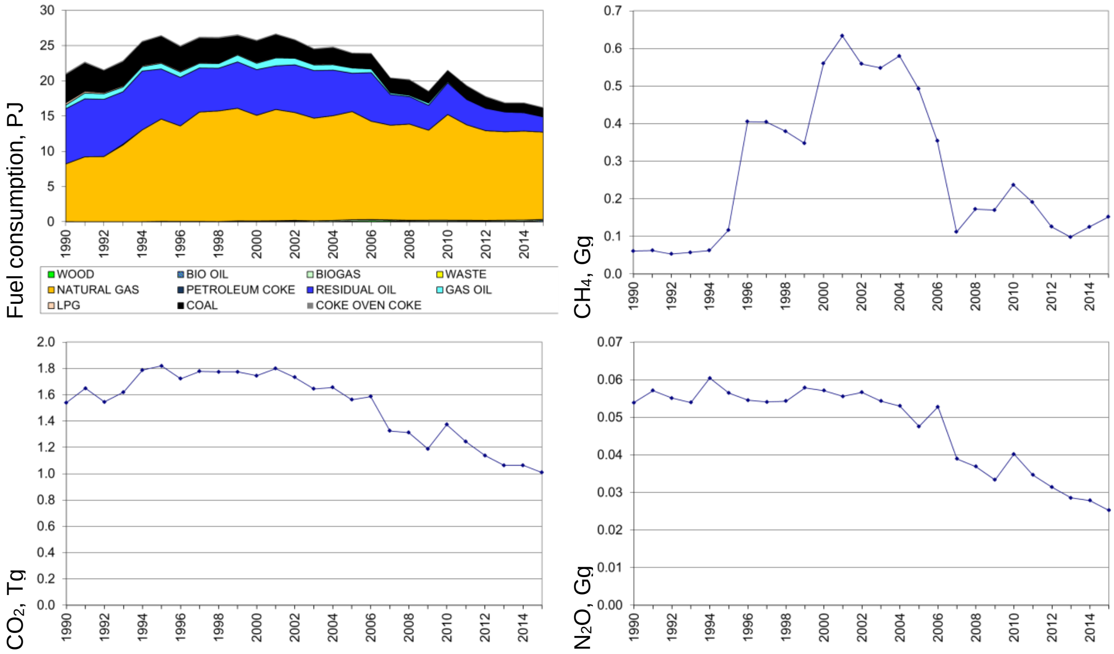


Figure 3.2.26 Time series for 1A2e Food processing, beverages and tobacco.

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 3.2.27 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.

The cement production decreased after 2007 and this is reflected in the time series.

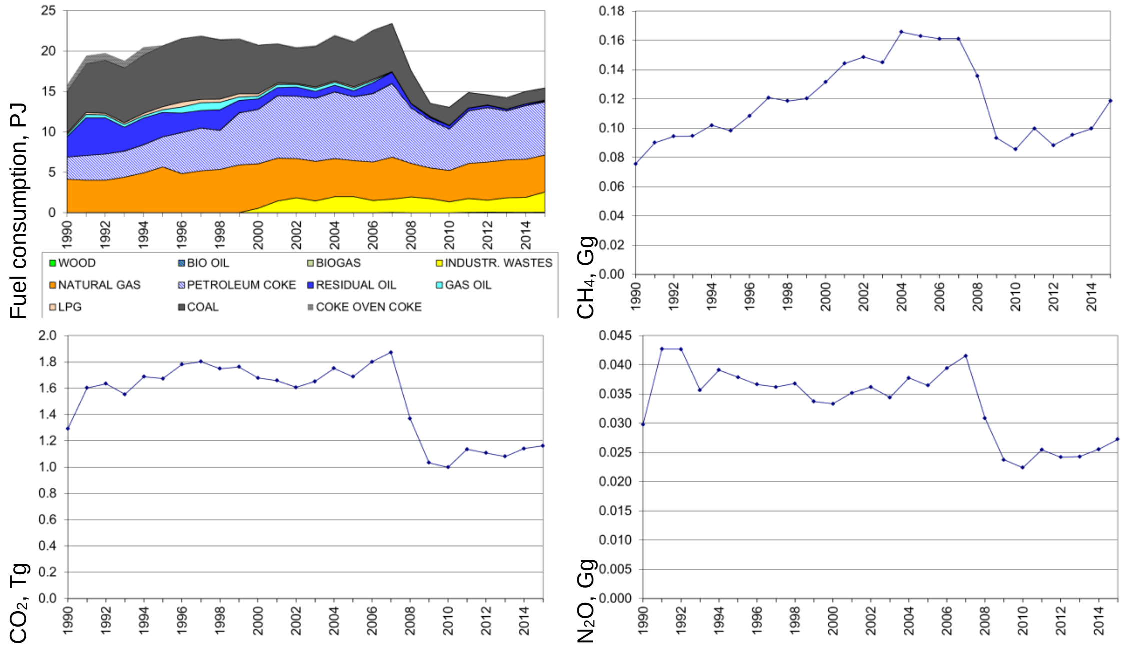


Figure 3.2.27 Time series for 1A2f Non-metallic minerals.

1A2g Other manufacturing industry

Other manufacturing industry is a considerable industrial subsector. Figure 3.2.28 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 wool production plants are available from 1995. This causes the increase in N_2O emission between 1994 and 1995.

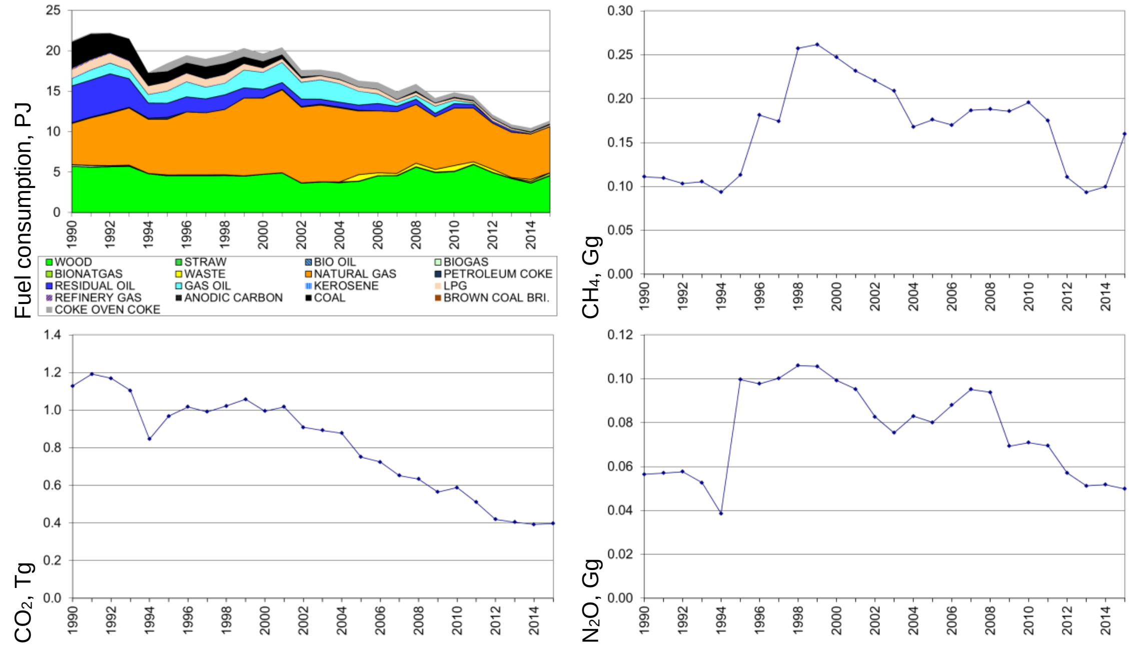


Figure 3.2.28 Time series for 1A2g Industry - other.

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 3.2.29-30 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.

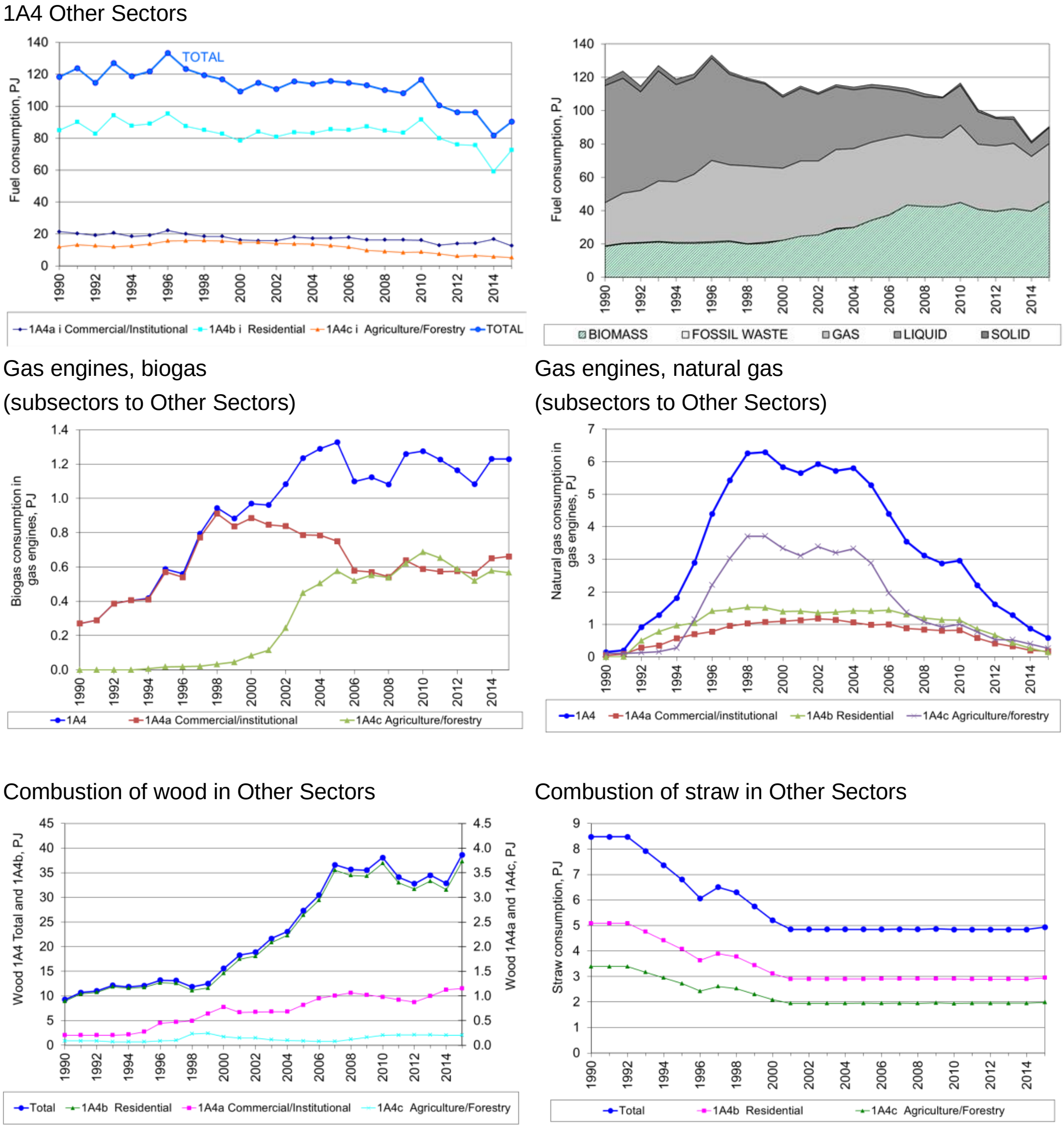


Figure 3.2.29 Time series for fuel consumption, 1A4 Other Sectors.

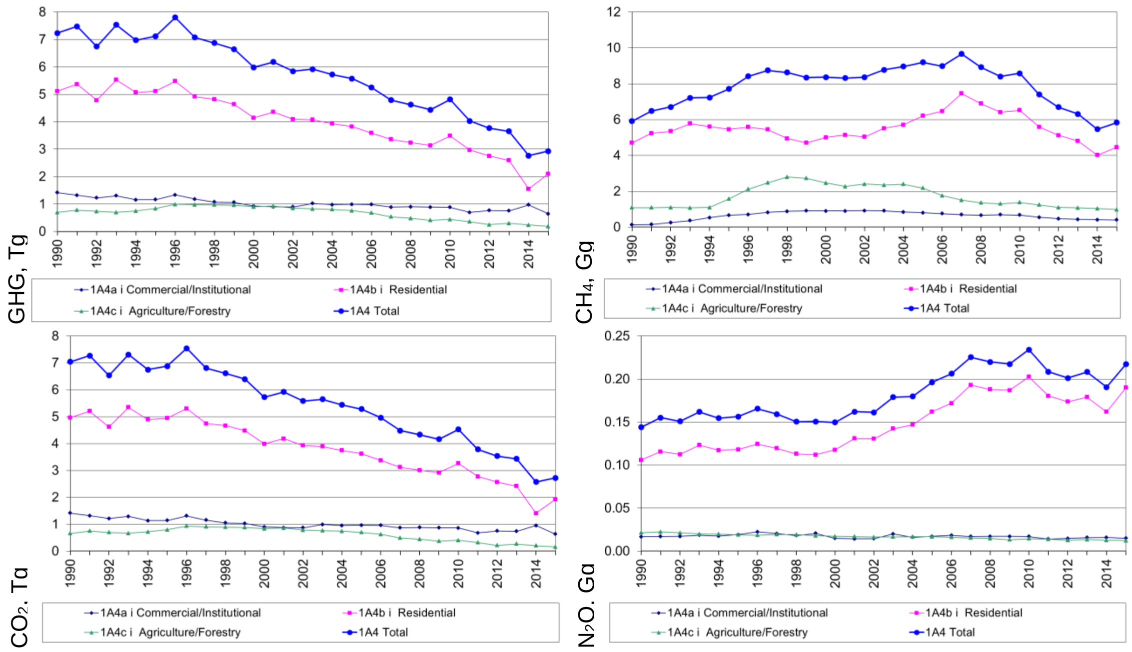


Figure 3.2.30 Time series for greenhouse gas emission, 1A4 Other Sectors.

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 3.2.31 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 41 % 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 since 1990. The consumption of wood and biogas has increased. The wood consumption in 2015 was 5.6 times the consumption in 1990.

The CO_2 emission has decreased 55 % 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 2015 was 3.1 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 3.2.31.

The N_2O emission in 2015 was 11 % lower than in 1990. The fluctuations of the N_2O emission are mainly a result of fluctuations in consumption of natural gas and waste.

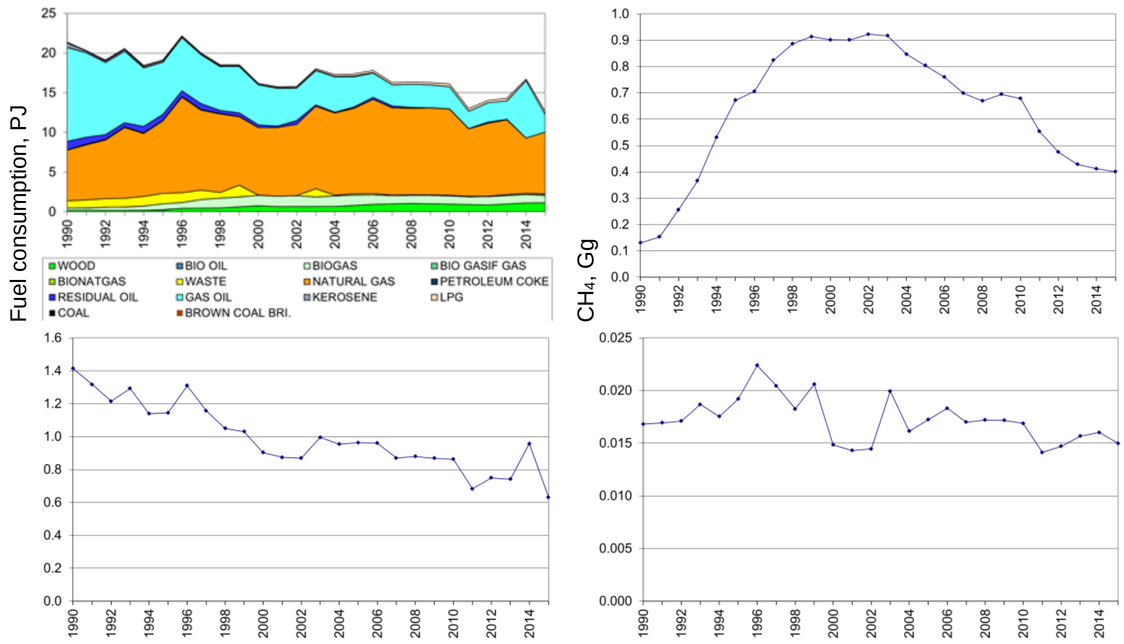


Figure 3.2.31 Time series for 1A4a Commercial /institutional.

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 3.2.32 shows the time series for fuel consumption and emissions.

For residential plants, the total fuel consumption was 15 % lower in 2015 than in 1990. The large decrease from 2010 to 2011 was caused by high temperature in the winter season of 2011. The low consumption of gas oil in 2014 seems to be related to an incorrect disaggregation of gas oil between sector 1A4a and 1A4b. This will be improved in the next inventory. The consumption of gas oil has decreased since 1990 whereas the consumption of wood has increased considerably (4.2 times the 1990 level). The consumption of natural gas has also increased since 1990.

The CO_2 emission has decreased by 61 % 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 5 % lower in 2015 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 79 % increase of N_2O emission since 1990 due to a higher emission factor for wood than for gas oil.

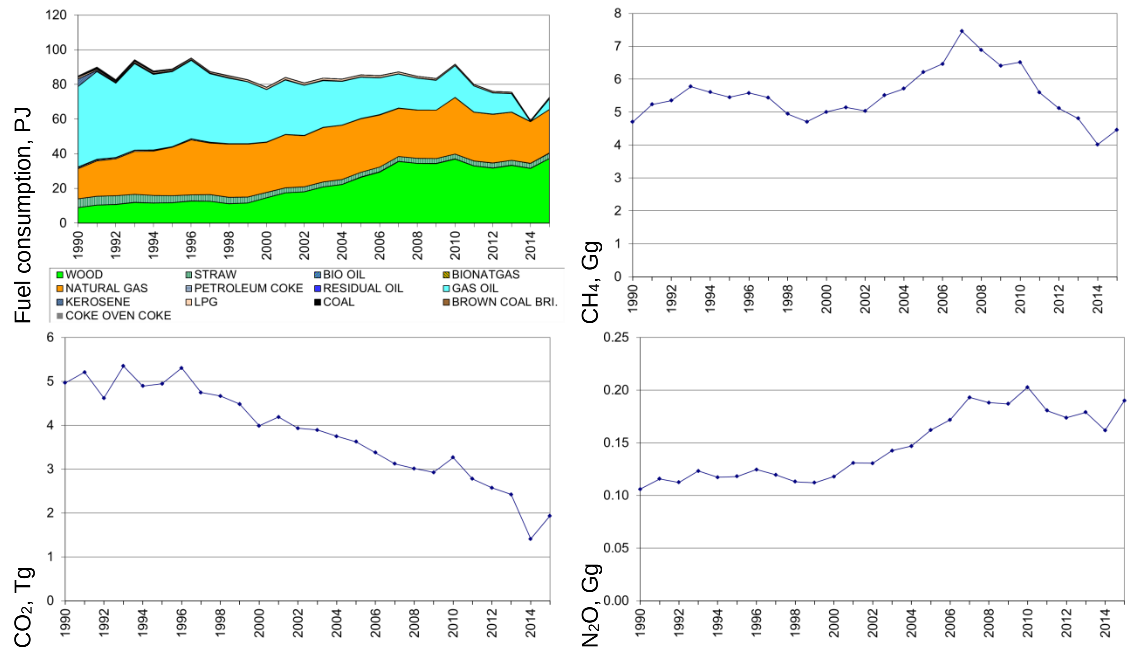


Figure 3.2.32 Time series for 1A4b Residential plants.

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 3.2.33 shows the time series for fuel consumption and emissions.

For plants in agriculture/forestry, the fuel consumption has decreased 46 % 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 after 2004, the consumption decreased again. A large part of the natural gas consumption has been applied in gas engines (Figure 3.2.29). Most CHP plants in agriculture/forestry based on gas engines came in operation in 1995-1999. The decrease after 2004 is a result of the liberalisation of the electricity market.

The consumption of coal, residual oil and straw has decreased since 1990. The consumption of biogas has increased.

The CO_2 emission in 2015 was 76 % 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 2015 was 10 % lower than the emission in 1990. The emission follows the time series for natural gas combusted in gas engines (Figure 3.2.29). 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 43 % 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.

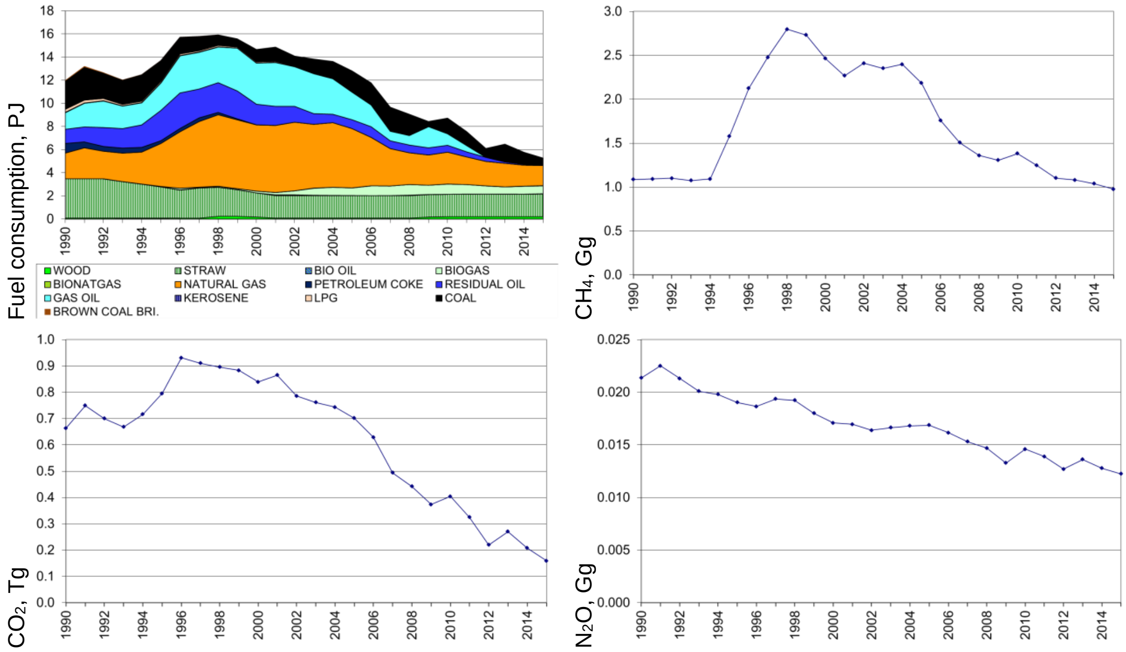


Figure 3.2.33 Time series for 1A4c Agriculture/Forestry.

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 2015/ trend.

Table 3.2.8 Methodology and type of emission factor, 2015.

		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 [4)]	CS	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 2015 or trend 1990-2015.
3. Only 2.5 % of the total coal consumption is included in the non-ETS category in 2015.
4. Only 15 % of the total residual oil consumption is included in the non-ETS category in 2015.
5. Tier 3 for 2 % of the gas oil consumption in 2015.

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 2015, 76 stationary combustion plants are specified as large point sources. Plant specific emission data are available from 70 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 2015 inventory was 199 PJ. This corresponds to 50 % of the overall fuel consumption for stationary combustion.

A list of the large point sources for 2015 is provided in Annex 3A-5. The number of large point sources registered in the databases increased from 1990 to 2015. 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 66 % 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 121).

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.

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, 2016c). The fuel consumption data flow is shown in Figure 3.2.34.

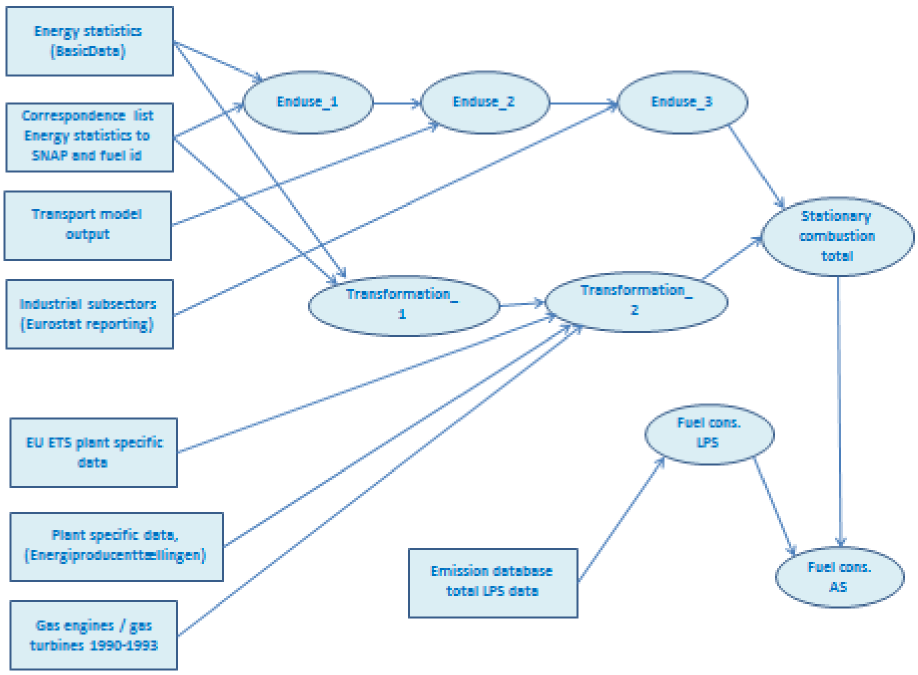


Figure 3.2.34 Fuel consumption data flow.

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 2015) 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 121.

For all other large point sources, the fuel consumption refers to a DEA database (DEA, 2016b). 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, 2016b) 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.

Fuel consumption for 1A1c Oil and gas extraction and 1A1b Petroleum refining

The consumption of natural gas reported in the EU ETS data are not in agreement with the energy statistics. This is due to the fact that the energy statistics is based on the default NCV for natural gas applied in Denmark whereas the EU ETS data are based on fuel analysis of the natural gas applied offshore. The total consumption of natural gas in 1A1c Oil and gas extraction applied in the emission inventories is based on the EU ETS data.

Fuel consumption for 1A1b Petroleum refining

The EU ETS data for fuel consumption reported by the two Danish refineries are not always in agreement with the energy statistics due to the use of default values for NCV in the energy statistics. The EU ETS data are based on fuel analysis. Refinery gas is only applied in the two refineries. The total consumption of refinery gas applied in the emission inventories is based on the EU ETS data.

Upgraded biogas distributed in the natural gas grid

Biogas upgraded for distribution in the natural gas grid (bio natural gas) has now been included as a separate fuel in the energy statistics and in the emission inventory.

Biogas distributed in the town gas grid

The energy statistics includes a consumption of biogas for town gas production. This biogas is distributed in the town gas grid (55 TJ in 2014 and 98 TJ in 2015). This fuel consumption has been included in the fuel category town gas in the fuel consumption data of the energy statistics and also in this emission inventory. In the next emission inventory the consumption will be included in the fuel category biogas.

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 2015. 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 has 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 20.31 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 57.06 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.

Biogas has been added to the town gas grid since 2014. This biogas distributed in the town gas grid will be treated as a separate fuel in future emission inventories and thus not included in the data for town gas.

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 3.2.35. In 2015, 3 % of the incinerated waste was hazardous waste.

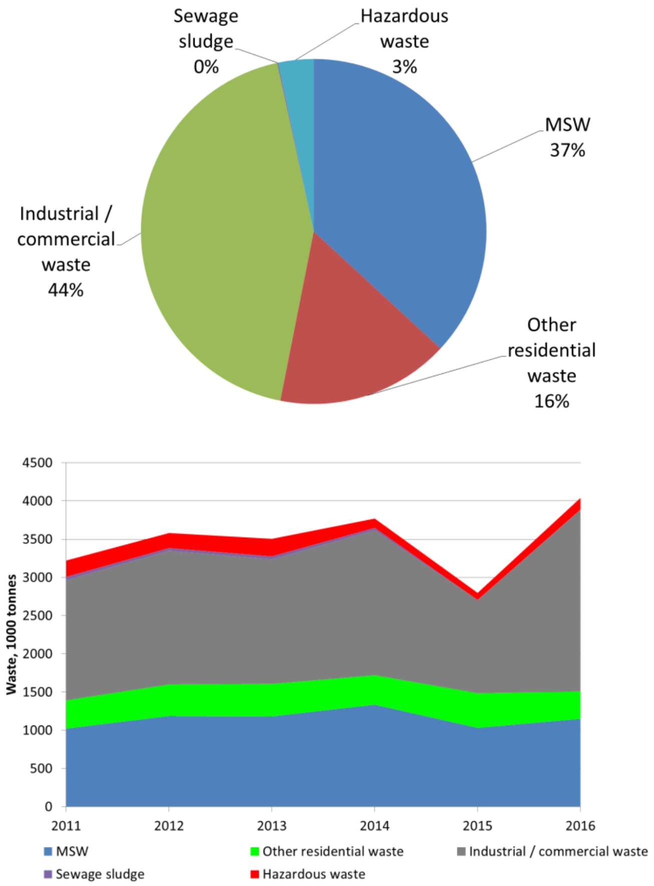


Figure 3.2.35 Waste fractions (weight) for incinerated waste in 2015 and the corresponding time series 2011-2016 (ADS, 2017).

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 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[6]. The Danish energy statistics specifies production and consumption of each of the biogas types. In 2015, 83 % of the applied biogas was based on manure /organic waste.

Biogas upgraded for distribution in the natural gas grid (bio natural gas) is not included in the fuel category "biogas" and in the figures below. This is also the case for bio gasification gas.

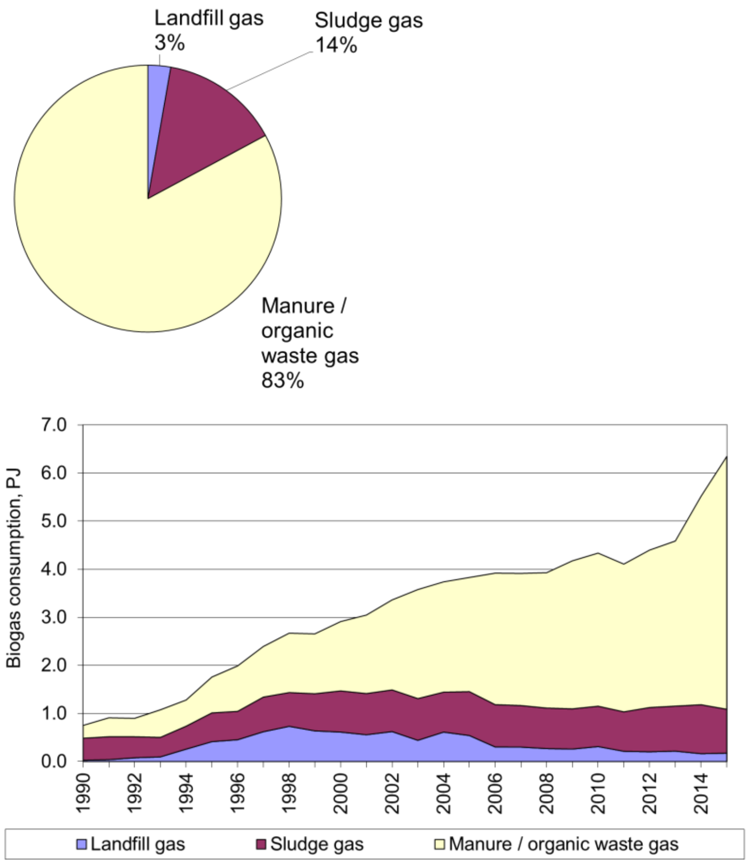


Figure 3.2.36 Biogas types 2015 and the corresponding time series 1990-2015 (DEA, 2016a).

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. 10.5 PJ in 2015. 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).

[6] Based on manure with addition of other organic waste.

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)[7].

An overview of the type of CO_2 emission factor is shown in Table 3.2.19. 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[8]. The EU ETS data have been applied for the years 2006 - 2015.

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[9], 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.

<u>Coal</u>

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 %.

[7] However, the CO_2 emission factor for gas oil refers to the EMEP/EEA Guidebook (EEA, 2007).
[8] See page 134 and 134.
[9] Applying specific methods defined in the EU decision.

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 eight plants that applies Tier 1 methodology[10]. 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.
- 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[11].

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, coke oven coke and fossil waste. The EU ETS data accounted for 66 % of the CO_2 emission from stationary combustion in 2015.

EU ETS data for coal

EU ETS data for 2015 were available from 18 coal fired plants. The plant specific information accounts for 97 % of the Danish coal consumption and 38 % of the total fossil CO_2 emission from stationary combustion plants.

Data from 17 of the 18 plants have been applied for estimating an average CO_2 emission factor for coal[12]. The average CO_2 emission factor for coal for these 17 units was 94.46 kg per GJ (Table 3.2.11). The plants all apply bituminous coal.

[10] 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.
[11] EN ISO 17025.
[12] Fuel consumption of the 17 plants adds up to 87% of the fuel consumption of the 18 plants. The remaining plant is not considered representative for the coal consumption in Denmark.

Table 3.2.11 EU ETS data for 17 coal fired plants, 2015.

	Average	Min	Max
Heating value, GJ per tonne	24.0	23.1	32.4
CO_2 implied emission factor, kg per GJ[1)]	94.46	93.154	98.140
Oxidation factor	0.9958	0.9896	1.0000

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	94.25
2013	93.95
2014	94.17
2015	94.46

1) Including oxidation factor.

EU ETS data for residual oil

EU ETS data for 2015 based on higher tier methodologies were available from 15 plants combusting residual oil. The EU ETS data accounts for 93 % of the residual oil consumption in stationary combustion.

Data from 10 of the 15 plants have been applied for estimating an average CO_2 emission factor for residual oil[13]. Aggregated data and time series are shown in Table 3.2.13 and Table 3.2.14.

Table 3.2.13 EU ETS data for 10 plants combusting residual oil.

	Average	Min	Max
Heating value, GJ per tonne	40.75	40.18	41.10
CO_2 implied emission factor, kg per GJ	79.17	78.66	79.77
Oxidation factor	1.000	1.000	1.000

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
2014	79.49
2015	79.17

1) Including oxidation factor.

[13] Fuel consumption of the 10 plants adds up to 92% of the fuel consumption of the 15 plants. The remaining plants are not considered representative for the residual oil consumption in Denmark.

EU ETS data for gas oil combusted in power plants or refineries

EU ETS data for 2015 based on higher tier methodologies were included from 2 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 2 % 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	36.68	36.55	36.69
CO_2 implied emission factor, kg per GJ	73.75	73.74	73.99
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
2014	74.18
2015	73.75

1) Including oxidation factor.

EU ETS data for waste

EU ETS data for 2015 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 43.3 kg/GJ. The emission factors are in the interval 34.0 kg/GJ to 58.6 kg/GJ. The EU ETS data accounts for 63 % of the incinerated waste.

Table 3.2.17 EU ETS data for waste incineration.

	Average	Min	Max
Heating value, GJ per tonne	10.65	10.50	11.30
CO_2 implied emission factor, kg per GJ	43.3	34.0	58.6
Oxidation factor	1.0	1.0	1.0

Table 3.2.18 CO_2 implied emission factor time series for waste incineration.

Year	CO_2 implied emission factor, kg per GJ[1)]
2013	43.0
2014	40.8
2015	43.3

EU ETS data for petroleum coke, coke oven coke, industrial waste and natural gas

The implemented EU ETS data set also includes CO_2 emission factors for industrial waste, petroleum coke, coke oven coke and natural gas. 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 130.

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 129.

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 34 % of the fossil CO_2 emission.

The CO_2 emission factors applied for 2015 are presented in Table 3.2.19. 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 1990-2015.

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 3.2.19.

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 3.2.19 CO_2 emission factors, 2015.

Fuel	Emission factor, kg per GJ Bio-mass	Fossil fuel	Reference type	IPCC fuel category
Coal, source category 1A1a Public electricity and heat production		94.46 1)	Country specific	Solid
Coal, Other source categories		94.6 3)	IPCC (2006)	Solid
Brown coal briquettes		97.5	IPCC (2006)	Solid
Coke oven coke		107 3)	IPCC (2006)	Solid
Other solid fossil fuels 6)		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		79.17 1)	Country-specific	Liquid
Residual oil, other source categories		78.6 3)	Country-specific	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		57.508	Country-specific	Liquid
Natural gas, off shore gas turbines		57.615	Country-specific	Gas
Natural gas, other		56.06	Country-specific	Gas
Waste	75.1 3)4)	+ 37 3)4)	Country-specific	Biomass and Other fuels
Straw	100		IPCC (2006)	Biomass
Wood	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
Bio-natural gas	55.55		Country-specific	Biomass

1) Plant specific data from EU ETS incorporated for individual plants.
2) Not applied in 2015. 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 corresponding IEF for CO_2, Other fuels is 82.22 kg CO_2 per GJ fossil waste (not including plant specific data).
5) Includes a high content of CO_2 in the gas.
6) Anodic carbon. Not applied in Denmark in 2015.

Coal

As mentioned above[14], EU ETS data have been utilised for the years 2006 - 2015 in the emission inventory. The emission factor for coal applied in 1A1a 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 2015, the implied emission factor (including oxidation factor) was 94.46 kg per GJ. The implied emission factor values were between 93.15 and 98.14 kg per GJ.

The emission factors for coal combustion in *Public electricity and heat production* in the years 2006-2015 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.

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 24.1-25.8 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 correla-

[14] EU ETS data for CO2.

tion 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.

In 2015, only 0.12 % of the CO_2 emission from coal consumption was based on the emission factor for 1A1a (94.46 kg/GJ). However, 12.5 % of the CO_2 from coal combustion was based on the EU ETS default emission factor 94.6 kg/GJ. The emission factor for coal applied in other sectors than 1A1a (94.6 kg/GJ) was applied for 2.4 % of the coal consumption. The remaining 85 % was covered by EU ETS data. All coal applied in Denmark is bituminous coal (DEA, 2016c).

Time series for the CO_2 emission factor are shown in Table 3.2.20.

Table 3.2.20 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
2014	94.17	94.6
2015	94.46	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 1990-2015.

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 1990-2015.

Other solid fossil fuels (Anodic carbon)

Anodic carbon was not applied in 2015. 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 were 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 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 - 2015.

EU ETS data were available for 100 % of the petroleum coke consumption in 2015.

Residual oil
The emission factor for residual oil applied in public electricity and heat production is based on EU ETS data.

As mentioned above[15] EU ETS data have been utilised for the 2006 - 2015 emission inventories. In 2015, the implied emission factor (including oxidation factor) for the plants combusting residual oil was 79.17 kg per GJ. The implied emission factor values were between 78.66 and 79.77 kg per GJ.

The emission factors for residual oil combustion in *Public electricity and heat production* in the years 2006-2015 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 residual oil combusted in other sectors than *1A1a Public electricity and heat production*, the applied emission factor is 78.6 kg per GJ. This emission factor refers to the average EU ETS data 2006-2009. The emission factor has been applied for all years for other sectors than public electricity and heat production.

In 2015, 15 % of the CO_2 emission from residual oil consumption was based on the emission factor, whereas 85 % of the residual oil consumption was covered by EU ETS data.

Time series for the CO_2 emission factor are shown in Table 3.2.21.

[15] EU ETS data for CO2.

Table 3.2.21 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	78.6	78.6
2006	78.6	78.6
2007	78.5	78.6
2008	78.5	78.6
2009	78.9	78.6
2010	79.2	78.6
2011	79.25	78.6
2012	79.21	78.6
2013	79.28	78.6
2014	79.49	78.6
2015	79.17	78.6

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 1990-2015.

Plant specific EU ETS data have been utilised for a few plants in the 2006 - 2015 emission inventories. In 2015, the implied emission factor for the power plants using gas oil was 73.75 kg per GJ. The EU ETS CO_2 emission factors were in the interval 73.74 – 73.99 kg per GJ. In 2015, only 2 % 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 1990-2015.

Orimulsion

The emission factor for orimulsion, 80 kg per GJ, refers to the Danish Energy Agency (DEA, 2016a). 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 1990-2015.

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 with the emission factor stated in the 2006 IPCC Guidelines (IPCC, 2006). The time series is shown in Table 3.2.22.

Table 3.2.22 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
2014	57.620
2015	57.508

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 2006-2015. Based on data for each oilfield implied emission factors have been estimated for 2006-2015. The average value for 2006-2009 has been applied for the years 1990-2005. The time series is shown in Table 3.2.23.

Table 3.2.23 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
2014	57.381
2015	57.615

Natural gas, other source categories

The emission factor for natural gas is estimated by the Danish gas transmission company, Energinet.dk[16]. The calculation is based on gas analysis carried out daily by Energinet.dk at Egtved.

In 2015, the natural gas import was 25 PJ, the natural gas export 82 PJ and a consumption that added up to 121 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 2000-2015. The emission factor applied for 1990-1999 refers to

[16] Former Gastra and before that part of DONG. Historical data refer to these companies.

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 3.2.24.

Table 3.2.24 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
2014	56.95
2015	57.06

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 - 2015 emission inventories, plant specific EU ETS data have been utilised for industrial waste combusted in cement production.

For 2013 - 2015, plant specific EU ETS data have been reported by CHP plants incinerating waste and for 2015 plant specific emission factors have been implemented for 10 plants. In 2015, the average emission factor for the 9 plants (the cement production plant not included) was 43.3 kg fossil CO_2 per GJ total waste. This is above the current emission factor, but due to waste supply differences the emission factors vary between plants – 34.0 kg/GJ to 58.6 kg/GJ. The 10 plants reporting data to EU ETS represent 70 % 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 1990-2015.

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 1990-2015.

Bio oil
The emission factor, 70.8 kg per GJ refers to the IPCC (2006). The consumption of bio oil is below 1 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 83 % of the consumption, see page 120.

The emission factor for biogas, 84.1 kg per GJ refer to Kristensen (2015a) 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, 2015a). The same emission factor has been applied for 1990-2015.

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 gasification gas is below 0.5 PJ for all years.

Bio natural gas
Biogas upgraded for distribution in the natural gas grid is referred to as bio natural gas in this report. Other references might refer to this fuel as biomethane or upgraded biogas. Bio natural gas has been applied in Denmark since 2014. The emission factor is based on the gas composition of bio natural gas: 98.5 % CH_4 and 1.5 % CO_2. These data refer to Danish Gas Technology Centre (Kristensen, 2015b).

CH_4 emission factors
The CH_4 emission factors applied for 2015 are presented in Table 3.2.25. In general, the same emission factors have been applied for 1990-2015. However, time series have been estimated for both natural gas fuelled engines and biogas fuelled engines, residential wood combustion, natural gas fuelled gas turbines[17] and waste incineration plants[17].

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.

[17] A minor emission source.

Emission factors that are not nationally referenced all refer to the IPCC Guidelines (IPCC, 2006).

Gas engines combusting natural gas or biogas account for 40% of the CH_4 emission from stationary combustion plants. The relatively high emission factor for gas engines is well-documented and further discussed below.

Table 3.2.25 CH_4 emission factors, 2015.

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-g	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-g	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	1A2 a-g	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	1A2 a-g	Industry	03	3	IPCC (2006), Tier 1, Table 2-3, Industry, petroleum coke.
		1A4a	Commercial/ Institutional	0201	10	IPCC (2006), Tier 1, Table 2-4, Commercial, Petroleum coke.
		1A4b	Residential	0202	10	IPCC (2006), Tier 1, Table 2-5, Residential / agricultural, Petroleum coke.
		1A4c	Agriculture/ Forestry	0203	10	IPCC (2006), Tier 1, Table 2-5, Residential / agricultural, Petroleum coke.
	RESIDUAL OIL	1A1a	Public electricity and heat production	010101	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.
				010105	4	IPCC (2006), Tier 3, Table 2-6, Utility, Large diesel engines
				010203	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-g	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-g	Industry	03	0.2	IPCC (2006), Tier 3, Table 2-7, Industry, gas oil, boilers.
				Turbines	3	IPCC (2006), Tier 1, Table 2-3, Industry, gas oil.
				Engines	24	Nielsen et al. (2010)

Fuel group	Fuel	CRF source category	CRF source category	SNAP	Emission factor, g per GJ	Reference
		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].
				020304	24	Nielsen et al. (2010)
	KEROSENE	1A2 a-g	Industry	all	3	IPCC (2006), Tier 1, Table 2-3, Industry, other kerosene.
		1A4a	Commercial/ Institutional	0201	10	IPCC (2006), Tier 1, Table 2-4, Commercial, other kerosene.
		1A4b i	Residential	0202	10	IPCC (2006), Tier 1, Table 2-5, Residential/agricultural, other kerosene.
		1A4c i	Agriculture/ Forestry	0203	10	IPCC (2006), Tier 1, Table 2-5, Residential/agricultural, other kerosene.
	LPG	1A1a	Public electricity and heat production	0101 0102	1	IPCC (2006), Tier 1, Table 2-2, Energy Industries, LPG.
		1A1b	Petroleum refining	0103	1	IPCC (2006), Tier 1, Table 2-2, Energy Industries, LPG.
		1A2 a-g	Industry	03	1	IPCC (2006), Tier 1, Table 2-3, Industry, LPG
		1A4a	Commercial/ Institutional	0201	5	IPCC (2006), Tier 1, Table 2-4, Commercial, LPG.
		1A4b i	Residential	0202	5	IPCC (2006), Tier 1, Table 2-5, Residential / agricultural, LPG.
		1A4c i	Agriculture/ Forestry	0203	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	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	1	IPCC (2006), Tier 3, Table 2-6, Utility, natural gas, boilers.
		1A1b	Petroleum refining	010306	1	Assumed equal to industrial boilers.
		1A1c	Oil and gas extraction	010503	1	Assumed equal to industrial boilers.
				010504	1.7	Nielsen et al. (2010)
		1A2 a-g	Industry	Other	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 020105	1 481	IPCC (2006), Tier 3, Table 2-10, Commercial, natural gas boilers. Nielsen et al. (2010)
		1A4b i	Residential	0202	1	IPCC (2006), Tier 3, Table 2-9. Residential, natural gas boilers.
				020204	481	Nielsen et al. (2010)
		1A4c i	Agriculture/ Forestry	0203	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)
		1A2 a-g	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	11	IPCC (2006), Tier 3, Table 2-6, Utility boilers, wood

Fuel group	Fuel	CRF source category	CRF source category	SNAP	Emission factor, g per GJ	Reference
		1A2 a-g	Industry	03	11	IPCC (2006), Tier 3, Table 2-7, Industry, wood, boilers.
		1A4a	Commercial/ Institution-al	0201	11	IPCC (2006), Tier 3, Table 2-10, Commercial, wood.
		1A4b i	Residential	0202	93.19	DCE estimate based on technology distri-bution 3)
		1A4c i	Agriculture/ Forestry	0203	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 consid-ered equal to this plant category)
	BIO OIL	1A1a	Public electricity and heat production	010102	3	IPCC (2006), Tier 1, Table 2-2, Energy industries, biodiesels.
				010105	24	Nielsen et al. (2010) assumed same emis-sion factor as for gas oil fuelled engines.
				0102	3	IPCC (2006), Tier 1, Table 2-2, Energy industries, biodiesels.
		1A2 a-g	Industry	03	3	IPCC (2006), Tier 1, Table 2-3, Industry, biodiesels.
				030902	0.2	-
		1A4b i	Residential	0202	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-g	Industry	03	1	IPCC (2006), Tier 1, Table 2-3, Industry, other biogas.
				Engines	434	Nielsen et al. (2010)
		1A4a	Commercial/ Institution-al	0201	5	IPCC (2006), Tier 1, Table 2-4, Commercial, other biogas.
				020105	434	Nielsen et al. (2010)
		1A4b	Residential	0202	1	Assumed equal to natural gas.
		1A4c i	Agriculture/ Forestry	0203	5	IPCC (2006), Tier 1, Table 2-5, Agriculture, other biogas.
				020304	434	Nielsen et al. (2010)
	BIO GASIF GAS	1A1a	Public electricity and heat production	010101	1	Assumed equal to biogas.
				010105	13	Nielsen et al. (2010)
		1A4a	Commercial/Institutional	020105	13	Nielsen et al. (2010)
	BIONATGAS	1A1a	Public electricity and heat production	0101	1	Assumed equal to natural gas.
		1A2 a-g	Industry	03	1	Assumed equal to natural gas.
		1A4a	Commercial/ Institution-al	0201	1	Assumed equal to natural gas.
		1A4b	Residential	0202	1	Assumed equal to natural gas.
		1A4c	Agriculture/ Forestry	0203	1	Assumed equal to natural gas.

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 below 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 gasification 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 3.2.26 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
2007-2015	481

Gas engines, biogas

SNAP 010105, 030905, 020105 and 020304

The emission factor for biogas engines was estimated to 434 g per GJ in 2015. 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 3.2.27.

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 3.2.27 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
2007-2015	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 3.2.28.

Table 3.2.28 CH_4 emission factor time series for residential wood combustion.

Year	Emission factor, g per GJ
1990	318
1991	312
1992	306
1993	300
1994	293
1995	286
1996	276
1997	267
1998	257
1999	237
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	111
2014	95
2015	93

The emission factors for each technology and the corresponding reference are shown in Table 3.2.29. The emission factor time series are estimated based on time series (1990-2015) for wood consumption in each technology

(DEPA, 2013). The time series for wood consumption in the 13 different technologies are illustrated in Figure 3.2.37. The consumption in pellet boilers and new stoves has increased.

Table 3.2.29 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.
Modern stove (2008-2015)	125	Estimated based on the emission factor for new stoves and the emission factors for NMVOC.
Modern stove (2015-2017)	125	Same as modern stove (2008-2015)
Modern stove (2017-)	125	Same as modern stove (2008-2015)
Eco labelled stove / new advanced stove (-2015)	2	Low emissions from wood burning in an ecolabelled residential boiler. Olsson & Kjällstrand (2005).
Eco labelled stove / new advanced stove (2015-)	2	Same as advanced / ecolabelled stoves
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)

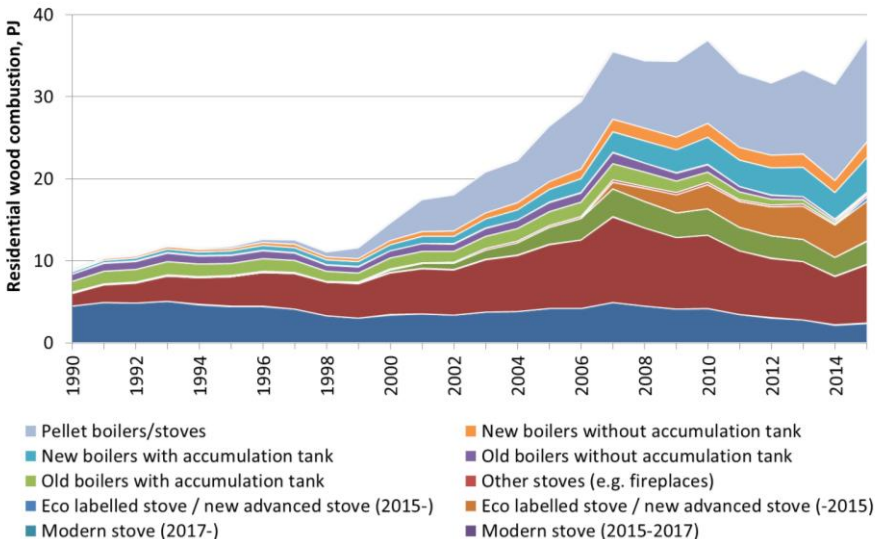


Figure 3.2.37 Technology specific wood consumption in residential plants.

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 2015 inventory are listed in Table 3.2.30. 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 1990-2015.

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 gasification 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.

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).

Table 3.2.30 N_2O emission factors 2015.

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-g	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-g	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-g	Industry	03	1.5	IPCC (2006), Tier 1, Table 2-3, manufacturing industries, other bituminous coal
	FOSSIL FLY ASH	1A1a	Public electricity and heat production	0101	0.8	Assumed equal to coal.
LIQUID	PETROLEUM COKE	1A2 a-g	Industry – other	03	0.6	IPCC (2006), Tier 1, Table 2-3, Industry, petroleum coke
		1A4a	Commercial/ Institutional	0201	0.6	IPCC (2006), Tier 1, Table 2-4, Commercial, petroleum coke
		1A4b i	Residential	0202	0.6	IPCC (2006), Tier 1, Table 2-5, Residential, petroleum coke
		1A4c i	Agriculture/Forestry	0203	0.6	IPCC (2006), Tier 1, Table 2-5, Residential/Agricultural, 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-g	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
		1A1c	Oil and gas extraction	010504	0.6	IPCC (2006), Tier 1, Table 2-2, Energy industries, gas oil
		1A2 a-g	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)

Fuel group	Fuel	CRF source category	CRF source category	SNAP	Emission factor, g per GJ	Reference
Continued						
		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)]
				020304	2.1	Nielsen et al. (2010)
	KEROSENE	1A2 a-g	Industry	03	0.6	IPCC (2006), Tier 1, Table 2-3, Industry, other kerosene
		1A4a	Commercial/Institutional	0201	0.6	IPCC (2006), Tier 1, Table 2-4, Commercial, other kerosene
		1A4b i	Residential	0202	0.6	IPCC (2006), Tier 1, Table 2-5, Residential, other kerosene
		1A4c i	Agriculture/Forestry	0203	0.6	IPCC (2006), Tier 1, Table 2-4, Commercial, other kerosene [1)]
	LPG	1A1a	Public electricity and heat production	0101 0102	0.1	IPCC (2006), Tier 1, Table 2-2, Energy industries, LPG
		1A1b	Petroleum refining	010306	0.1	IPCC (2006), Tier 1, Table 2-2, Energy industries, LPG
		1A2 a-g	Industry	03	0.1	IPCC (2006), Tier 1, Table 2-3, Industry, LPG
		1A4a	Commercial/Institutional	0201	0.1	IPCC (2006), Tier 1, Table 2-4, Commercial, LPG
		1A4b i	Residential	0202	0.1	IPCC (2006), Tier 1, Table 2-5, Residential, LPG
		1A4c i	Agriculture/Forestry	0203	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	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	1	IPCC (2006), Tier 3, Table 2-6, Natural gas, Utility, boiler
		1A4b	Petroleum refining	010306	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-g	Industry	03	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	1	IPCC (2006), Tier 3, Table 2-10, Commercial, natural gas boilers
				Engines	0.58	Nielsen et al. (2010)
		1A4b i	Residential	0202	1	IPCC (2006), Tier 3, Table 2-9, Residential, natural gas boilers
				Engines	0.58	Nielsen et al. (2010)
		1A4c i	Agriculture/Forestry	0203	1	IPCC (2006), Tier 3, Table 2-10, Commercial, natural gas boilers [1)]
				Engines	0.58	Nielsen et al. (2010)
WA-STE	WASTE	1A1a	Public electricity and heat production	0101 0102	1.2	Nielsen et al. (2010)
		1A2 a-g	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. WA-STE	1A2 a-g	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,

Fuel group	Fuel	CRF source category	CRF source category	SNAP	Emission factor, g per GJ	Reference
						Energy industries, wood
Continued						
		1A2 a-g	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 bio-mass
		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	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-g	Industry	03	0.6	IPCC (2006), Tier 1, Table 2-3, Industry, biodiesels
				030902	0.4	-
		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-g	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)
		1A4b	Residential	0202	1	Assumed equal to natural gas.
		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 GASIF GAS	1A1a	Public electricity and heat production	010101	0.1	Assumed equal to biogas.
				010105	2.7	Nielsen et al. (2010)
		1A4a	Commercial/ Institutional	020105	2.7	Nielsen et al. (2010)
	BIONATGAS	1A1a	Public electricity and heat production	0101 or 0102	1	Assumed equal to natural gas.
		1A2 a-g	Industry	03	1	Assumed equal to natural gas.
		1A4a	Commercial/Institutional	0201	1	Assumed equal to natural gas.
		1A4b	Residential	0202	1	Assumed equal to natural gas.
		1A4c	Agriculture/Forestry	020,3	1	Assumed equal to natural gas.

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). This year the uncertainty has been estimated only by the tier 1 approach. The tier 1 approach is 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 emission source categories applied are listed in Table 3.2.31.

Source categories

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.

The 2015 uncertainty levels have been applied in the tier 1 approach.

Fuel

The applied uncertainty rates for fuel consumption are shown below.

Table 3.2.31 Uncertainties for fuel consumption 2015.

IPCC Source category	2015	Reference
1A1, 1A2, 1A4 St. comb. Coal, ETS data, CO_2	0.5%	ETS data
1A1, 1A2, 1A4 St. comb. Coal, no ETS data, CO_2	0.9%	Estimated based on IPCC (2006) values.
1A1, 1A2, 1A4 St. comb., BKB, CO_2	2.9%	Estimated based on IPCC (2006) values.
1A1, 1A2, 1A4 St. comb., Coke oven coke, CO_2	1.8%	Estimated based on IPCC (2006) values.
1A1, 1A2, 1A4 St. comb., Fossil waste, ETS data, CO_2	2%	DCE assumption
1A1, 1A2, 1A4 St. comb., Fossil waste, no ETS data, CO_2	5%	DCE assumption
1A1, 1A2, 1A4 St. comb., Petroleum coke, ETS data, CO_2	0.5%	ETS data
1A1, 1A2, 1A4 St. comb., Petroleum coke, no ETS data, CO_2	1.9%	Estimated based on IPCC (2006) values.
1A1, 1A2, 1A4 St. comb., Residual oil, ETS data, CO_2	0.5%	ETS data
1A1, 1A2, 1A4 St. comb., Residual oil, no ETS data, CO_2	1.6%	Estimated based on IPCC (2006) values.
1A1, 1A2, 1A4 St. comb., Gas oil, CO_2	2.6%	Estimated based on IPCC (2006) values.
1A1, 1A2, 1A4 St. comb., Kerosene, CO_2	1.7%	Estimated based on IPCC (2006) values.
1A1, 1A2, 1A4 St. comb., LPG, CO_2	2.6%	Estimated based on IPCC (2006) values.
1A1b,St. comb., Refinery gas, CO_2	1.0%	Estimated based on IPCC (2006) values.
1A1, 1A2, 1A4, Stationary combustion, Natural gas, onshore, CO_2	1.3%	Estimated based on IPCC (2006) values. Off-shore gas turbines not included in this category.
1A1c Off shore gas turbines, Natural gas, CO_2	0.5%	ETS data for 2015, IPCC (2006) for 1990.
1A1, Stationary Combustion, SOLID, CH_4	1.0%	IPCC (2006), less than 1%
1A1, Stationary Combustion, LIQUID, CH_4	1.0%	IPCC (2006), less than 1%
1A1, Stationary Combustion, not engines, GAS, CH_4	1.0%	IPCC (2006), less than 1%
1A1, Stationary Combustion, WASTE, CH_4	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	3.0%	DCE assumption
1A2, Stationary Combustion, SOLID, CH_4	2.0%	IPCC (2006)
1A2, Stationary Combustion, LIQUID, CH_4	2.0%	IPCC (2006)
1A2, Stationary Combustion, not engines, GAS, CH_4	2.0%	IPCC (2006)
1A2, Stationary Combustion, WASTE, CH_4	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%	IPCC (2006)
1A4, Stationary Combustion, SOLID, CH_4	3.0%	IPCC (2006)
1A4, Stationary Combustion, LIQUID, CH_4	3.0%	IPCC (2006)
1A4, Stationary Combustion, not engines, GAS, CH_4	3.0%	IPCC (2006)
1A4, Stationary Combustion, WASTE, CH_4	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%	IPCC (2006)
1A4, Stationary Combustion, Residential wood combustion, CH_4	20.0%	DCE assumption
1A4, Stationary Combustion, Residential and agricultural straw combustion, CH_4	15.0%	DCE assumption
1A1, 1A2, 1A4 Natural gas fuelled engines, GAS, CH_4	1.0%	Lindgren (2010)
1A1, 1A2, 1A4 Biogas fuelled engines, GAS, CH_4	3.0%	DCE assumption
1A1, Stationary Combustion, SOLID, N_2O	1.0%	IPCC (2006), less than 1%
1A1, Stationary Combustion, LIQUID, N_2O	1.0%	IPCC (2006), less than 1%
1A1, Stationary Combustion, GAS, N_2O	1.0%	IPCC (2006), less than 1%
1A1, Stationary Combustion, WASTE, N_2O	3.0%	DCE assumption
1A1, Stationary Combustion, BIOMASS, N_2O	3.0%	DCE assumption
1A2, Stationary Combustion, SOLID, N_2O	2.0%	IPCC (2006)
1A2, Stationary Combustion, LIQUID, N_2O	2.0%	IPCC (2006)
1A2, Stationary Combustion, GAS, N_2O	2.0%	IPCC (2006)
1A2, Stationary Combustion, WASTE, N_2O	3.0%	DCE assumption
1A2, Stationary Combustion, BIOMASS, N_2O	10.0%	IPCC (2006)
1A4, Stationary Combustion, SOLID, N_2O	3.0%	IPCC (2006)
1A4, Stationary Combustion, LIQUID, N_2O	3.0%	IPCC (2006)
1A4, Stationary Combustion, GAS, N_2O	3.0%	IPCC (2006)
1A4, Stationary Combustion, WASTE, N_2O	3.0%	DCE assumption
1A4, Stationary Combustion, not residential wood and not residential/agricultural straw, BIOMASS, N_2O	10.0%	IPCC (2006)
1A4b, Stationary Combustion, Residential wood combustion, N_2O	20.0%	DCE assumption
1A4b/c, Stationary Combustion, Residential and agricultural straw combustion, N_2O	15.0%	DCE assumption

Emission factors

Uncertainties for emission factors are shown in Table 3.2.32.

Table 3.2.32 Uncertainties for emission factors, 2015.

IPCC Source category	2015	Reference
1A1, 1A2, 1A4 St. comb. Coal, ETS data, CO_2	0.3%	ETS data, 2015 estimate
1A1, 1A2, 1A4 St. comb. Coal, no ETS data, CO_2	1.0%	DCE assumption
1A1, 1A2, 1A4 St. comb., BKB, CO_2	5.0%	IPCC (2000), chapter 2.1.1.6.
1A1, 1A2, 1A4 St. comb., Coke oven coke, CO_2	5.0%	IPCC (2000), chapter 2.1.1.6.
1A1, 1A2, 1A4 St. comb., Fossil waste, ETS data, CO_2	5.0%	ETS data, DCE estimate based on Astrup et al. (2012).
1A1, 1A2, 1A4 St. comb., Fossil waste, no ETS data, CO_2	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%	ETS data, 2015 estimate
1A1, 1A2, 1A4 St. comb., Petroleum coke, no ETS data, CO_2	5.0%	IPCC (2000), chapter 2.1.1.6.
1A1, 1A2, 1A4 St. comb., Residual oil, ETS data, CO_2	0.5%	ETS data, 2015 estimate
1A1, 1A2, 1A4 St. comb., Residual oil, no ETS data, CO_2	2.0%	Jensen & Lindroth (2002).
1A1, 1A2, 1A4 St. comb., Gas oil, CO_2	1.5%	Based on interval in IPCC (2006).
1A1, 1A2, 1A4 St. comb., Kerosene, CO_2	3.0%	Based on interval in IPCC (2006).
1A1, 1A2, 1A4 St. comb., LPG, CO_2	4.0%	Based on interval in IPCC (2006).
1A1b,St. comb., Refinery gas, CO_2	2.0%	1990: IPCC (2000), chapter 2.1.1.6. 2015: 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%	Lindgren (2010). Personal communication.
1A1c Off shore gas turbines, Natural gas, CO_2	0.5%	ETS data for 2015, but not for 1990
1A1, Stationary Combustion, SOLID, CH_4	100%	Based on interval in IPCC (2006), table 2.12
1A1, Stationary Combustion, LIQUID, CH_4	100%	Based on interval in IPCC (2006), table 2.12
1A1, Stationary Combustion, not engines, GAS, CH_4	100%	Based on interval in IPCC (2006), table 2.12
1A1, Stationary Combustion, WASTE, CH_4	100%	Based on interval in IPCC (2006), table 2.12
1A1, Stationary Combustion, not engines, BIOMASS, CH_4	100%	Based on interval in IPCC (2006), table 2.12
1A2, Stationary Combustion, SOLID, CH_4	100%	Based on interval in IPCC (2006), table 2.12
1A2, Stationary Combustion, LIQUID, CH_4	100%	Based on interval in IPCC (2006), table 2.12
1A2, Stationary Combustion, not engines, GAS, CH_4	100%	Based on interval in IPCC (2006), table 2.12
1A2, Stationary Combustion, WASTE, CH_4	100%	Based on interval in IPCC (2006), table 2.12
1A2, Stationary Combustion, not engines, BIOMASS, CH_4	100%	Based on interval in IPCC (2006), table 2.12
1A4, Stationary Combustion, SOLID, CH_4	100%	Based on interval in IPCC (2006), table 2.12
1A4, Stationary Combustion, LIQUID, CH_4	100%	Based on interval in IPCC (2006), table 2.12
1A4, Stationary Combustion, not engines, GAS, CH_4	100%	Based on interval in IPCC (2006), table 2.12
1A4, Stationary Combustion, WASTE, CH_4	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%	Based on interval in IPCC (2006), table 2.12
1A4, Stationary Combustion, Residential wood combustion, CH_4	150%	Upper value in IPCC (2006), table 2.12.
1A4, Stationary Combustion, Residential and agricultural straw combustion, CH_4	150%	Upper value in IPCC (2006), table 2.12.
1A1, 1A2, 1A4 Natural gas fuelled engines, GAS, CH_4	2%	1990: DCE estimate based on Nielsen et al. (2010). 2015: Jørgensen et al. (2010). Uncertainty data for NMVOC + CH_4.
1A1, 1A2, 1A4 Biogas fuelled engines, GAS, CH_4	10%	DCE estimate based on Nielsen et al. (2010).
1A1, Stationary Combustion, SOLID, N_2O	400%	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 %	IPCC (2000)
1A1, Stationary Combustion, GAS, N_2O	750%	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%	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%	DCE, rough estimate based on a default value of 400 % when the emission factor is based on emission measurements from plants in Denmark.

IPCC Source category	2015	Reference
Continued		
1A2, Stationary Combustion, SOLID, N_2O	400%	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 %	IPCC (2000)
1A2, Stationary Combustion, GAS, N_2O	750%	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%	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, BIOMASS, N_2O	400%	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%	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 %	IPCC (2000)
1A4, Stationary Combustion, GAS, N_2O	750%	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%	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%	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%	DCE estimate.
1A4b/c, Stationary Combustion, Residential and agricultural straw combustion, N_2O	500%	DCE estimate.

Results

The tier 1 uncertainty estimates for stationary combustion emission inventories are shown in Table 3.2.33. Detailed calculation sheets are provided in Annex 3A-7.

The tier 1 uncertainty interval for greenhouse gas is estimated to be ±2.2 % and trend in greenhouse gas emission is -50.5 % ± 1.0 %-age points. The main sources of uncertainty for greenhouse gas emission 2015 are the CO_2 emission from waste incineration without EU ETS data, 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 waste incineration (the part without EU ETS data), N_2O emission from residential wood combustion and N_2O emissions from biomass in energy industries (1A1).

Table 3.2.33 Danish uncertainty estimates, tier 1 approach, 2015.

Pollutant	Uncertainty Total emission, %	Trend 1990-2015, %	Uncertainty trend, %-age points
GHG	±2.2	-50.5	±1.0
CO_2	±1.1	-51.2	±0.6
CH_4	±59	+43	±52
N_2O	±182	+1.5	±203

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 2015 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., 2015). The national external review forms a vital part of the QA activities for stationary combustion.

The 2004, 2006, 2009 and 2015 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 3.2.34 lists the sector specific PM's for data storage level 1.

Table 3.2.34 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. DCE and DEA have renewed the data delivery agreement in 2015. 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 3.2.35 below.

Table 3.2.35 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 2015.
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 2015. 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 2015.
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. Some 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 (2015 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 spreadsheet from the Danish energy statistics (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 2015 update of the agreement with DEA.

SO_2 and NO_x emission data from electricity producing plants > $25MW_e$ (Energinet.dk)

Energinet.dk collects SO_2 and NO_x emission data for plants larger than 25 MW_e. Energinet.dk forwards data for implementation in the emission inventory. Data are on production unit level. 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, see 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 2015 update of the agreement with DEA.

Data processing, level 1

Table 3.2.36 lists the sector specific PM's for data processing level 1.

Table 3.2.36 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 % in 1990-2014. However, the difference in 2015 was 2.16 % for CO_2. 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 3.2.37 lists the sector specific PM's for data storage level 2.

Table 3.2.37 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 3.2.38 lists the sector specific PM's for data storage level 4.

Table 3.2.38 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/operator in Denmark, DONG Energy has 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 3.2.39 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 2014 are shown in Table 3.2.40.

The main recalculations are discussed below.

Table 3.2.39 Recalculations, emissions reported this year / emissions reported last year.

Pollutant	1990	1995	2000	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
							%						
CO_2	100.55	100.52	100.63	100.65	100.61	100.81	100.91	100.71	100.90	101.10	101.40	101.40	101.61
CH_4	99.96	100.01	99.98	100.02	100.01	100.01	100.01	100.01	100.01	100.02	100.03	101.25	102.15
N_2O	100.16	100.15	100.11	100.20	100.15	100.15	100.27	100.16	100.25	100.30	100.42	100.84	101.35

Table 3.2.40 Recalculations for stationary combustion, 2014.

	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	-61.4	0.1	0.0	-0.4%	0.1%	0.0%
1A1a Public electricity and heat production	-61.4	0.1	0.0	-0.5%	0.1%	0.0%
1A1b Petroleum refining	0.0	0.0	0.0	0.0%	0.0%	0.0%
1A1c Oil and gas extraction	0.0	0.0	0.0	0.0%	0.0%	0.0%
1A2 Industry	8.8	0.9	0.4	0.3%	10.4%	1.3%
1A2a Iron and steel	3.9	0.0	0.0	4.7%	4.3%	6.2%
1A2b Non-ferrous metals	0.0	0.0	0.0	-100.0%	-100.0%	-100.0%
1A2c Chemicals	62.0	0.9	0.4	18.5%	540.3%	18.1%
1A2d Pulp, paper and print	-58.5	-0.4	-1.9	-40.9%	-81.5%	-74.8%
1A2e Food processing, beverages and tobacco	-114.5	-0.2	-0.5	-9.7%	-6.7%	-6.0%
1A2f Non-metallic minerals	91.7	0.1	0.6	8.7%	2.4%	7.9%
1A2gviii Other manufacturing industry	24.2	0.5	2.0	6.6%	26.7%	14.5%
1A4 Other sectors	385.0	4.2	1.9	17.6%	3.2%	3.5%
1A4ai Commercial/institutional: Stationary	387.6	-0.5	0.4	68.1%	-4.8%	8.2%
1A4bi Residential: Stationary	-2.5	4.8	1.6	-0.2%	5.0%	3.3%
1A4ci Agriculture/Forestry/Fishing: Stationary	0.0	0.0	0.0	0.0%	-0.1%	0.0%
Stationary combustion	332.5	5.2	2.4	1.6%	2.2%	1.3%

For stationary combustion plants, the emission estimates for the years 1990-2014 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 2012, 2013 and 2014.

The reported CO_2 emission is higher for all years due to the recalculation of the CO_2 emission factor for residual oil.

The increased CO_2 emission in 2014 from sector *1A4a i Commercial / institutional: Stationary* is related to an improved disaggregation between transport and stationary combustion for gas / diesel oil. However, the disaggregation between 1A4a and 1A4b is not correct and will be improved in future inventories (see page 111).

The CH_4 emission is higher mainly for 2013 and 2014 than reported last year. This is related to a higher emission from residential plants. This occurs due to a recalculation of the residential wood consumption in the Danish energy statistics (+1.0 PJ in 2013 and + 1.3 PJ in 2014).

The increased N_2O emission reported for 2014 is also related to the improved data for residential wood combustion in the energy statistics.

In the reporting last year a very small emission was included in subsector 1A2b Non-ferrous metals. This is now reported not occurring and this is in agreement with the updated energy statistics. The update of the disaggregation between industrial subsectors is also reflected in other of the industrial subsectors.

The fossil carbon content of waste applied in the reference approach is now the implied emission factor from the national approach in CRF rather than based on the default emission factor for waste. Thus plant specific data are implemented in the emission factor applied in the reference approach.

Improvements related to reviews

"ERT recommends that Denmark continue its investigations on how EU-ETS can inform country-specific emission factors. Focusing on residual fuel oil (small combustion activities outside of EU-ETS) and waste incineration with energy recovery. Noting that application of country-specific emission factor for waste incineration will be most challenging across time series.".

The improved CO_2 emission factors for residual oil were initiated based on the 2016 review.

For waste incineration EU ETS data have been implemented for 2015. Data are only available for a few years, but DCE will in future years analyse data and at some point implement the collected EU ETS data in an improved country specific emission factor and - if possible - a time series.

3.2.9 Source specific planned improvements

Biogas distributed in the town gas grid will be included in the fuel category biogas in the next emission inventory.

The disaggregation of the gas oil consumption between the sectors 1A4a and 1A4b will be corrected for 2014.

The difference between national approach and national approach was above 2 % for 2015. This will be part of the ongoing dialogue with the Danish Energy Agency, and if possible data will be improved.

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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).

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.

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 DCE, Aarhus University, in order to produce the emission inventories. The output results from the DCE models are calculated in a 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.

[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.

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 shows the fuel consumption for domestic transport based on DEA statistics for 2015 in CRF sectors. The fuel consumption figures in time series 1985-2015 are given in Annex 2.B.16 (CRF format) and are shown for 2015 in Annex 2.B.15 (CollectER format). Road transport has a major share of the fuel consumption for domestic transport. In 2015, this sector's fuel consumption share is 77 %, while the fuel consumption shares for Off road agriculture/forestry and Manufacturing industries (mobile) are 7 % and 5 %, respectively. For the remaining sectors, the total fuel consumption share is 11 %.

Table 3.3.2 Fuel consumption (PJ) for domestic transport in 2015 in CRF sectors.

CRF ID	Fuel consumption (PJ)
Manufacturing industries/Construction (mobile)	9.8
Civil aviation (Domestic)	1.8
Road transport: Passenger cars	95.9
Road transport:Light duty vehicles	19.6
Road transport:Heavy duty vehicles	47.9
Road transport: Mopeds & motorcycles	1.0
Railways	3.4
National navigation (Shipping)	4.9
Commercial/Institutional: Mobile	2.3
Residential: Household and gardening (mobile)	0.8
Agriculture/Forestry/Fishing: Off-road agriculture/forestry	14.8
Agriculture/Forestry/Fishing: National fishing	7.2
Other. Mobile	2.7
Road transport total	164.3
Other mobile total	47.8
Domestic total	212.2
Civil aviation (International)	36.5
Navigation (international)	30.5

From 1990 to 2015, diesel (sum of diesel and biodiesel) and gasoline (sum of gasoline and E5) fuel consumption has changed by 41 % and - 16 %, respectively (Figure 3.3.1), and in 2015 the fuel consumption shares for diesel and gasoline were 70 % and 27 %, respectively (not shown). Other fuels only have a 3 % 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].

[2] Biofuels are sold at gas filling stations and assumed used by road transport vehicles.

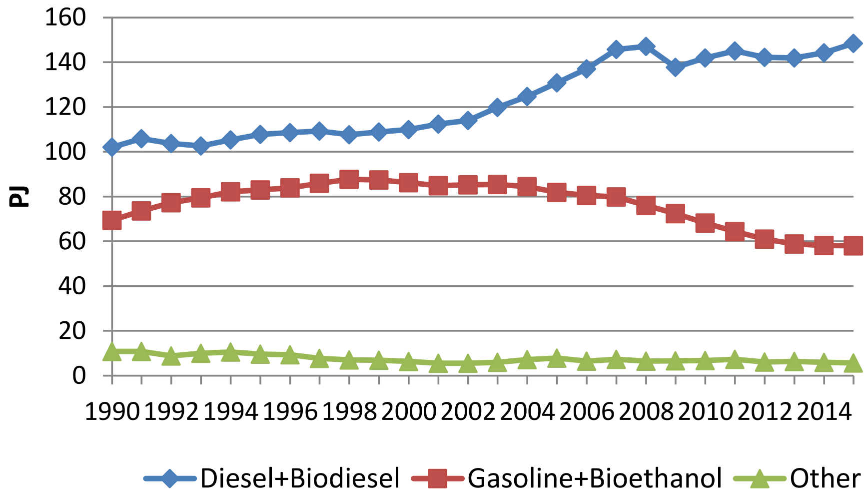


Figure 3.3.1 Fuel consumption pr fuel type for domestic transport 1990-2015.

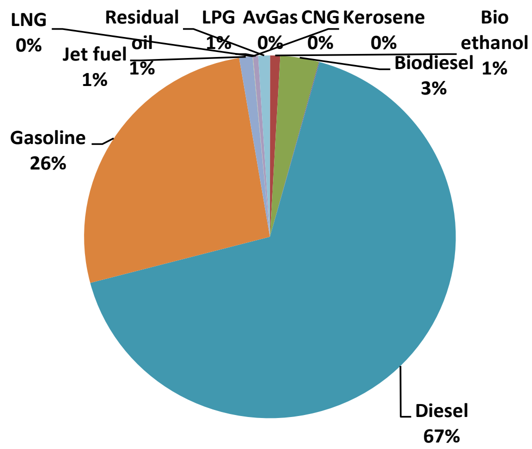


Figure 3.3.2 Fuel consumption share pr fuel type for domestic transport in 2015.

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).

[3] The sum share of bioethanol and biodiesel in the gasoline and diesel fuel blends for road transport is 5.5 %, in 2015.

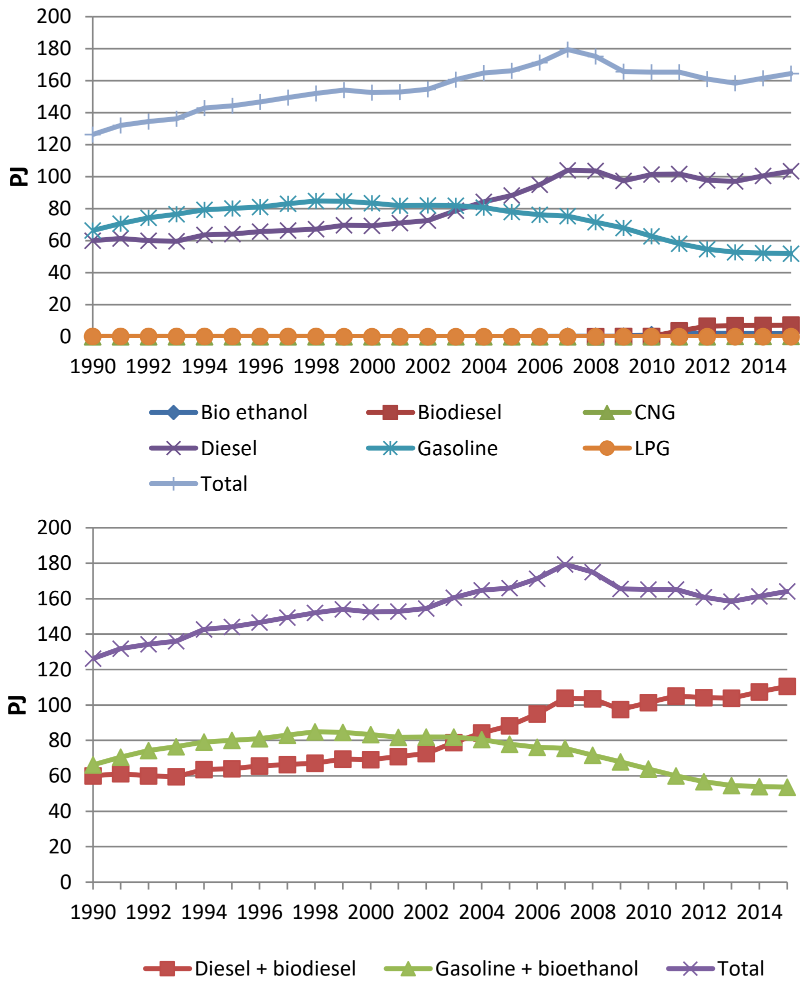


Figure 3.3.3 Fuel consumption pr fuel type and as totals for road transport 1990-2015

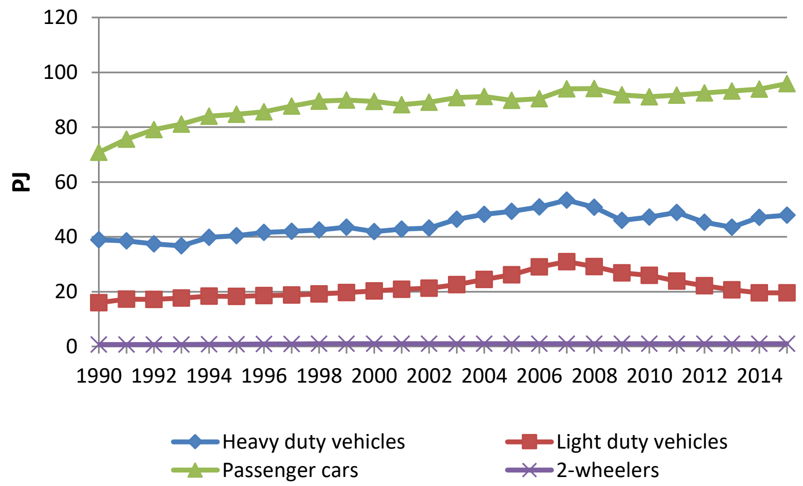


Figure 3.3.4 Total fuel consumption pr vehicle type for road transport 1990-2015.

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 characterized 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 2008-2014, respectively.

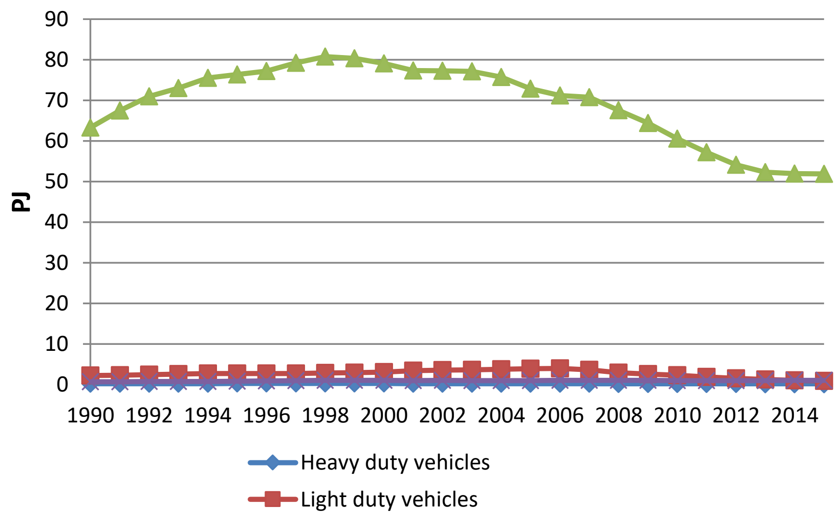


Figure 3.3.5 Gasoline fuel consumption pr vehicle type for road transport 1990-2015.

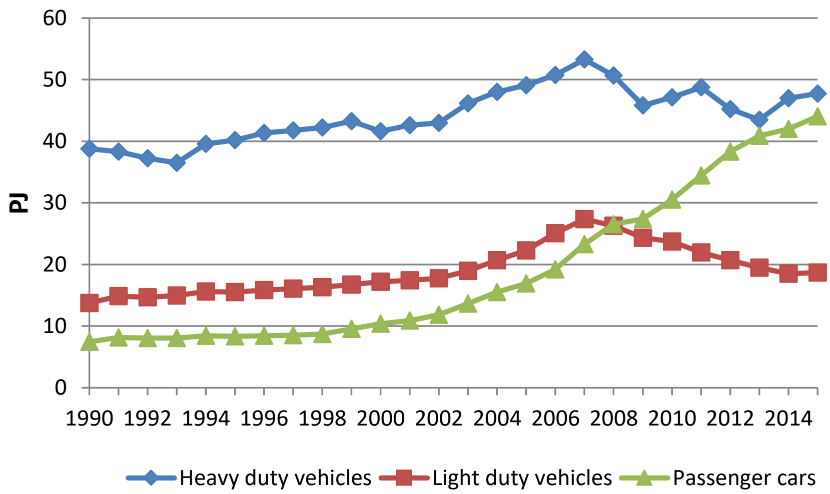


Figure 3.3.6 Diesel fuel consumption pr vehicle type for road transport 1990-2015.

In 2015, fuel consumption shares for gasoline passenger cars, diesel heavy-duty vehicles, diesel passenger cars, diesel light duty vehicles and gasoline light duty vehicles were 32, 29, 27 and 11 %, respectively (Figure 3.3.7).

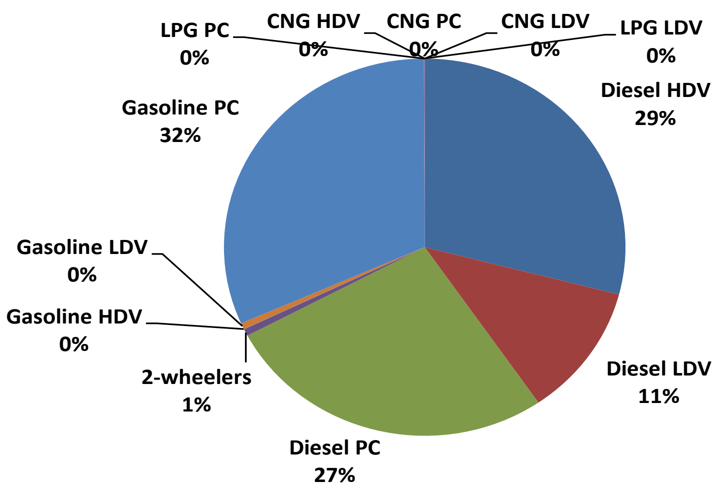


Figure 3.3.7 Fuel consumption share (PJ) per vehicle type for road transport in 2015.

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 1985-2015 time series are shown pr fuel type in Figures 3.3.9-3.3.12 for diesel, gasoline and jet fuel, respectively.

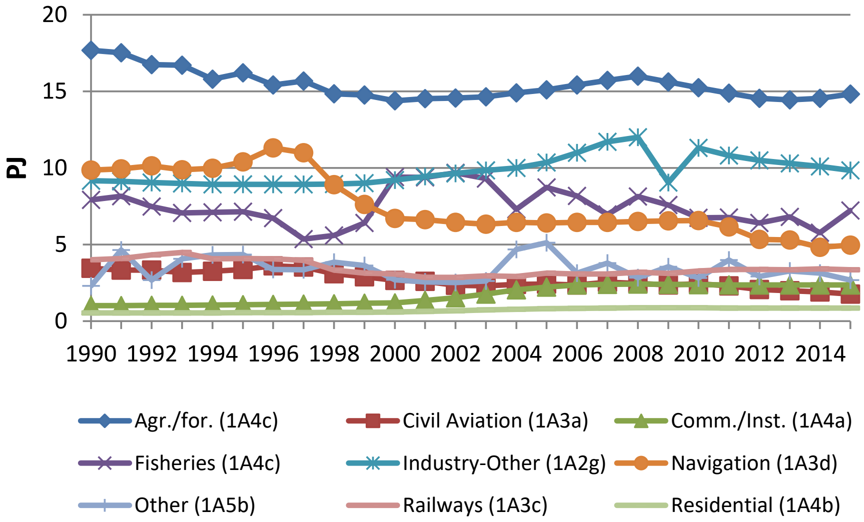


Figure 3.3.8 Total fuel consumption in CRF sectors for other mobile sources 1990-2015.

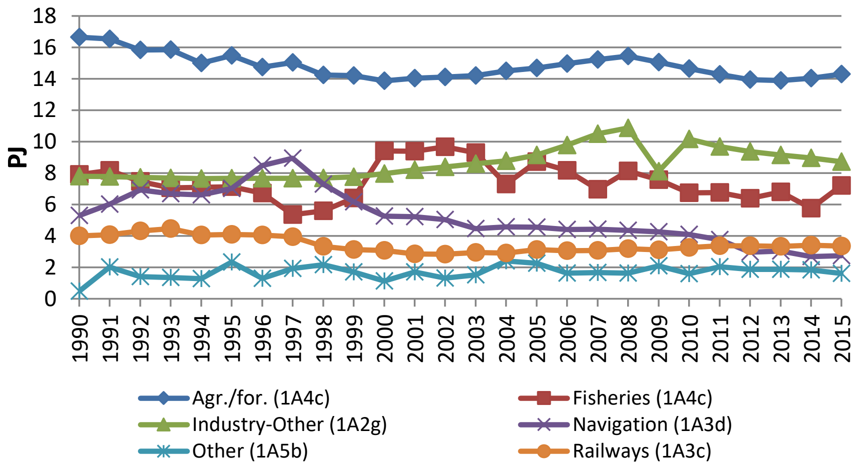


Figure 3.3.9 Diesel fuel consumption in CRF sectors for other mobile sources 1990-2015.

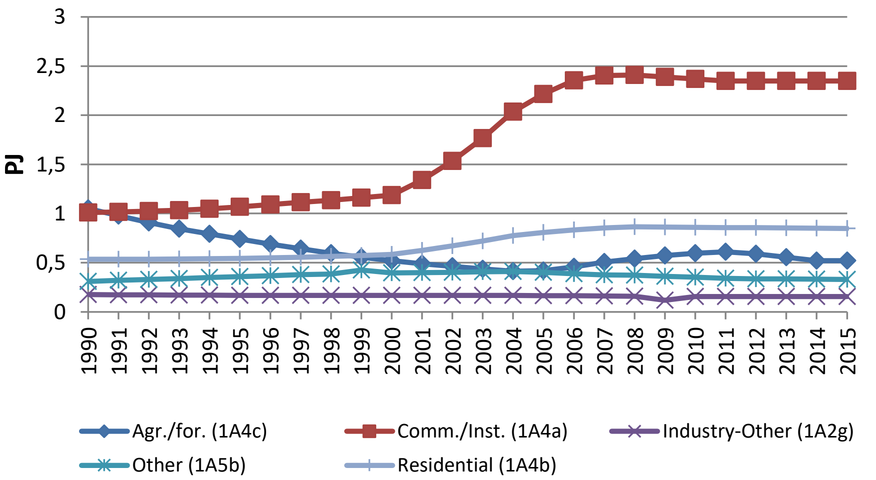


Figure 3.3.10 Gasoline fuel consumption in CRF sectors for other mobile source 1990-2015.

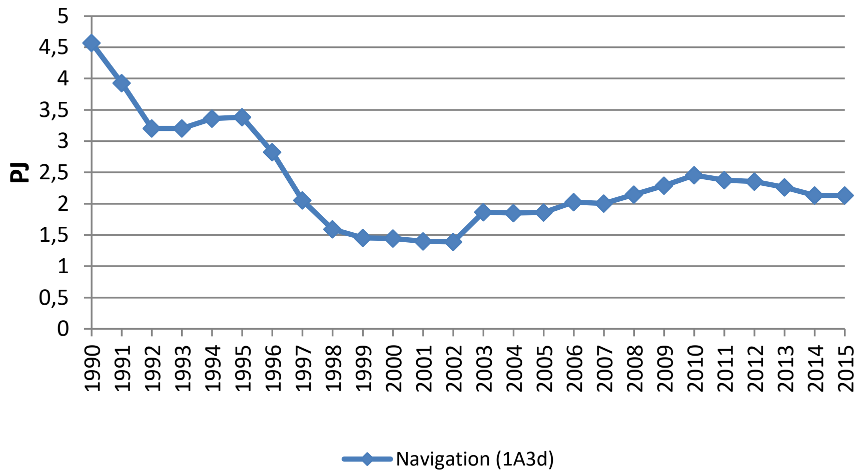


Figure 3.3.11 Residual oil fuel consumption in CRF sectors for other mobile sources 1990-2015.

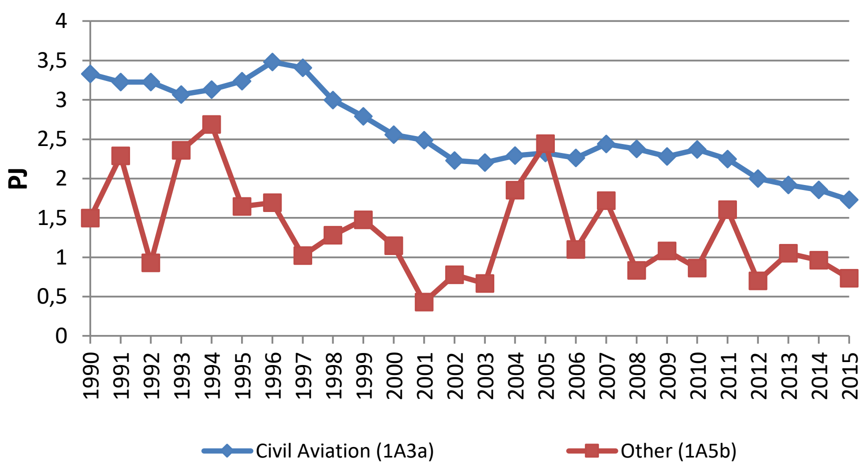


Figure 3.3.12 Jet fuel consumption in CRF sectors for other mobile sources 1990-2015.

In terms of diesel, the fuel consumption decreases for agricultural machines until 2000, due to fewer numbers of tractors and harvesters. After 2000, the increase in the engine sizes of new sold machines makes the total fuel consumption grow until 2008, whereas from 2008 to 2013 the turnover of old less fuel efficient machinery is the key factor for the total fuel consumption decrease. 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. From 2009 onwards the fuel efficiency improvements for new sold vehicles is the main reason for total fuel consumption decline. 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. From 2011 to 2012, the total consumption of jet fuel decreased significantly due to a drop in the number of domestic flights.

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.

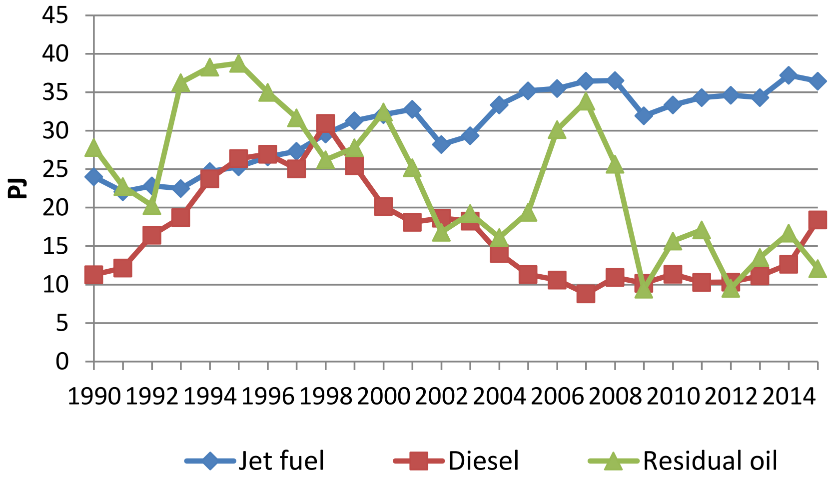


Figure 3.3.13 Bunker fuel consumption 1990-2015.

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 2015 in CRF sectors. The emission figures in time series 1990-2015 are given in Annex 3.B.16 (CRF format) and are shown for 1990 and 2015 in Annex 3.B.15 (CollectER format).

From 1990 to 2015, the road transport emissions of CO_2 and N_2O have increased by 23 and 42 %, respectively, whereas the emissions of CH_4 have decreased by 81 % (from Figures 3.3.14 - 3.3.16). From 1990 to 2015 the other mobile CO_2 emissions have decreased by 15 %, (from Figures 3.3.18 - 3.3.20).

Table 3.3.3 Emissions of CO_2, CH_4 and N_2O in 2015 for road transport and other mobile sources.

	CO_2 ktonnes	CH_4 tonnes	N_2O tonnes
Manufacturing industries/Construction (mobile)	718	29	32
Civil aviation (Domestic)	128	2	7
Road transport: Passenger cars	6 705	259	191
Road transport:Light duty vehicles	1 356	8	43
Road transport:Heavy duty vehicles	3 312	63	189
Road transport: Mopeds & motorcycles	69	85	1
Railways	0	0	0
National navigation (Shipping)	0	0	0
Commercial/Institutional: Mobile	0	0	0
Residential: Household and gardening (mobile)	0	0	0
Agriculture/Forestry/Fishing: Off-road agriculture/forestry	248	5	8
Agriculture/Forestry/Fishing: National fishing	374	16	9
Other, Mobile	171	172	3
Road transport exhaust total	62	36	1
Road transport non exhaust total	1 096	98	51
Other mobile sources total	534	13	14
Domestic total	197	10	7
Civil aviation (International)	11 442	415	425
Navigation (International)	0	0	0

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 2015, the respective emission shares were 58, 29, 12 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 2015 emission shares for CH_4 were 63, 20, 15 and 2 % for passenger cars, 2-wheelers, heavy-duty vehicles and light-duty vehicles, respectively (Figure 3.3.17).

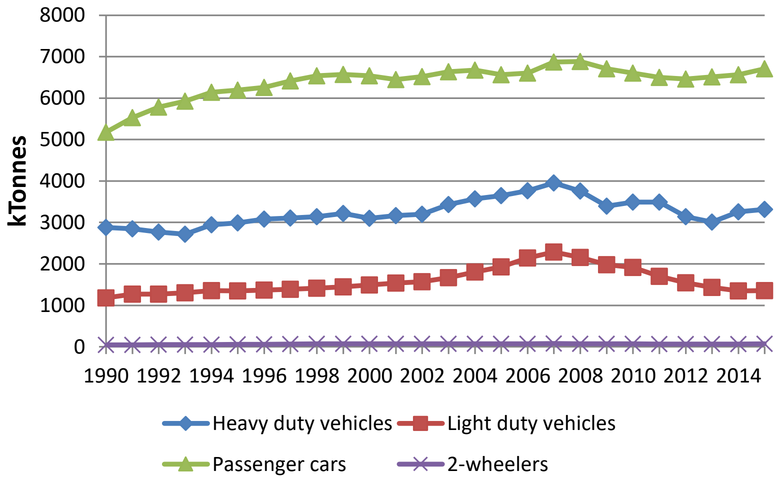


Figure 3.3.14 CO_2 emissions (k-tonnes) pr vehicle type for road transport 1990-2015.

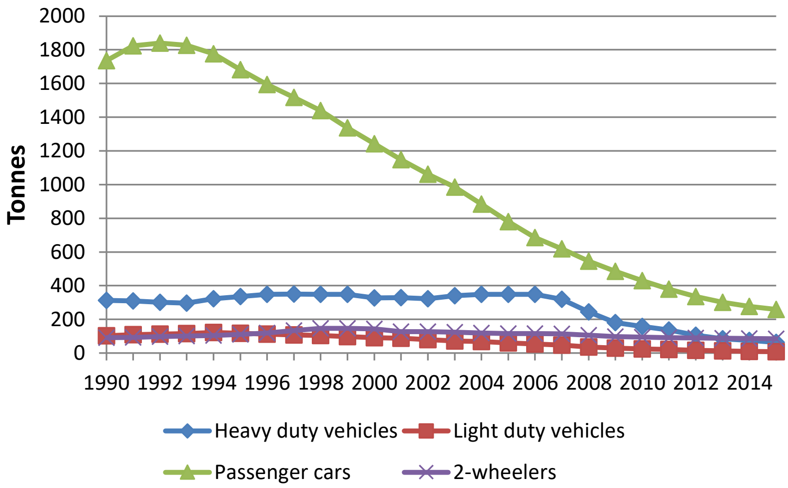


Figure 3.3.15 CH_4 emissions (tonnes) pr vehicle type for road transport 1990-2015.

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 2015, emission shares for passenger cars, heavy and light-duty vehicles were 45, 45 and 10 %, 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.

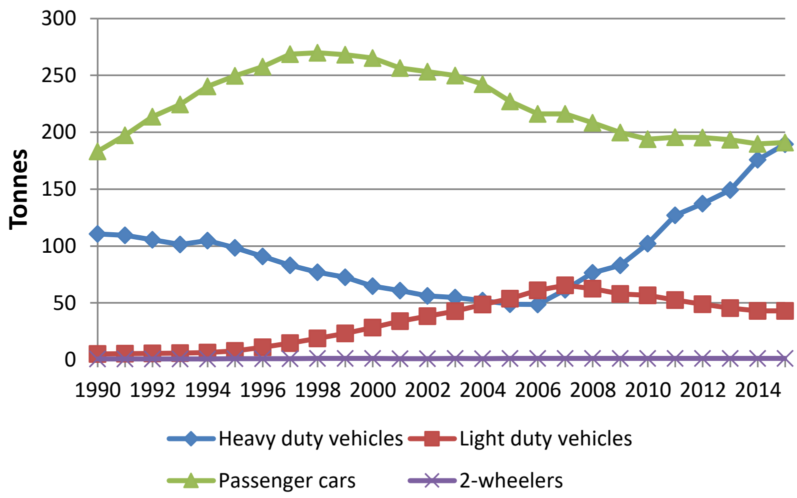


Figure 3.3.16 N_2O emissions (tonnes) pr vehicle type for road transport 1990-2015.

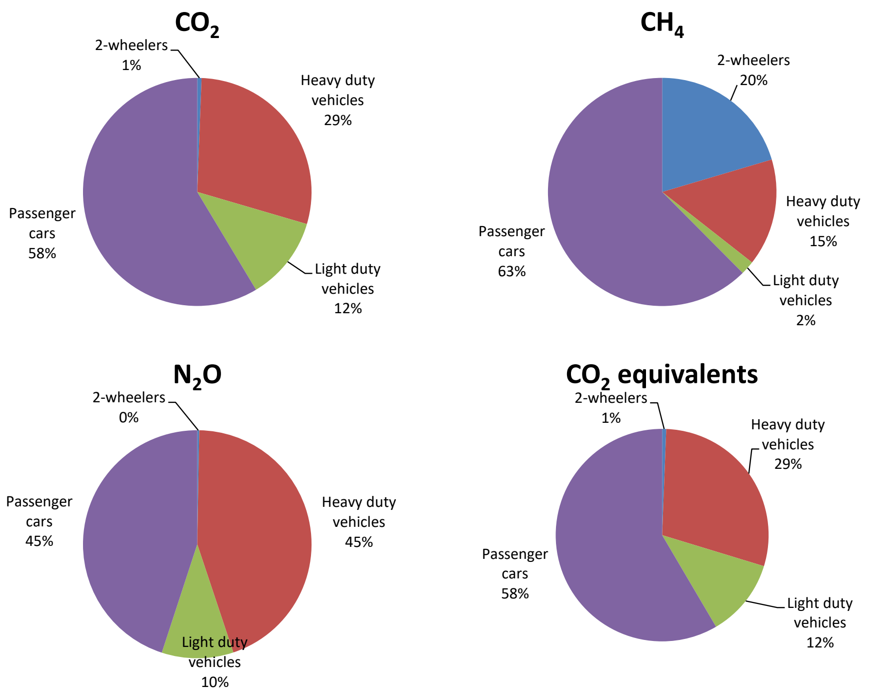


Figure 3.3.17 CO_2, CH_4 and N_2O emission shares and GHG equivalent emission distribution for road transport in 2015.

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 46, 20 and 11 %, respectively (Figure 3.3.21). The 1990-2015 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 45 % and 9 %, respectively in 2015. The 2015 emission shares for Agriculture/forestry/fisheries (1A4c) and Industry (1A2g) are 29 % and 8 %, respectively, whereas the remaining sectors have emission shares of 4 % or less.

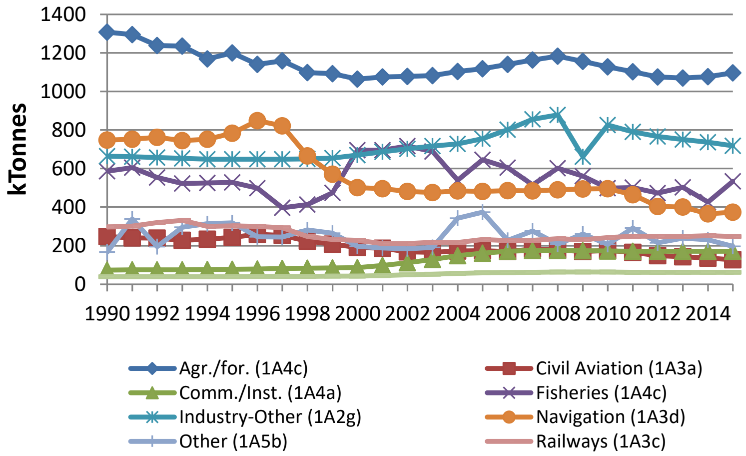


Figure 3.3.18 CO_2 emissions (ktonnes) in CRF sectors for other mobile sources 1990-2015.

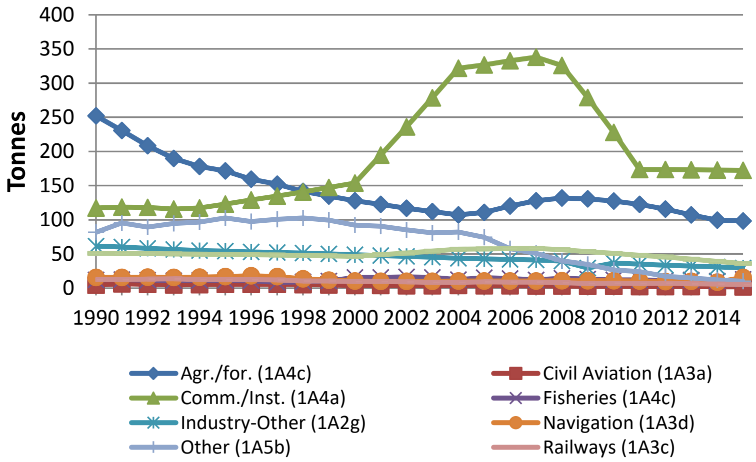


Figure 3.3.19 CH_4 emissions (tonnes) in CRF sectors for other mobile sources 1990-2015.

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).

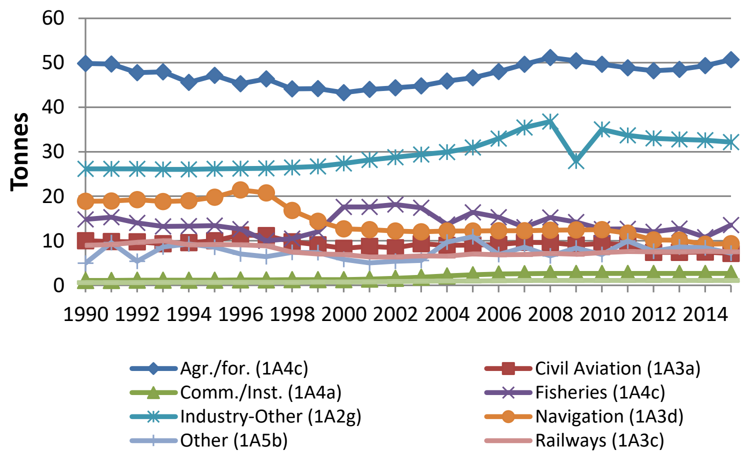


Figure 3.3.20 N_2O emissions (tonnes) in CRF sectors for other mobile sources 1990-2015.

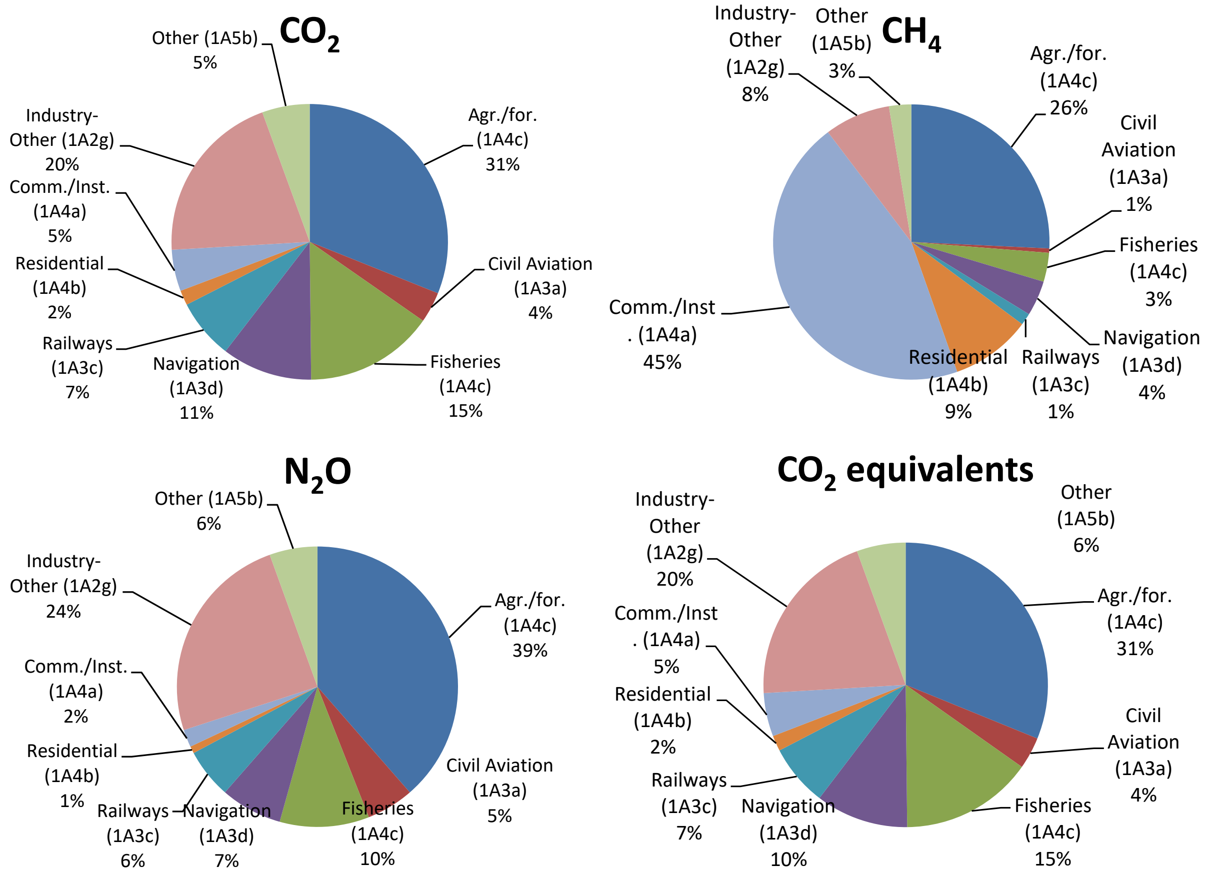


Figure 3.3.21 CO_2, CH_4 and N_2O emission shares and GHG equivalent emission distribution for other mobile sources in 2015.

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 1990-2015 are given in Annex 3.B.16 (CRF format) and are shown for 1990 and 2015 in Annex 3.B.15 (CollectER format). For further explanations regarding 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 33 %, 8 % and 26 %, 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 3.3.22 for 2015, split into sea transport and civil aviation. All emission figures in the 1990-2015 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 2015.

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 3.3.22 are similar to the fuel consumption development.

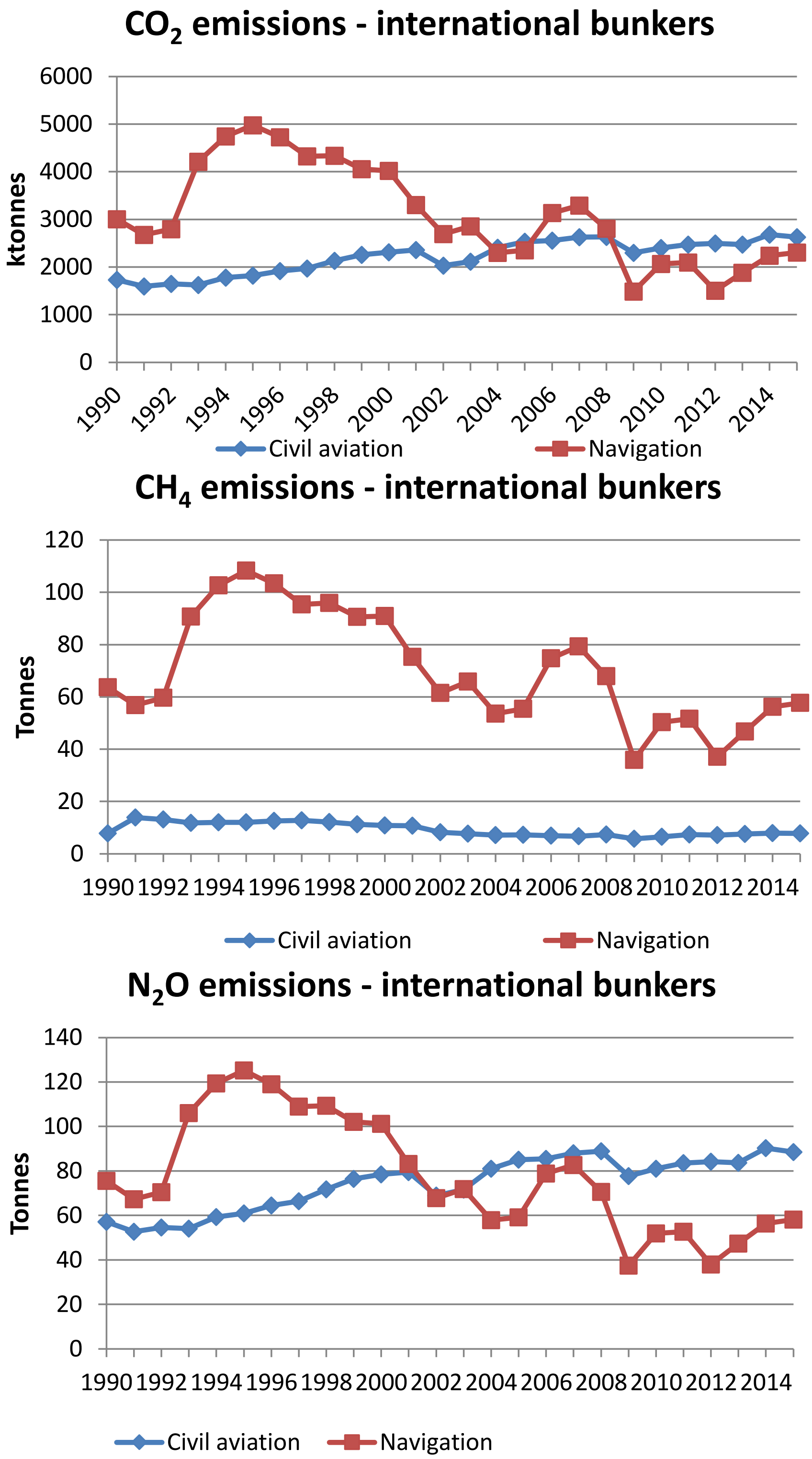


Figure 3.3.22 CO_2, CH_4 and N_2O emissions for international transport 1990-2015.

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 ENVS, using the European COPERT 5 model methodology (EMEP/EEA, 2013)[4]. 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 5 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.

[4] The main difference between the previous COPERT 4 model version and COPERT 5 is NOx emission factor updates for diesel cars and vans. Official documentation for COPERT 5 still awaits, the previous model version – Copert 4 - is explained by EMEP/EEA (2013).

Table 3.3.4 Model vehicle classes and sub-classes and trip speeds.

Vehicle classes	Fuel type	Engine size/weight	Trip speed [km pr h] 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, 2016). 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 1985-2015, 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 determines 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, 2016) 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 2015.

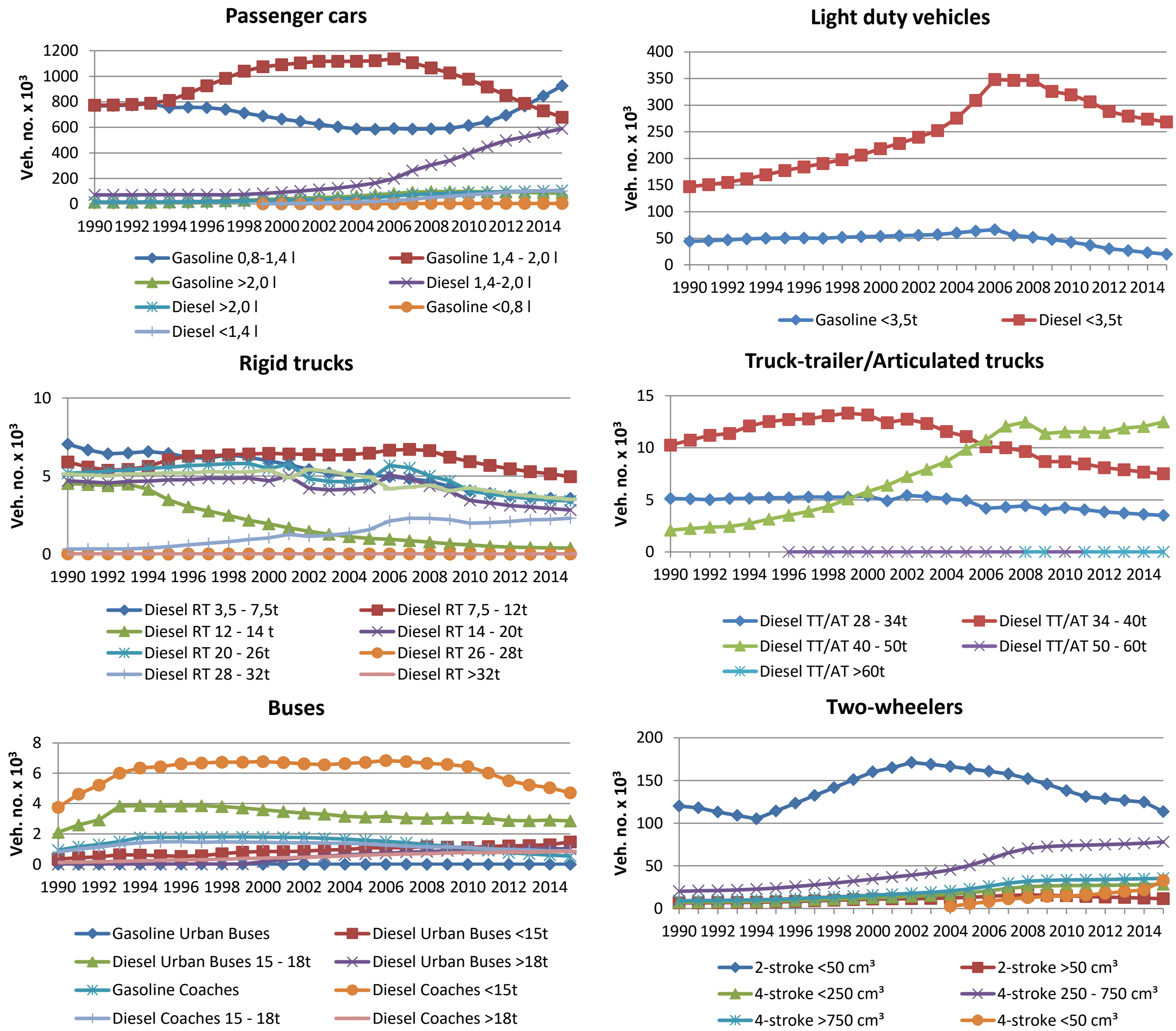


Figure 3.3.23 Number of vehicles in sub-classes in 1990-2015.

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 due to the restructuring of car taxes that made it less advantageous buying vans for private use.

For the truck-trailer and articulated truck combinations, there is a tendency towards the use of increasingly fewer but larger trucks throughout the time period. The decline in fleet numbers for many of the truck categories is due to the combined effects of the global financial crisis, the fleet shift towards fewer and larger trucks, international market competition (foreign transport companies are effectively gaining Danish market shares), and the reflagging of Danish commercial trucks to companies based in the neighbouring countries.

The sudden change in the level of urban bus and coach numbers from 1991 to 1995 is due to uncertain fleet data from Statistics Denmark.

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 1985-2015 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:

$$N_{j,y} = \sum_{i=FYear(j)}^{LYear(j)} N_{i,y} \qquad (1)$$

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.

$$M_{j,y} = \frac{\sum_{i=FYear(j)}^{LYear(j)} N_{i,y} \cdot M_{i,y}}{\sum_{i=FYear(j)}^{LYear(j)} N_{i,y}} \qquad (2)$$

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 (2015). 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 1990-2015. The trends in vehicle numbers per layer are also shown in Figure 3.3.24. The latter figure shows how vehicles complying with the gradually stricter EU emission levels (EURO 1-5, Euro I-VI etc.) have been introduced into the Danish motor fleet.

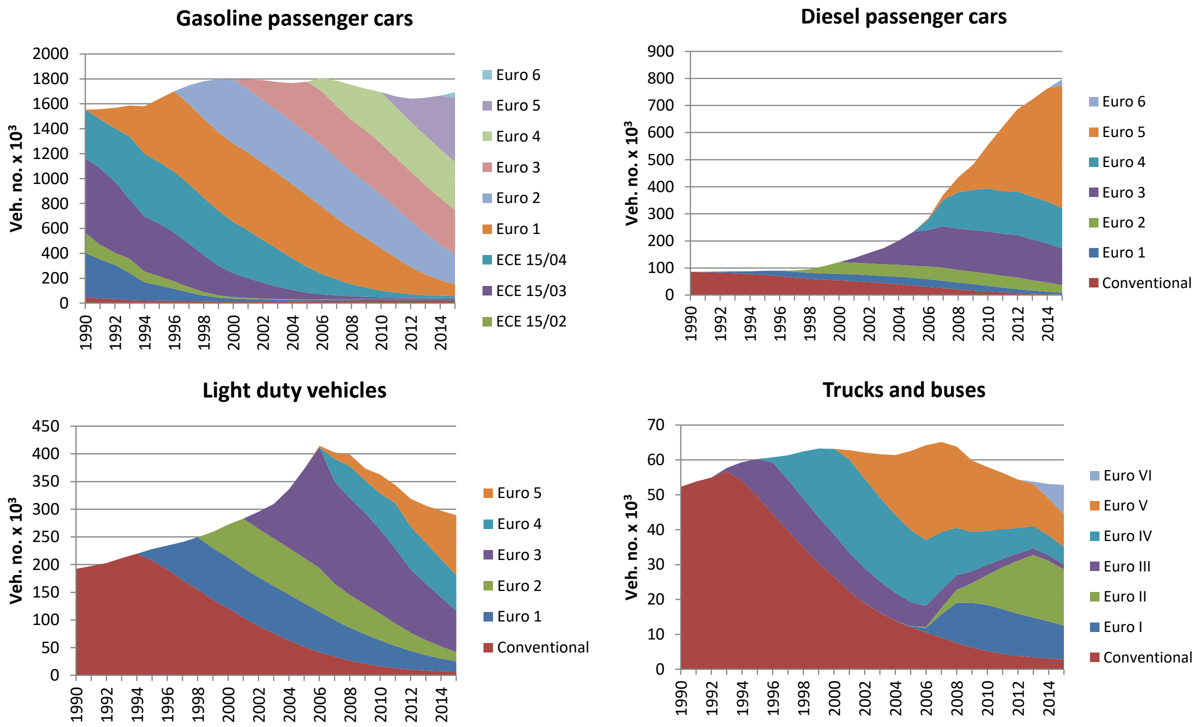


Figure 3.3.24 Layer distribution of vehicle numbers pr vehicle type in 1990-2015.

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:** 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:** 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 vans, the chassis dynamometer test cycle used in the EU for emission approval is the NEDC (New European Driving Cycle), see e.g. www.dieselnet.com. The test cycle is also used for fuel consumption measurements. 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 cycle[5] (average speed: 19 km per 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 7 km at an average speed of 63 km per h. More information regarding the fuel measurement procedure can be found in the EU-directive 80/1268/EØF.

[5] 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.

The NEDC test cycle is not adequately describing real world driving behavior, and as an effect, for diesel cars and vans, there is an increasing mismatch between the step wise lowered EU emission limits the vehicles comply with during the NEDC test cycle, and the more or less constant emissions from the same vehicles experienced during real world driving. In order to bridge this emission inconsistency gap a new test procedure for future Euro 6 vehicles, the so-called Euro 6c vehicles, the "World-Harmonized Light-Duty Vehicles Test Procedure" (WLTP), has been developed which simulates much more closely real world driving behavior. The new test procedure still awaits its final adoption by the EU and the announcement of new legislative emission limits. This is expected to happen in September 2017.

For the new Euro 6c vehicles it has been decided that emission measurements must also be made with portable emission measurement systems (PEMS) during real traffic driving conditions with random acceleration and deceleration patterns. During the new Real Driving Emission (RDE) test procedure the emissions of NO_x are not allowed to exceed the existing (NEDC based) emission limits by more than 110 % by January 2017 for all new car models and by January 2019 for all new cars[6]. From January 2020 the NO_x emission not-to-exceed levels are adjusted downwards to 50 % for all new car models and by January 2021 for all new cars[7]. Implementation dates for vans are one year later.

In the road transport emission model, the dates for implementation of the Euro 6c technology is set to 1/9 2018 and 1/9 2019, for diesel cars and vans, respectively. For "Euro 6c+" the implementation dates are set to 1/1 2021 and 1/1 2022 for cars and vans, respectively.

For NOx, VOC (NMVOC + CH_4), CO and PM, the emissions from road transport vehicles have to comply with the different EU directives listed in Table 3.3.7. The emission directives distinguish between three vehicle classes according to vehicle reference mass[8]: 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 2.B.3.

For heavy-duty vehicles (trucks and buses), the emission limits are given in g pr kWh and the measurements are carried out for engines in a test bench, using the ECE R-49, EU ESC (European Stationary Cycle) and ETC (European Transient Cycle) test cycles, depending on the Euro norm and exhaust gas after-treatment system installed. For Euro VI engines the WHSC (World Harmonized Stationary Cycle) and WHTC (World Harmonized Transient Cycle) test cycles are used. For a description of the test cycles, see e.g. www.dieselnet.com.

In terms of the sulphur content in the fuels used by road transportation vehicles, the EU directive 2003/17/EF describes the fuel quality standards agreed

[5] For ambient test temperatures below 3 degrees Celsius, not-to-exceed emission limits are 60 % higher. For ambient test temperatures below minus 2 degrees Celsius the emission limits no longer apply.
[6] For ambient test temperatures below 0 degrees Celsius, not-to-exceed emission limits are 60 % higher. For ambient test temperatures below minus 7 degrees Celsius the emission limits no longer apply.
[8] Reference mass: net vehicle weight + mass of fuel and other liquids + 100 kg.

by the EU. In Denmark, the sulphur content in gasoline and diesel was reduced to 10 ppm in 2005, by means of a fuel tax reduction for fuels with 10 ppm sulphur contents.

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
Continued…			
	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]

Continued…			
	Euro IV	168/2013	2017
	Euro V	168/2013	2021
Motor cycles	Conventional	Conventional	0
	Euro I	97/24	2000
	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).

Fuel consumption and emission factors

In practice, the emissions from vehicles in traffic are different from the legislation limit values and, therefore, the latter figures are not suited for total emission calculations. Besides difference in test versus real world driving behaviour, as discussed in the previous section, the emission limit values do not reflect the emission impact of cumulated mileage driven, and engine and exhaust after treatment maintenance levels for the vehicle fleet as a whole.

Therefore, in order to represent the Danish fleet and to support average national emission estimates, the selected emission factors must be derived from numerous emission measurements, using a broad range of real world driving patterns and a sufficient number of test vehicles. It is similarly important to have separate fuel consumption and emission data for cold-start emission calculations and gasoline evaporation (hydrocarbons).

The fuel consumption and emission factors used in the Danish inventory come from the COPERT 5 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 order to account for the trend towards more fuel efficient vehicles being sold in Denmark in the later years, fuel consumption factors for Euro 5 and Euro 6 passenger cars are estimated in the following way.

In the Danish fleet and mileage database kept by DTU Transport, 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 (average from all new registrations) 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/km in 2020. For years beyond 2020 annual fuel efficiency improvement rates are used for new cars depending on fuel type as suggested by DEA (2016b).

From 2006 up to last historical year, CO_2 emission factors are also calculated for each year's new sold cars, as new registrations average 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 5 are set up valid for Euro 4+ vehicles in the COPERT model. The COPERT 5 CO_2 factors are derived from fuel consumption factors included in the COPERT 5 model, that 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 4 vehicles under TA_{inuse} are used to scale the trip speed dependent fuel consumption factors provided by COPERT 5 for Euro 4 layers onwards.

For vans, trucks, urban buses and coaches, annual fuel efficiency improvement rates are used for new vehicles depending on fuel type as suggested by DEA (2016b).

Adjustment for EGR, SCR and filter retrofits

In COPERT 5 emission factors are 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 period 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 stabilize 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 pr 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 h 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 (Danish rural and highway trip speed; c.f. Table 3.3.6). For trip speeds between 19 and 63 km per hour (Danish urban trip speed; c.f. Table 3.3.6) 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 5 takes into account deterioration as a linear function of mileage for gasoline fuelled EURO 1-6 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. The deterioration factors are shown in Annex 3.B.6 for 2015.

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 2015 are given in Cappelen et al. (2016). 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 5. 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 5. 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.

$$R_{j,y} = N_{j,y} \cdot M_{j,y} \cdot ((1-\beta) \cdot HR + \beta \cdot WR) \quad (10)$$

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:

$$S_{j,y}^{\ C} = N_{j,y} \cdot \frac{M_{j,y}}{l_{trip}} \cdot ((1-\beta) \cdot HS + \beta \cdot WS) \quad (11)$$

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 $E^d(U)$:

$$E_{j,y}^{\ d}(U) = 365 \cdot N_{j,y} \cdot e^d(U) \quad (12)$$

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 5 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 Authority data (see DEA, 2015).

For gasoline, the DEA data for road transport are adjusted at first, 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. Next, the fuel and emission results for all gasoline vehicles are scaled with the percentage difference between the adjusted bottom-up gasoline fuel consumption obtained after step one and total gasoline fuel sold.

The DEA data for diesel consist of fuel sold in Denmark and used on Danish roads and fuel sold in Denmark and used abroad. The latter diesel fuel contribution is estimated by the Danish Ministry of Taxation based on studies on fuel price differences across borders, fuel discount for haulage contractors and fuel tanking behavior of truck and bus operators as well as private cars (see e.g. the Danish Ministry of Taxation, 2015).

The amount of diesel fuel sold in Denmark and used abroad is allocated to trucks and coaches in a first step and emissions are scaled accordingly (Figure 3.3.35). Next, the percentage difference between the adjusted bottom-up diesel fuel consumption obtained after step one and total diesel fuel sold is used to scale fuel and emission results for all diesel vehicles regardless of vehicle category (Figure 3.3.26). The data behind the Figures 3.3.25 and 3.3.26 are also listed in Annex 3.B.8.

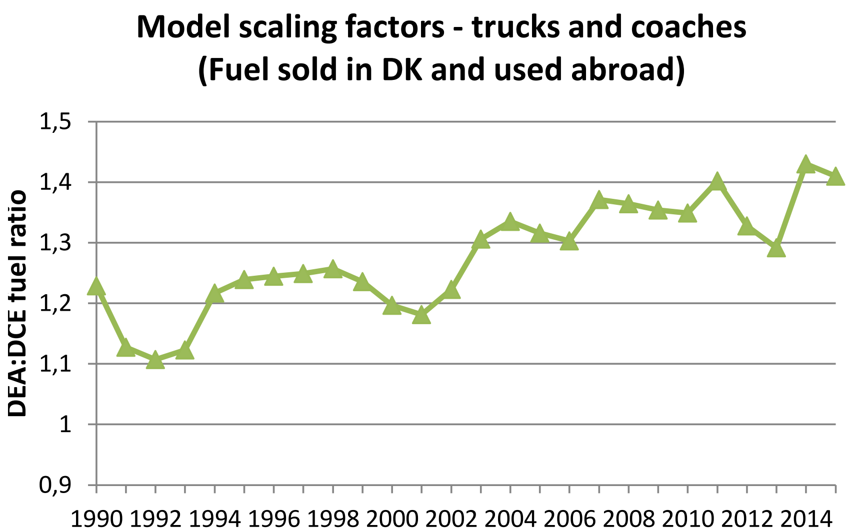


Figure 3.3.25 Fuel ratios (fuel and emission adjustment factors) for trucks and coaches: Bottom-up fuel consumption plus diesel used abroad vs bottom-up fuel consumption.

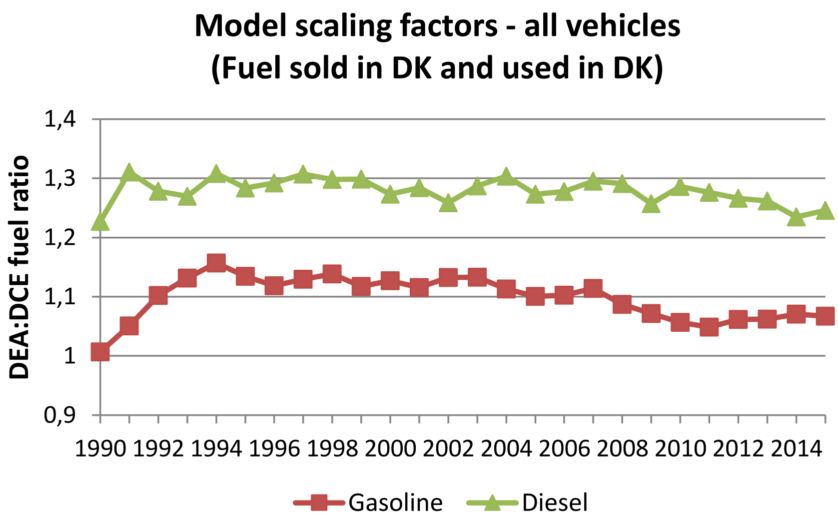


Figure 3.3.26 Gasoline and diesel fuel ratios (fuel and emission adjustment factors) regardless of vehicle category: Fuel sold and used in Denmark vs adjusted bottom-up fuel consumption

The reasons for the differences between DEA sales figures and bottom-up fuel estimates shown in Figure 3.3.26 are mostly due to a combination of the uncertainties related to COPERT 5 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 are shown in Annex 3.B.7 for 1985-2015. The total fuel consumption and emissions are shown in Annex 3.B.8, per vehicle category and as grand totals, for 1985-2015 (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 2015.

In the following Figures 3.3.27 - 3.3.30, 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 1990-2015).

For CO_2 the neat gasoline/diesel emission factors shown in Table 3.3.6 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 3.3.6), 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 3.3.6) the average fuel related CO_2 emission factors, $emf_{CO2,E}(BF\%)$ become:

(13)

$$EF_{CO_2,E}(BF\%) = EF_{CO_2,E}(BF0) \cdot (100 - BF\%_E)$$

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:

$$EF_{CO_2,km}(BF\%) = EF_{CO_2,E}(BF\%) \cdot FC_E(BF0) \qquad (14)$$

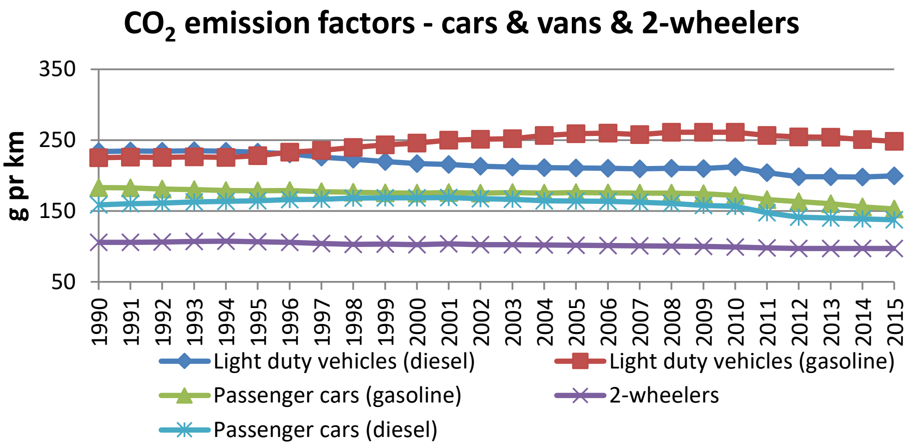
A literature review carried out in the Danish research project REBECA revealed no significant changes in emission factors between neat gasoline and E5 gasoline-ethanol blends for the combustion related emission components; NO_x, CO and VOC (Winther et al., 2012). Hence, due to the current low ethanol 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	2014	2015
Neat gasoline	73	73	73	73	73	73	73	73	73	73	73
Neat diesel	74	74	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	63.1	63.1
Bio ethanol	0	0	0	0	0	0	0	0	0	0	0
Biodiesel	0	0	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	70.5	70.5
Diesel, average	74	74	74	74	73.9	74	71.5	69.4	69.2	69.1	69.2
	Biofuel share (BF%) of Danish road transport fuels										
	1990-2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
	0	0.09	0.14	0.13	0.21	0.69	3.40	5.30	5.50	5.50	5.50



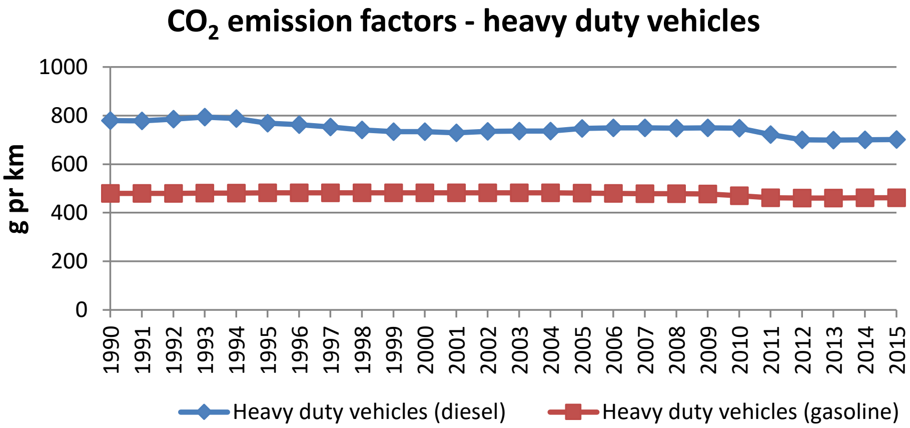


Figure 3.3.27 Km related CO_2 emission factors per vehicle type for Danish road transport (1990-2015).

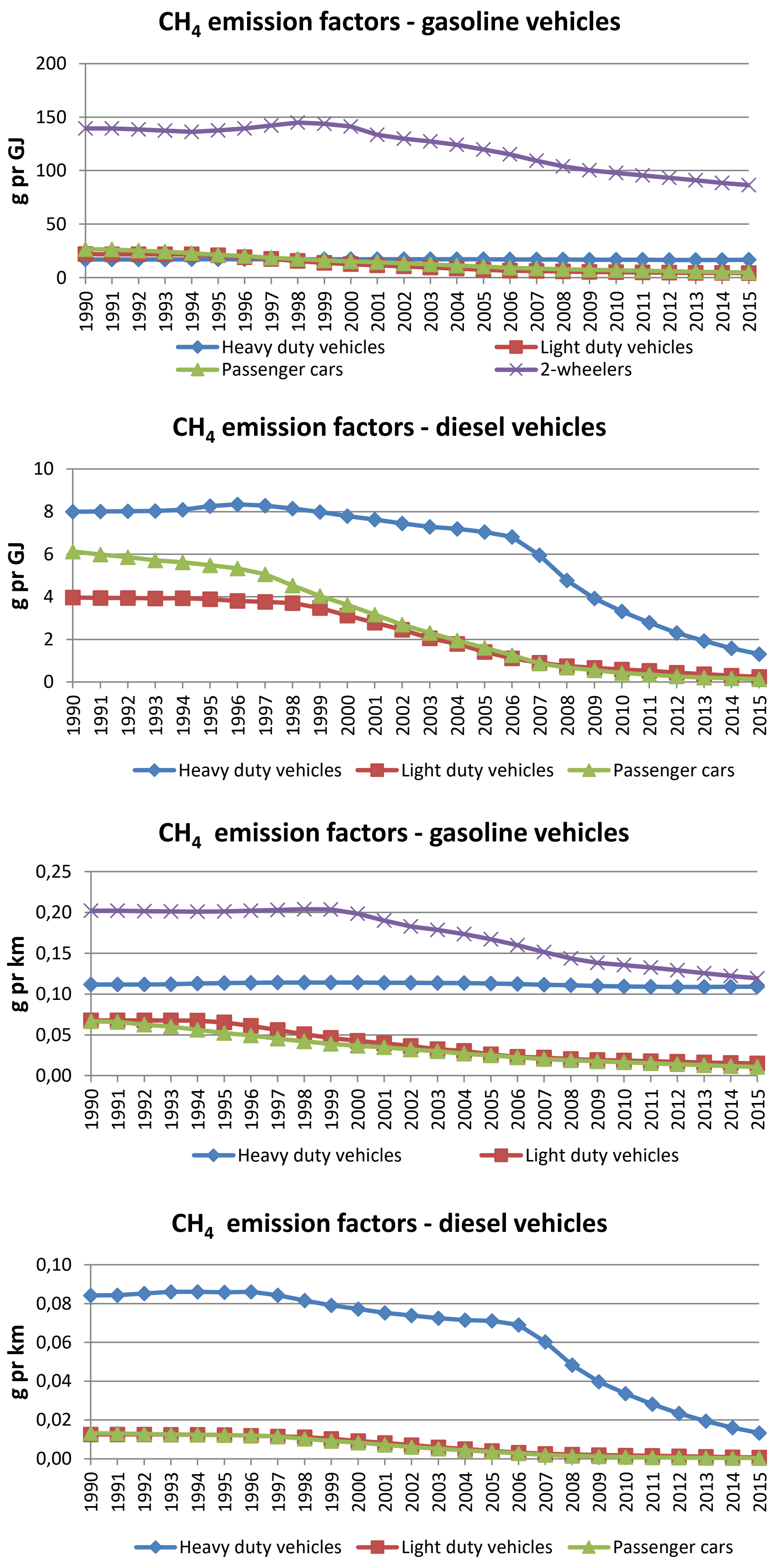


Figure 3.3.28 Fuel and km related CH_4 emission factors per vehicle type for Danish road transport (1990-2015).

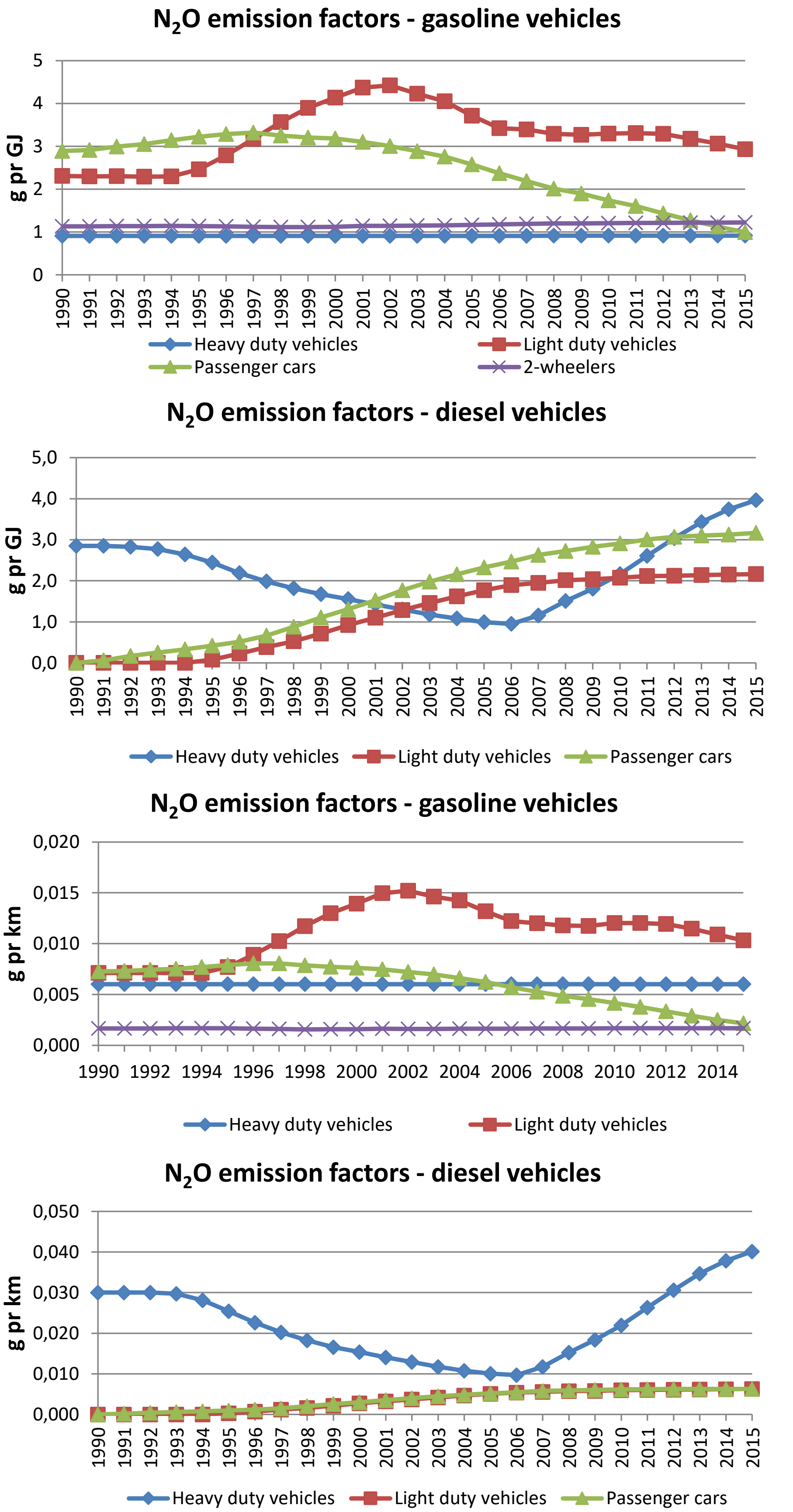


Figure 3.3.29 Fuel and km related N_2O emission factors per vehicle type for Danish road transport (1990-2015).

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 in internal DCE models 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 used in the DCE emission model for aviation consists of air traffic statistics provided by the Danish Transport and Construction Agency and Copenhagen Airport. Fuel statistics for jet fuel consumption and aviation gasoline are obtained from the Danish energy statistics (DEA, 2016).

For 2001 onwards, the Danish Transport and Construction Agency provides data records per flight (city-pairs). Each flight record consists of e.g. ICAO codes for aircraft type, origin and destination airport, maximum takeoff mass (MTOM), flight call sign and aircraft registration number.

In the DCE model, each aircraft type is paired with a representative aircraft type, for which fuel consumption and emission data exist in the EMEP/EEA databank. As a basis, the type relation table is taken from the Eurocontrol AEM model, which is the primary source for the present EMEP/EEA fuel consumption and emission data. Supplementary aircraft types are assigned to representative aircraft types based on the type relation table already established in the previous version of the DCE model (e.g. Winther, 2012).

Additional aircraft types not present in the type relation table are identified by using different aircraft dictionaries and internet look-ups. In order to select the most appropriate aircraft representative type, the main selection criteria are the identified aircraft type, aircraft maximum takeoff mass, engine types, and number of engines. During this sequence, small aircraft with piston engines using aviation gasoline are excluded from the calculations.

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[9], in a time series from 2001-2015. The airport split is necessary to make due to the differences in LTO emission factors (cf. 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.

[9] Excluding flights for Greenland and the Faroe Islands. These flights are separately listed in Annex 3.B.10.

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.

For inventory years prior to 2001, detailed LTO/aircraft type statistics are obtained from Copenhagen Airport (for this airport only), while information of total takeoff numbers for other Danish airports is provided by the Danish Transport and Construction Agency. 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.

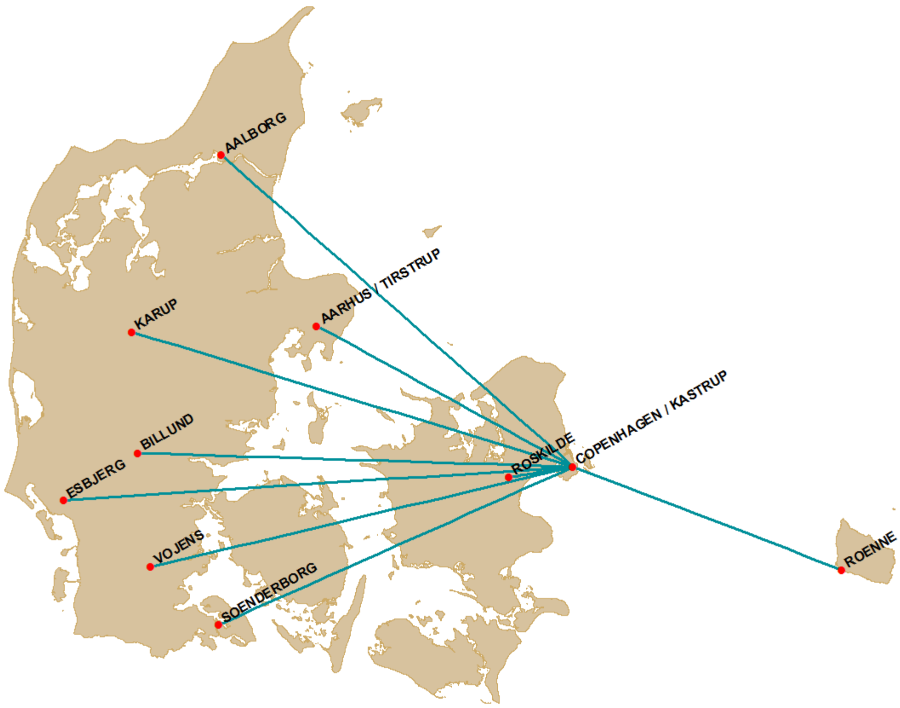


Figure 3.3.30 Most frequent domestic flying routes for large aircraft in Denmark.

Copenhagen Airport is the starting or end point for most of the domestic aviation made by large aircraft in Denmark (Figure 3.3.30; 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 and Construction Agency, 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.

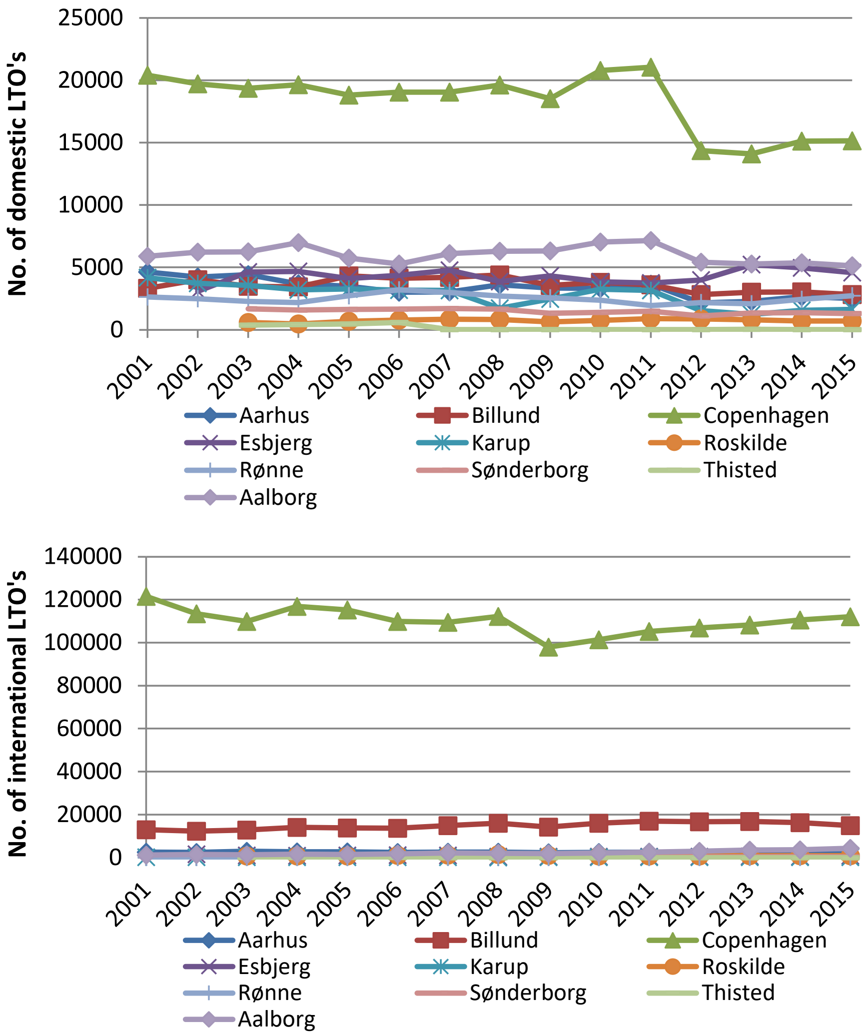


Figure 3.3.31 No. of LTO's for the most important airports in Denmark 2001-2015.

Figure 3.3.31 shows the number of domestic and international LTO's for Danish airports[10], in a time series from 2001-2015.

Non-road working machinery and equipment

Non-road working machinery and equipment are used in agriculture, forestry and industry, for household/gardening purposes and for sailing purposes (recreational craft).

For the most important types of building and construction machinery (industrial non-road) annual new sales data for 1996 onwards has been provided by the Association of Danish Agricultural Machinery Dealers. From engine manufacturers engine load factors have been provided based on electronic engine power registrations (Sjøgren 2016; Mikkelsen 2016). Further, equipment size - engine size relations, equipment scrapping curves and annual working hours as a function of machinery age has been included in the model (Sjøgren 2016; Mikkelsen 2016).

For other machinery types, 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

[10] Flights for Greenland and the Faroe Islands are included under domestic in the figure.

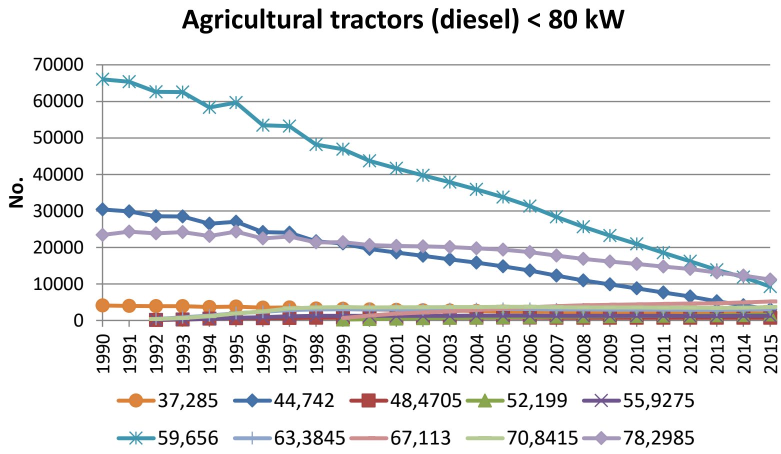
Association of Danish Agricultural Machinery Dealers and the Association of Producers and Distributors of Fork Lifts in Denmark.

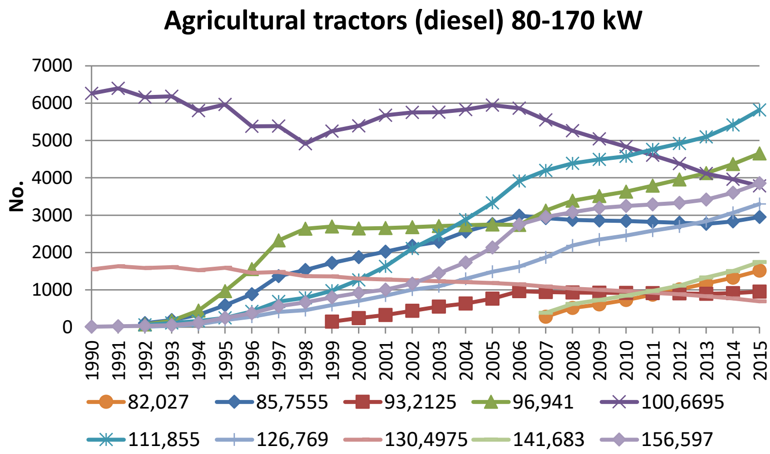
The stock development from 1990-2015 for the most important types of machinery are shown in Figures 3.3.32-3.3.39 below. The stock data are also listed in Annex 2.B.11, together with figures for load factors, engine sizes and annual working hours. As regards stock data for the remaining machinery types, please refer to (Winther et al., 2006).

It is important to note that key experts within the field of industrial non-road activities assume a significant decrease in the activities for 2009 due 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 3.3.32-3.3.33, 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 3.3.34, are very clear. From 1990 to 2013, tractor and harvester numbers decrease by around 43 % and 65 %, respectively, whereas the average increase in engine size for tractors is 52 % and 246 % for harvesters, in the same time period.





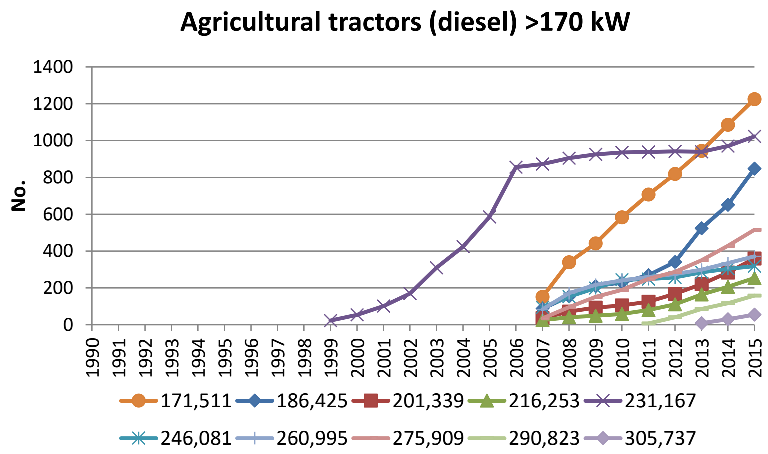
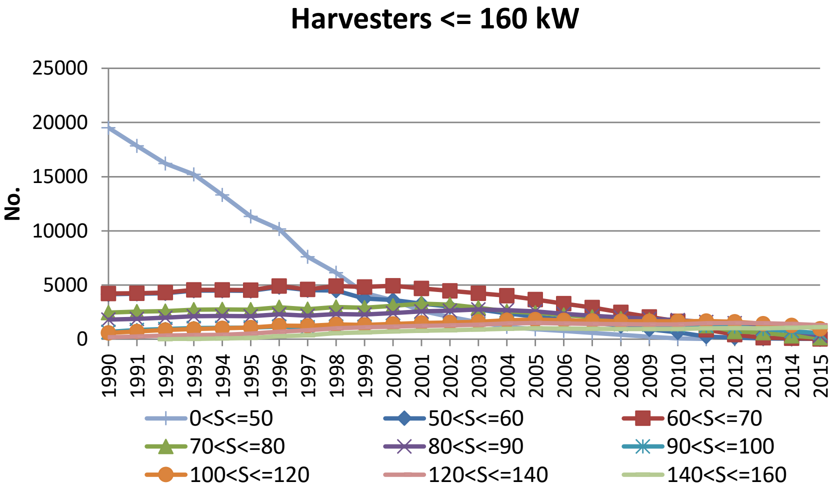


Figure 3.3.32 Total numbers in kW classes for tractors from 1990 to 2015.



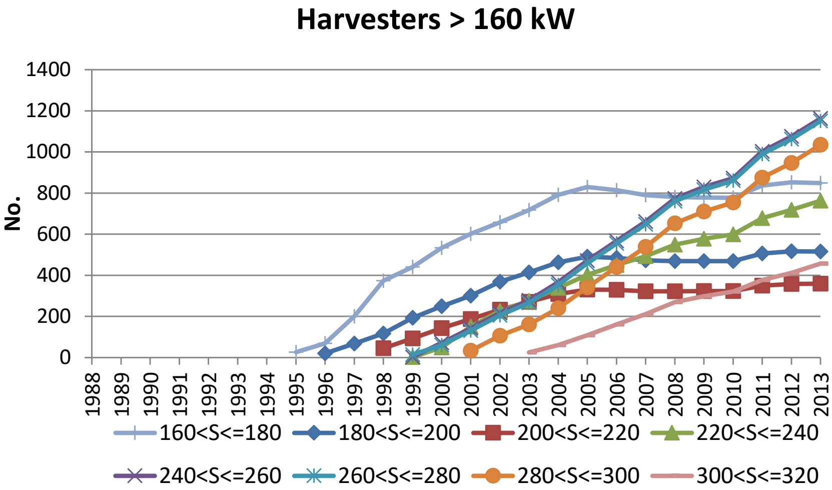
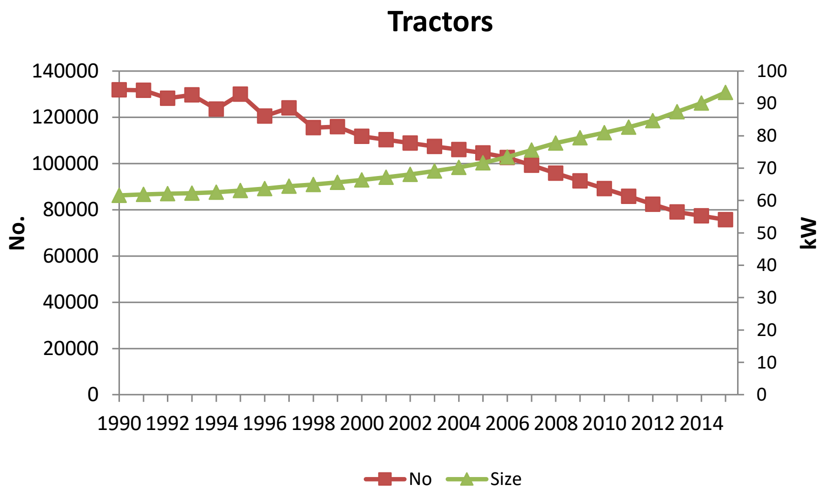


Figure 3.3.33 Total numbers in kW classes for harvesters from 1990 to 2015.



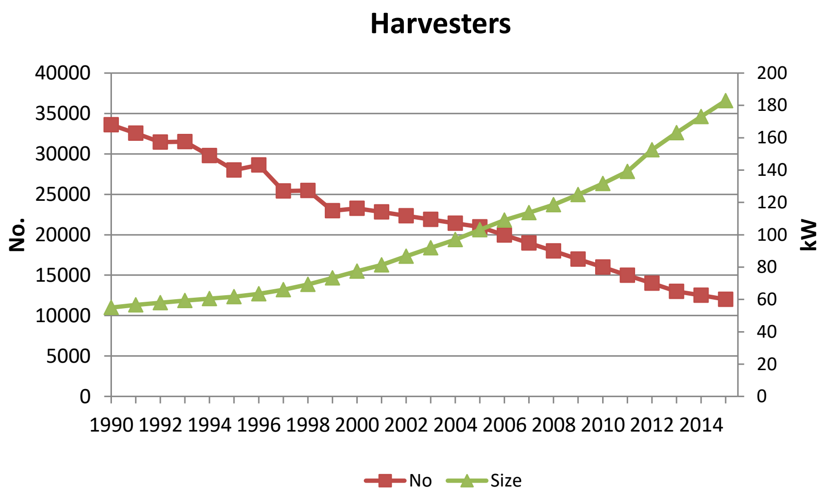


Figure 3.3.34 Total numbers and average engine size for tractors and harvesters (1990 to 2015).

The most important machinery types for industrial use are different types of construction machinery and fork lifts. The Figures 3.3.35 and 3.3.36 show the 1990-2015 stock development for specific types of construction machinery and diesel fork lifts. Due to lack of data, 1996-1999 average sales data for construction machinery is used for 1995 and back. However, it is assumed that telescopic loaders first enter into use in 1986 (Jensen, Scantruck 2016). For most of the machinery types, there is an increase in machinery numbers from 1990 onwards, due to increased construction activities.

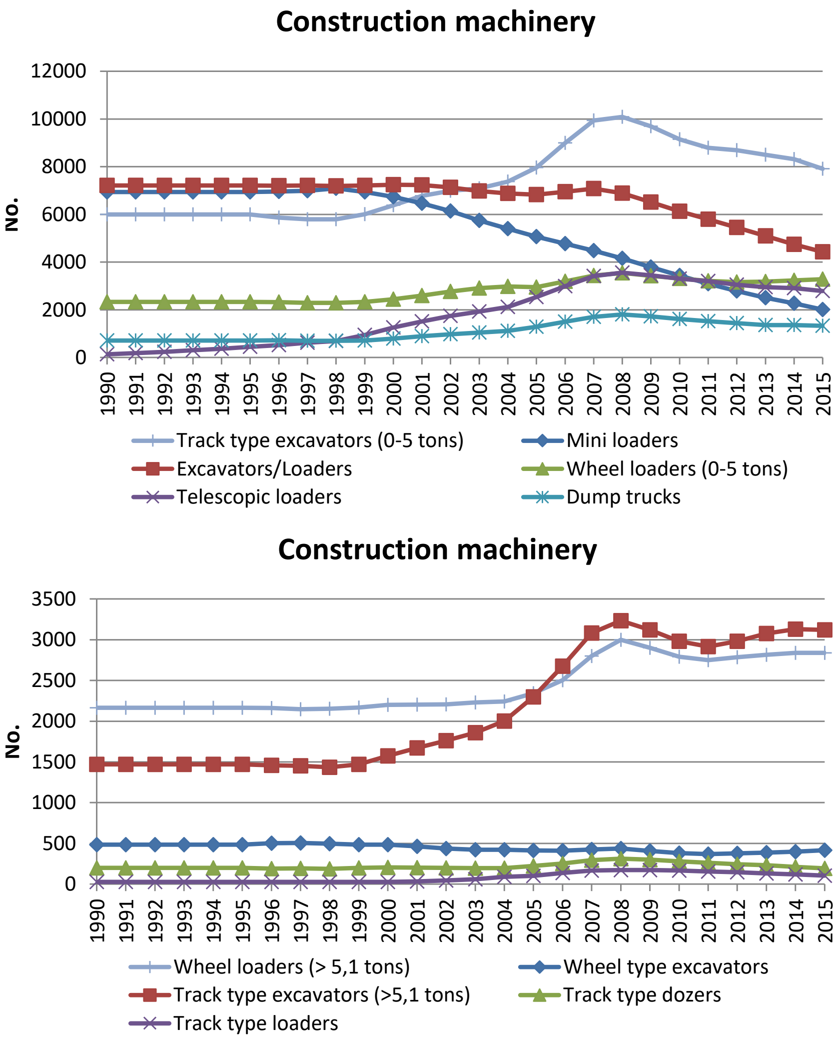


Figure 3.3.35 1990-2015 stock development for specific types of construction machinery.

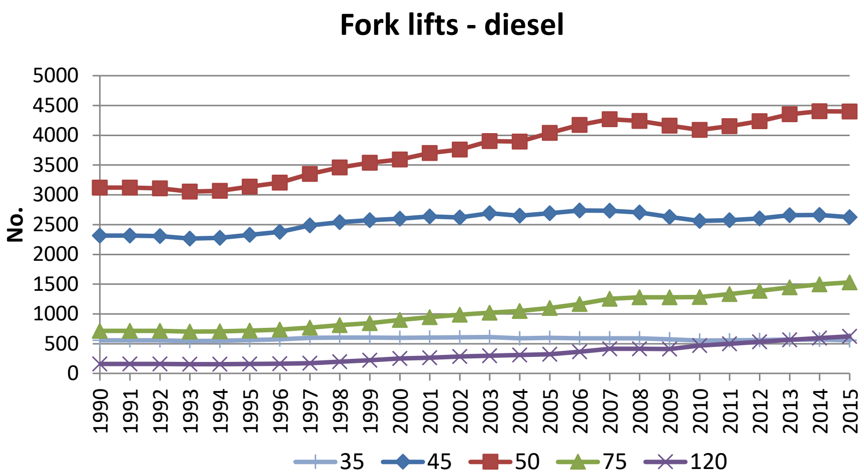
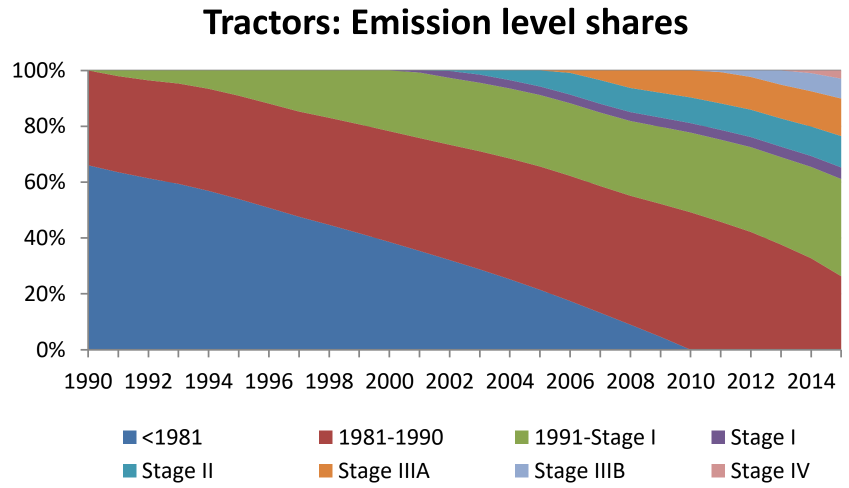
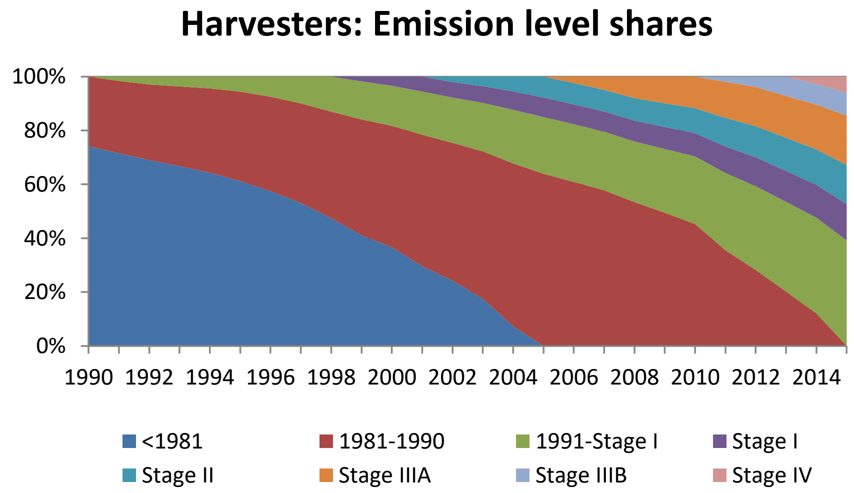


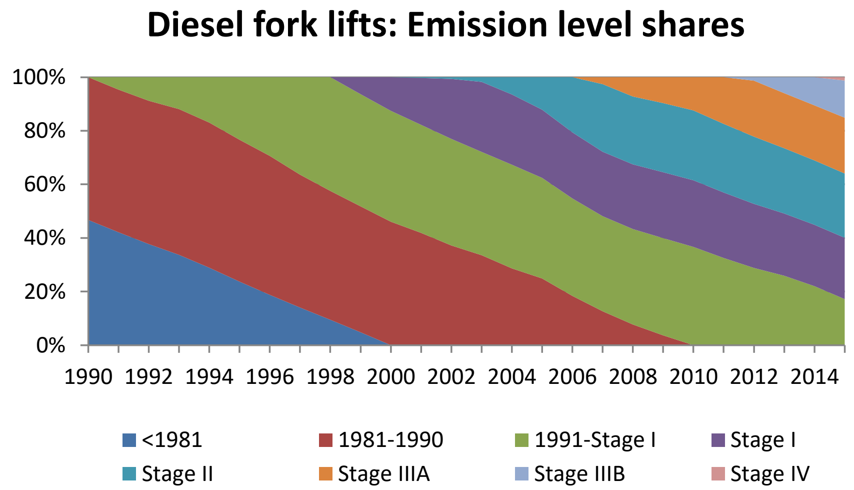
Figure 3.3.36 Total numbers of diesel fork lifts in kW classes from 1990 to 2015.

The emission level shares for tractors, harvesters, construction machinery and diesel fork lifts are shown in Figure 3.3.37, 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 3.3.37. 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 3.3.37.







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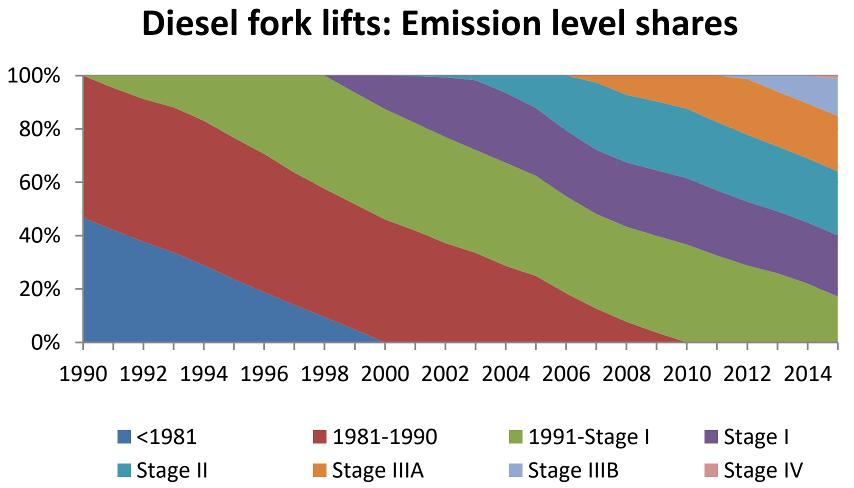

Figure 3.3.37 Emission level shares for tractors, harvesters, construction machinery and diesel fork lifts (1990 to 2015).

The 1990-2015 stock development for the most important household and gardening machinery types is shown in Figure 3.3.38.

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 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.

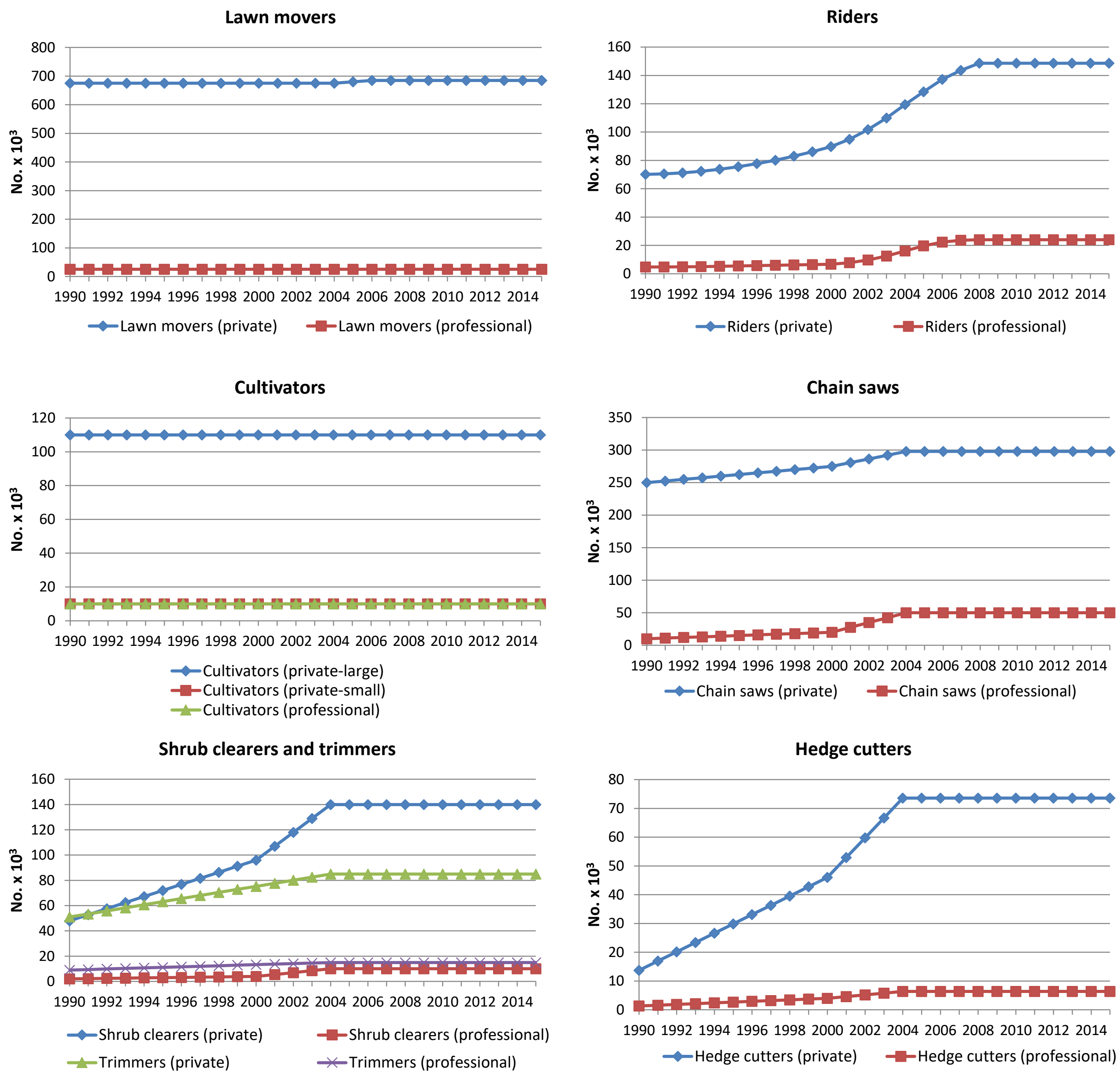

Figure 3.3.38 Stock development 1990-2015 for the most important household and gardening machinery types.

Figure 3.3.39 shows the development in numbers of different recreational craft from 1990-2015. The 2004 stock data for recreational craft are repeated for 2005+, due to lack of data from the Danish Sailing Association.

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).

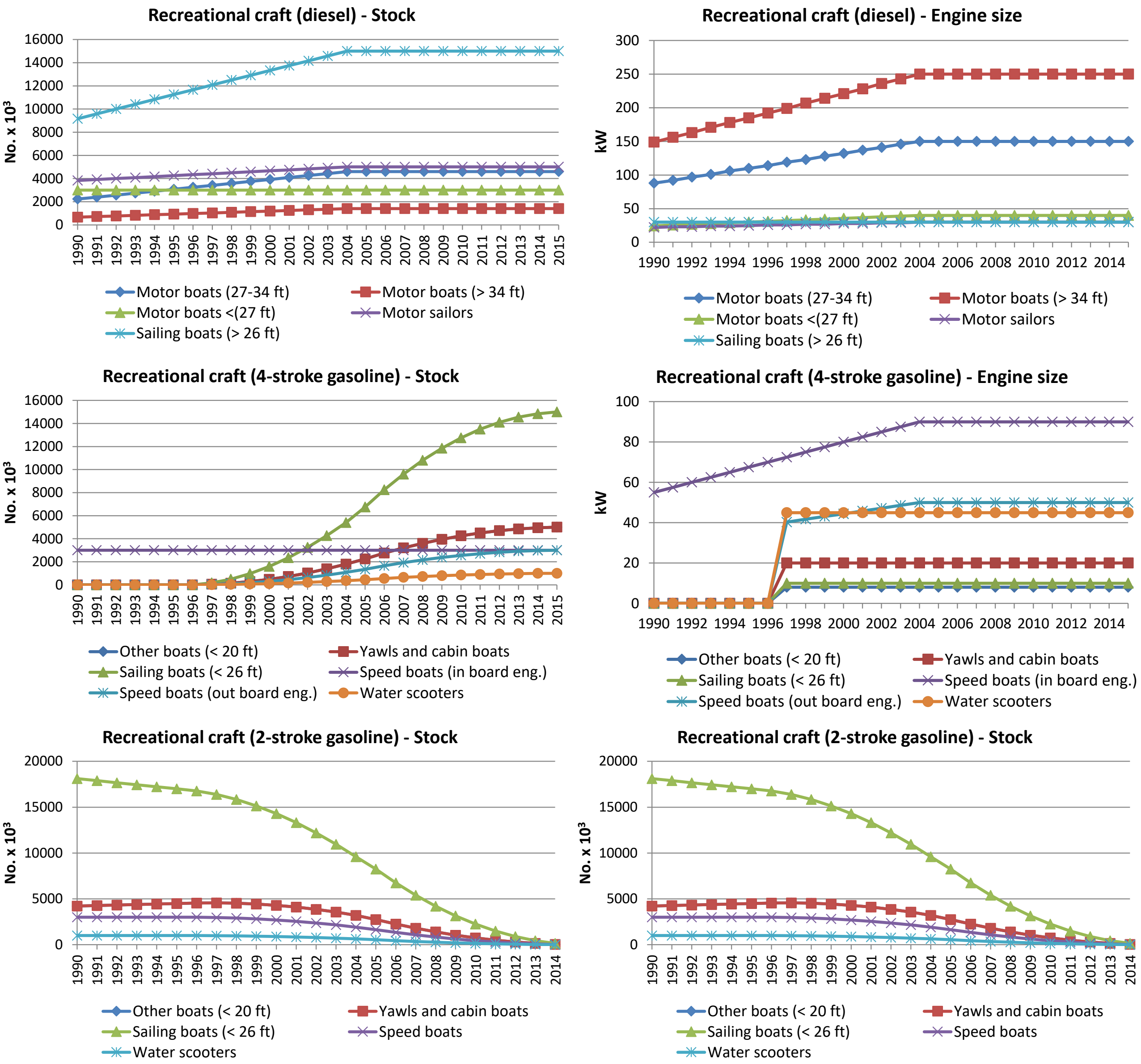

Figure 3.3.39 1990-2015 Stock and engine size development for recreational craft.

National sea transport

The methodology 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 is described by Winther (2008).

Table 3.3.9 lists the most important domestic ferry routes in Denmark in the period 1990-2015. 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 2006-2015, the above mentioned traffic and technical data for specific ferries have been provided by Nielsen (2016) in the case of Mols-Linien (Sjællands Odde-Ebeltoft, Sjællands Odde-Århus, Kalundborg-Århus), by Jørgensen (2016) for Færgen A/S (Køge-Rønne, Tårs-Spodsbjerg), by Jørgensen (2015) and Kruse (2015) for Samsø Rederi (Hou-Sælvig), by Mortensen (2015) for Færgeselskabet Læsø (Frederikshavn-Læsø) and by Møller for Ærøfærgerne (Svendborg-Ærøskøbing). For Esbjerg/Hanstholm/Hirtshals-Torshavn traffic and technical data have been provided by Dávastovu (2010).

Table 3.3.7 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
Hou-Sælvig	1990+
Hundested-Grenaa	1990-1996
Frederikshavn-Læsø	1990+
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+
Svendborg-Ærøskøbing	1990+
Tårs-Spodsbjerg	1990+

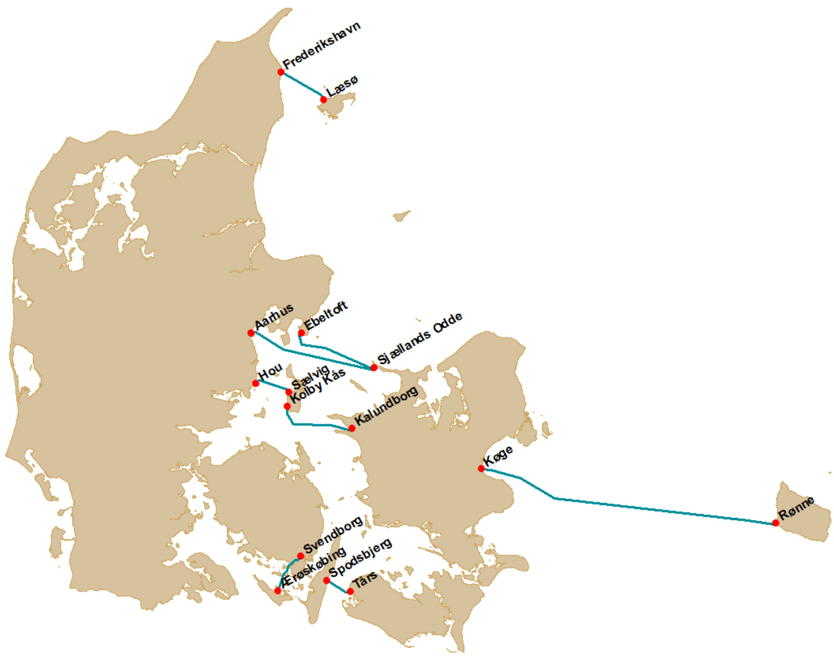

Figure 3.3.40 Domestic regional ferry routes in Denmark (2015).

The number of round trips per ferry route from 1990 to 2015 is provided by Statistics Denmark (2016), see Figure 3.3.41 (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). There is a lack of historical traffic data for 1985-1989, and hence, data for 1990 are used for these years, to support the fuel consumption and emission calculations.

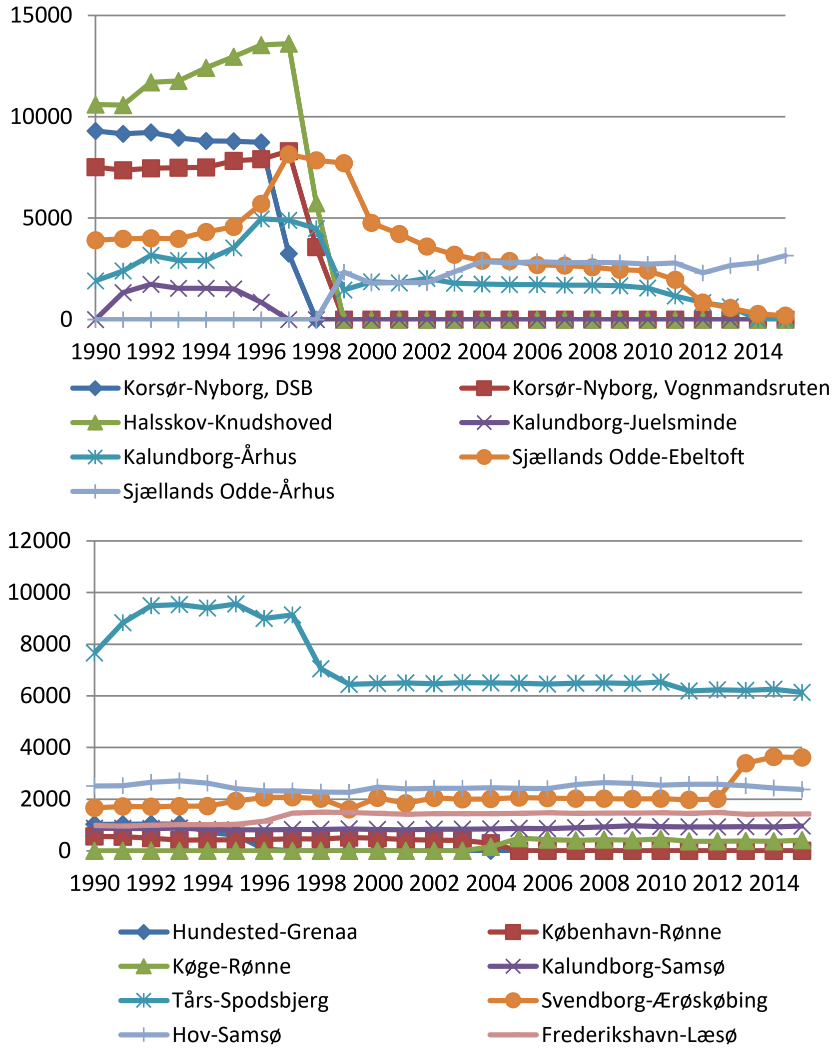

Figure 3.3.41 No. of round trips for the most important ferry routes in Denmark 1990-2015.

It is seen from Table 3.3.7 (and Figure 3.3.41) 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 1990-2015 inventory period, the fuel figure for 1996 has been adjusted according to the developments in local ferry route traffic shown in Annex 2.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, 2016 and Thorarensen, 2016).

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 based fuel consumption estimates for regional ferries, 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 (2016). For international sea transport, the basis is in principle 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/Hirtshals-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 2015 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 Stage I-IV 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 Stage IIIA and IIIB railways machinery (Table 3.3.12). For Stage I-IV tractors the relevant directives are 2000/25 and 2005/13 (Table 3.3.8).

For emission approval of the EU Stage I, II and IIIA engine technologies, emissions (and fuel consumption) measurements are made using the steady state test cycle ISO 8178 C1, referred to as the Non-Road Steady Cycle (NRSC), see e.g. www.dieselnet.com. In addition to the NRSC test, the newer Stage IIIB and IV (and optionally Stage IIIA) engine technologies are tested under more realistic operational conditions using the new Non-Road Transient Cycle (NRTC).

For gasoline, the directive 2002/88 distinguishes between Stage I and II hand-held (SH) and not hand-held (NS) types of machinery (Table 3.3.9). Emissions are tested using one of the specific constant load ISO 8178 test cycles (D2, G1, G2, G3) depending on the type of machinery.

For Stage V machinery, EU directive 2016/1628 relate to non-road machinery other than agricultural tractors and railways machinery (Table 3.3.8) and non-road gasoline machinery (Table 3.3.9). EU directive 167/2013 relate to Stage V agricultural and forestry tractors (Table 3.3.8). The Stage V emission limits are also shown in Annex 3.B.11.

Table 3.3.8 Overview of EU emission directives relevant for diesel fuelled non-road machinery.

Stage	Engine size	CO	VOC	NO_x	VOC+NO_x	PM	Diesel machinery			Tractors	
								Implement. date		EU	Implement.
	[kW]	[g/kWh]					EU Directive	Transient	Constant	Directive	Date
Stage I											
A	130<=P<560	5	1.3	9.2	-	0.54	97/68	1/1 1999	-	2000/25	1/7 2001
B	75<=P<130	5	1.3	9.2	-	0.7		1/1 1999	-		1/7 2001
C	37<=P<75	6.5	1.3	9.2	-	0.85		1/4 1999	-		1/7 2001
Stage II											
E	130<=P<560	3.5	1	6	-	0.2	97/68	1/1 2002	1/1 2007	2000/25	1/7 2002
F	75<=P<130	5	1	6	-	0.3		1/1 2003	1/1 2007		1/7 2003
G	37<=P<75	5	1.3	7	-	0.4		1/1 2004	1/1 2007		1/1 2004
D	18<=P<37	5.5	1.5	8	-	0.8		1/1 2001	1/1 2007		1/1 2002
Stage IIIA											
H	130<=P<560	3.5	-	-	4	0.2	2004/26	1/1 2006	1/1 2011	2005/13	1/1 2006
I	75<=P<130	5	-	-	4	0.3		1/1 2007	1/1 2011		1/1 2007
J	37<=P<75	5	-	-	4.7	0.4		1/1 2008	1/1 2012		1/1 2008
K	19<=P<37	5.5	-	-	7.5	0.6		1/1 2007	1/1 2011		1/1 2007
Stage IIIB											
L	130<=P<560	3.5	0.19	2	-	0.025	2004/26	1/1 2011	-	2005/13	1/1 2011
M	75<=P<130	5	0.19	3.3	-	0.025		1/1 2012	-		1/1 2012
N	56<=P<75	5	0.19	3.3	-	0.025		1/1 2012	-		1/1 2012
P	37<=P<56	5	-	-	4.7	0.025		1/1 2013	-		1/1 2013
Stage IV											
Q	130<=P<560	3.5	0.19	0.4	-	0.025	2004/26	1/1 2014	1/1 2014	2005/13	1/1 2014
R	56<=P<130	5	0.19	0.4	-	0.025		1/10 2014	1/10 2014		1/10 2014
Stage V[A]											
NRE-v/c-7	P>560	3.5	0.19	3.5		0.045	2016/1628		2019	167/2013[B]	2019
NRE-v/c-6	130≤P≤560	3.5	0.19	0.4		0.015			2019		2019
NRE-v/c-5	56≤P<130	5.0	0.19	0.4		0.015			2020		2020
NRE-v/c-4	37≤P<56	5.0			4.7	0.015			2019		2019
NRE-v/c-3	19≤P<37	5.0			4.7	0.015			2019		2019
NRE-v/c-2	8≤P<19	6.6			7.5	0.4			2019		2019
NRE-v/c-1	P<8	8.0			7.5	0.4			2019		2019
Generators	P>560	0.67	0.19	3.5		0.035			2019		2019

A = For selected machinery types, Stage V includes emission limit values for particle number.

B = Article 63 in 2016/1628 revise Article 19 in 167/2013 to include Stage V limits as described in 2016/1628.

Table 3.3.9 Overview of the EU Emission Directives relevant for gasoline fueled 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]	Implement. date
EU Directive 2002/88	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
EU Directive 2016/1628	Stage V						
Hand held (<19 kW)	NRSh-v-1a	S<50	805	-	-	50	2019
	NRSh-v-1b	50≤S	805	-	-	72	2019
Not hand held (P<19 kW)	NRS-vr/vi-1a	80≤S<225	610	-	-	10	2019
	NRS-vr/vi-1b	S≥225	610	-	-	8	2019
Not hand held (19=<P<30 kW)	NRS-v-2a	S≤1000	610	-	-	8	2019
	NRS-v-2b	S>1000	4.40*	-	-	2.70*	2019
Not hand held (30=<P<56 kW)	NRS-v-3	any	4.40*	-	-	2.70*	2019

* Or any combination of values satisfying the equation $(HC+NOx) \times CO^{0.784} \leq 8.57$ and the conditions CO ≤ 20.6 g/kWh and (HC+NOx) ≤ 2.7 g/kWh

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 $HC+NO_x$ limits are provided for gasoline engines depending on the rated engine power and the engine type (stern-drive vs. outboard) while CO, $HC+NO_x$, 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	Rated Engine Power, P_N	Impl. Date	CO	HC + NO_x	PM
l/cyl.	kW		g/kWh	g/kWh	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		CO	HC + NO_x	PM
	kW		g/kWh	g/kWh	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 Directives relevant for railway locomotives and motorcars.

				CO	HC	NO_x	HC+NO_x	PM	
	EU directive	Engine size [kW]		g/kWh					Imp. date
Locomotives	2004/26	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
	2004/26	Stage IIIB	RB	3.5	-	-	4	0.025	1/1 2012
	2016/1628	Stage V							
		0<P	RLL-v/c-1	3.5	-	-	4	0.025	2021
Motor cars	2004/26	Stage IIIA							
		130<P	RC A	3.5	-	-	4	0.2	1/1 2006
	2004/26	Stage IIIB							
		130<P	RC B	3.5	0.19	2	-	0.025	1/1 2012
	2016/1628	Stage V							
		0<P	RLR-v/c-1	3.5	0.19	2	-	0.015	2021

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

- 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.
- 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.
- 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.
- 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.
- 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.easa.europa.eu" hosted by the European Aviation Safety Agency (EASA).

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 Per 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[11]: Diesel engines (> 130 kW) installed on a ship constructed on or after 1 January 2016.

The three tier NOx 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 (Sulphur Emission Control Area) areas and outside SECA's.

[11] 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 (Mølgård, 2016) 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 used by Mols Linjen. For the LNG fueled ferry in service on the Hou-Sælvig route CH_4 and NMVOC emission factors are taken from Bengtsson et al. (2011).

For ship diesel and residual oil fuelled 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. For auxiliary power units (APU), ICAO (2011) is the data source for APU load specific NO_x, CO and VOC emission factors for different APU aircraft groups to be linked with the different representative aircraft types. VOC/CH_4 splits for aviation are taken from EMEP/EEA (2013).

For all sectors, emission factors for the years 1990 and 2015 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 2015 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[12]		
			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	0.66	74.00	3.34
080100	Military	Gasoline	6.37	73.00	1.03
080300	Recreational craft	Diesel	3.22	74.00	2.97
080300	Recreational craft	Gasoline	12.96	73.00	1.61
080402	National sea traffic	Diesel	1.83	74.00	1.87
080402	National sea traffic	LNG	94.47	56.80	0.00
080402	National sea traffic	Residual oil	1.98	78.00	1.96
080403	Fishing	Diesel	1.80	74.00	1.87
080404	International sea traffic	Diesel	1.82	74.00	1.87
080404	International sea traffic	Residual oil	2.00	78.00	1.96
080501	Air traffic, Dom. < 3000 ft.	AvGas	21.90	73.00	2.00
080501	Air traffic, Dom. < 3000 ft.	Jet fuel	2.06	72.00	11.89
080502	Air traffic, Int. < 3000 ft.	AvGas	21.90	73.00	2.00
080502	Air traffic, Int. < 3000 ft.	Jet fuel	2.48	72.00	5.30
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	1.04	74.00	3.49
080600	Agriculture	Gasoline	147.69	73.00	1.68
080700	Forestry	Diesel	0.58	74.00	3.62
080700	Forestry	Gasoline	240.84	73.00	0.46
080800	Industry	Diesel	1.46	74.00	3.27
080800	Industry	Gasoline	59.90	73.00	1.49
080800	Industry	LPG	7.69	63.10	3.50
080900	Household and gardening	Gasoline	42.49	73.00	1.27
081100	Commercial and institutional	Gasoline	73.38	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	2.27	72.00	6.18
080502	Air traffic, Int. < 3000 ft.	AvGas	21.90	73.00	2.00
080502	Air traffic, Int. < 3000 ft.	Jet fuel	1.73	72.00	3.17
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

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).

[12] 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/Mols Linjen/Bengtsson et al. (2011)/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 takeoff (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 are 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:

$$FC^{a}_{LTO} = \sum_{m=1}^{5} t_m \cdot ff_{a,m} \qquad (15)$$

Where FC = fuel consumption (kg), m = LTO mode (approach/landing, taxi in, taxi out, 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:

$$E^{a}_{LTO} = \sum_{m=1}^{5} FC_{a,m} \cdot EI_{a,m} \qquad (16)$$

Where EI = emission index (g per kg fuel). 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). For taxi in and taxi out, specific times-in-modes data are provided by Eurocontrol for the airports present in the Danish inventory. The taxi times-in-modes data are shown in Annex 2.B.10 for the years 2001-2015.

The fuel consumption and emissions for aircraft auxiliary power units (APU's) are calculated with the same method used to estimate LTO fuel consumption and emissions for aircraft main engines (formulas 15 and 16). ICAO (2011) is the data source for APU load specific fuel flows (kg per s) and emission rates (g per kg fuel) for different APU aircraft groups (characterised by seating capacity and age). APU times-in-modes for arrival, start-up, boarding and main engine start are also provided by ICAO (2011), whereas push back time intervals are taken from an emission study made in Copenhagen Airport (Ellermann et al., 2011; Winther et al., 2015).

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 (aggregated) for 2015. APU data for fuel flows, emission rates and times-in-modes are also shown in Annex 3.B.10, together with the correspondence table for APU group-representative aircraft type.

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:

$$E(y)=E_{x_i}+\frac{(y-x_i)}{x_{i+1}-x_i}\cdot(E_{x_{i+1}}-E_{x_i}) \qquad y<x_{max},\ i = 0,1,2....max-1 \qquad (17)$$

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[13]. 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 (fuel balance) in the model is 0.93 in 2015, 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 and Construction Agency. 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 2001 derived from the detailed city-pair emission inventory.

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

[13] Excluding flights for Greenland and the Faroe Islands.

emission factors for 2001 are derived from the detailed city-pair emission inventory.

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:

$$E_{Basis}(X)_{i,j,k} = N_{i,j,k} \cdot HRS_{i,j,k} \cdot P \cdot LF_i \cdot EF_{y,z} \tag{19}$$

where E_{Basis} = fuel consumption/emissions in the basic situation, N = number of engines, HRS = annual working hours, P = average rated engine size 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:

$$DF_{i,j,k}(X) = \frac{K_{i,j,k}}{LT_i} \cdot DF_{y,z} \tag{20}$$

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:

$$DF_{i,j,k}(X) = \sqrt{\frac{K_{i,j,k}}{LT_i}} \cdot DF_{y,z} \tag{21}$$

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:

$$TF_{i,j,k}(X) = TF_z \tag{22}$$

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:

$$E(X)_{i,j,k} = E_{Basis}(X)_{i,j,k} \cdot TF(X)_{i,j,k} \cdot (1 + DF(X)_{i,j,k}) \tag{23}$$

The evaporative hydrocarbon emissions from fuelling are calculated as:

$$E_{Evap,\,fuelingi} = FC_i \cdot EF_{Evap,\,fueling} \tag{24}$$

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:

$$E_{Evap,\mathrm{tank},i} = N_i \cdot EF_{Evap,\mathrm{tank},i} \tag{25}$$

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:

$$E(X) = \sum_i N_i \cdot T_i \cdot S_{i,j} \cdot P_i \cdot LF_j \cdot EF_{k,l,y} \tag{26}$$

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:

$$E(X) = \sum_i EC_{i,k} EF_{k,l,y} \tag{27}$$

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:

$$EF_{k,l,y} = \frac{\sum_{year=X}^{year=X-LT} EF_{k,l}}{LT_{k,l}} \tag{28}$$

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 2015 and as time series 1990-2015 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. Consequently, 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.

From 2015, LNG is being used by one specific ferry route in Denmark. No LNG is reported in DEA statistics for national sea transport, and hence this ferry fuel consumption is taken from “non-industrial combustion plants” (020200) in order to obtain a fuel balance.

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.

Road transport

For natural gas and LPG, the difference between fuel reported in DEA statistics and bottom-up estimates for road transport is outbalanced with fuel totals from “non-industrial combustion plants” (020200) in order to obtain a fuel balance.

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 2015 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 2015		4.9	33.5	119.5
Trend uncertainty		4.9	7.0	50.4

Table 3.3.19 Tier 2 Uncertainty factors for activity data and emission factors in 2015.

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 2015.

		1990			2015			1990-2015		
		Median	Uncertainty (%)		Median	Uncertainty (%)		Median	Uncertainty (%)	
		Emission	Lower (-)	Upper (+)	Emission	Lower (-)	Upper (+)	Emission	Lower (-)	Upper (+)
CO_2	Kton-nes	13447	5	5	15005	5	5	12	10	10
CH_4	Tonnes	2933	27	37	839	26	41	-71	30	42
N_2O	Tonnes	583	43	177	704	40	149	21	107	134
CO_2 eq.	Kton-nes	13710	5	5	15256	5	5	11	10	11

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 2013 inventory (Winther, 2015).

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, Færgeselskabet Læsø, Samsø Rederi, Ærøfærgerne A/S, 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.
- ICAO: Civil aviation auxiliary power units.
- Non-road machinery: References given in NERI reports.
- National sea transport and fisheries: TEMA2010 (NO_X, VOC, CO and TSP), MAN Diesel & Turbo (sfc, NO_X), specific data from Mols Linjen (NO_x, CO, NMVOC, TSP) and LNG emission factors (NO_x, CO, NMVOC, TSP) from Bengtsson et al. (2011) and.

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[2]	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 and Construction Agency	Michael Weber	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	Peter Ottosen	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[2]	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	Jesper Mølgård	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 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 and Construction Agency (Civil Aviation Agency of Denmark)

The Danish Transport and Construction Agency 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 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. In 2016, a comprehensive data update were made for the most important building and construction machinery concerning engine load factors, equipment size - engine size relations, equipment scrapping curves and annual working hours as a function of engine age.

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 and key experts from the most important engine manufacturers. IFAG (The Association of Producers and Distributors of Fork Lifts in Denmark) provides for 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 Environment and Food of Denmark. 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 2015 inventory, new 2015 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, Færgeselskabet Læsø, Samsø Rederi, Ærøfærgerne A/S, 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 5 provides factors for fuel consumption and for all exhaust emission components, which are included in the national inventory. For several reasons, COPERT 5 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 5 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 provided by Eurocontrol (the European aviation safety organization) specifically for detailed national inventory use and was evaluated by the transport expert panel in the TFEIP (Task Force for Emission Inventories and Projections) under UNECE CLRTAP.

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. (2015) and in the present report. The fuel consumption and emission data is regarded as one of the most comprehensive data collections 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 for engine manufacturing years going back to 1949, as well as NO_X, VOC and CO emission factors for engines built after 2010, was provided by the engine manufacturer MAN Diesel & Turbo. PM_{10} and $PM_{2.5}$ fractions of total TSP were also provided by the latter source.

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 and Construction Agency 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 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 and Construction Agency (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 and Construction Agency 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, 2015) 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.

See 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 per 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, 2001b, 2008, 2015) 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 (Data2015 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 regarding both 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 2015.xls" has been set up to check that the fuel consumption and emission totals from CollectER imported in Data2015 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 2016.

Civil aviation

Small changes in the list of aircraft types – representative aircraft types has been made in the model used for calculating civil aviation emissions.

The following largest percentage differences (in brackets) for civil aviation are noted for: CO_2 (-0.4 %), CH_4 (3.4 %) and N_2O (14.7 %).

Road transport

The fuel consumption and emission factors for road transport have been updated with data from the updated COPERT model – COPERT V. In addition, CNG vehicles and gasoline hybrid cars and vans have been explicitly included in the model.

The percentage emission change interval and year of largest percentage differences (low %; high %, year) for the different emission components are: CO_2 (0 %), CH_4 (-1.1 %; 0.6 %, 2013) and N_2O (-0.5 %; 1.5 %, 2012).

Railways

No changes have been made.

Navigation

A few changes have been made in relation to engine load factors for two specific ferries in 2013 and 2014.

The following largest percentage differences (in brackets) for domestic navigation are noted for: CO_2 (-0.2 %), CH_4 (-0.2 % and N_2O (-0.2 %).

Industry

A complete revision of the non-road model containing building and construction machinery has been made. From engine manufacturers new input data for engine load factors have been provided based on electronic engine power registrations. Further, equipment size - engine size relations, equipment scrapping curves and annual working hours as a function of engine age has been included in the model. From Stage IIIA engine emission levels onwards, specific fuel consumption factors have been updated also based on engine manufacturers advice.

The following largest percentage differences (in brackets) for mobile industry are noted for: CO_2 (-28 %), CH_4 (-27 % and N_2O (-14 %).

Commercial and institutional

No changes have been made.

Residential

No changes have been made.

Agriculture/forestry

Changes have been made to the non-road model in relation to diesel fuelled agricultural machinery. From Stage IIIA engine emission levels onwards, specific fuel consumption factors have been updated also based on engine manufacturers advice.

The following largest percentage differences (in brackets) for mobile industry are noted for: CO_2 (-9 %), CH_4 (-0.5 % and N_2O (-2.1 %).

Fishing

Fuel transferal made between fisheries and national sea transport has resulted in minor changes in fuel consumption for fisheries, due to changes in national sea transport as described above.

The following largest percentage differences (in brackets) for fisheries are noted for: CO_2 (0.2 %), CH_4 (0.2 % and N_2O (0.2 %).

Other (Military and recreational craft)

Updated emission factors derived from the road transport model have caused a few emission changes from 1985-2014. The following largest percentage differences (in brackets) for military are noted for: CO_2 (0 %), CH_4 (-0.5 %) and N_2O (0.5 %).

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, CRF sector 1A 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, 2016). 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.

The Climate Convention reporting tables include a comparison of the national approach and the reference approach estimates.

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 – 10.5 PJ in 2015.

The CO_2 emission from oxidation of lube oil during use was 31.7 Gg in 2015 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 60.6 Gg in 2015. 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 0.17 Gg in 2015. Methodology and emission data for non-energy use of bitumen are shown in NIR Chapter 4.5.6.

The national approach and the reference approach have been compared and the differences between the two approaches are shown in Table 3.4.1 below.

Table 3.4.1 Difference between national approach and reference approach.

Year	Difference Energy consumption [%]	Difference CO_2 emission [%]
1990	0.28	-0.31
1991	-0.55	-0.95
1992	-0.02	-0.62
1993	-0.40	-0.99
1994	-0.31	-0.88
1995	-0.56	-0.92
1996	-0.49	-0.74
1997	-0.03	-0.11
1998	1.49	1.33
1999	-0.58	-0.87
2000	0.26	0.07
2001	0.75	0.65
2002	0.05	-0.12
2003	0.10	-0.05
2004	-0.01	-0.15
2005	-0.89	-0.90
2006	-0.64	-0.82
2007	-0.91	-1.00
2008	-0.17	-0.32
2009	-1.63	-1.69
2010	0.12	-0.16
2011	-0.96	-1.00
2012	-1.37	-1.62
2013	-0.72	-1.00
2014	-1.33	-1.46
2015	-1.94	-2.16

The comparison of the national approach and the reference approach is illustrated in Figure 3.4.1. In 2015, the fuel consumption rates in the two approaches differ by 1.94 % and the CO_2 emission differs by 2.16 %. In the years 1990-2014 both the fuel consumption and the CO_2 emission differ by less than 1.7 %.

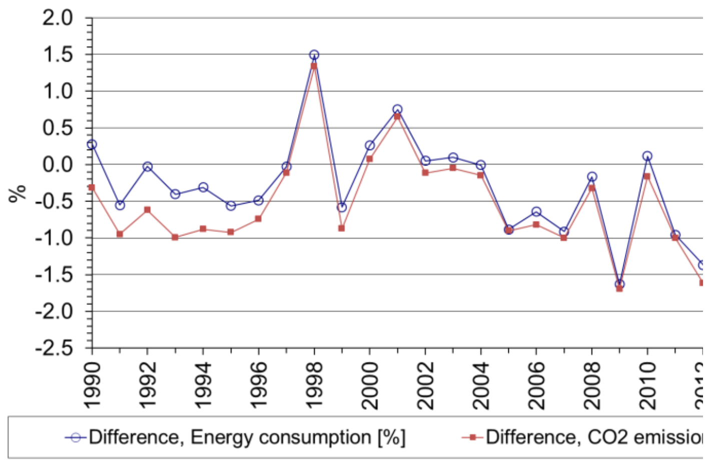

Figure 3.4.1 Comparison of the reference approach and the national approach.

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, 2012 and 2015 are due to high statistical differences in the Danish energy statistics in these years.

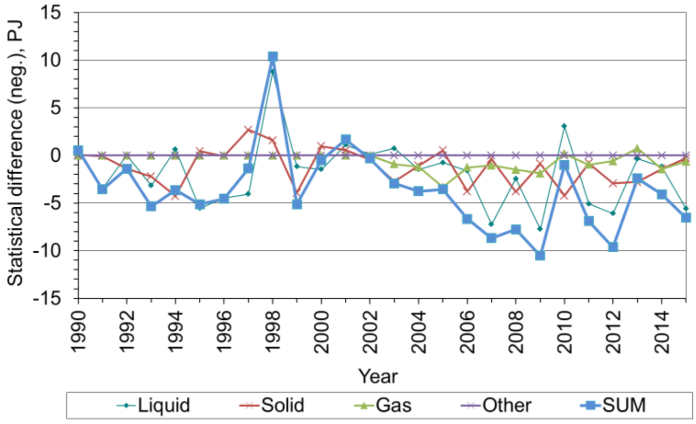

Figure 3.4.2 Statistical difference in the Danish energy statistics (DEA, 2016).

The large difference in 2015 is related to fuel consumption, mainly for liquid fuels. The difference for liquid fuels is 2.65 % or 6.4 PJ. The statistical difference for liquid fuels in the Danish energy statistics is 5.6 PJ for 2015. This difference mainly relate to crude oil (3.4 PJ) and to gas/diesel oil (1.9 PJ). In addition to the statistical difference of the energy statistics, the Danish emission inventory includes more residual oil than the energy statistics due to the fact that plant and ferry specific fuel consumption data add up to a total that exceeds the total consumption in the energy statistics.

The differences mentioned above will be part of the ongoing dialogue with the Danish Energy Agency and data will be improved if possible. The Danish energy statistics is always updated for the latest 3 years and thus the large statistical difference in 2015 energy data is likely to decrease in the annual update of the energy statistics published in 2017.

Finally, for gaseous fuels the Danish emission inventory includes higher fuel consumption for off shore gas turbines than included in the energy statistics. The fuel consumption applied in the inventory is based on EU ETS data that are not in agreement with the energy statistics (0.7 PJ higher than the energy statistics in 2015). This is also discussed in NIR Chapter 3.2.5 and will be part of the ongoing dialogue with the Danish Energy Agency.

References for Chapter 3.4

Danish Energy Agency (DEA), 2016: The Danish energy statistics, Available at: https://ens.dk/service/statistik-data-noegletal-og-kort/maanedlig-og-aarlig-energistatistik (2017-02-07)

IPCC, 2006: Revised 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Available at: http://www.ipcc-nggip.iges.or.jp/public/2006gl/index.html (2015-06-23).

3.5 Fugitive emissions (CRF sector 1B)

3.5.1 Overview of sector

Fugitive emissions from fuels include emissions from production, storage, refining, transport, venting and flaring of oil and natural gas. Denmark has no production of solid fuels, and accordingly greenhouse gas emissions from solid fuels are not occurring. The fugitive sector consists of the following CRF categories:

- 1B2a Oil
- 1B2b Natural gas
- 1B2c Venting and flaring

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

Table 3.5.1 National and fugitive emissions of CO_2, CH_4 N_2O and GHG in 2015, and the fugitive emissions share of national total emissions.

	National emission	Fugitive emission	Fugitive/national emission
	Gg CO_2 eq.	Gg CO_2 eq.	%
CO_2	35 147	247	0.7
CH_4	6849	101	1.5
N_2O	5294	43	0.8
GHG	47 289	391	0.8

Table 3.5.2 list the results from the key category analysis for approach 1 and approach 2 for fugitive emission sources.

Table 3.5.2 Key categories in the fugitive emission sector.

CRF table	Pollutant	Key category identification	
		Approach 1	Approach 2
1.B.2.a.1 Exploration, oil	CO_2	-	-
1.B.2.a.2 Production, oil	CO_2	-	-
1.B.2.a.3 Transport, oil	CO_2	-	-
1.B.2.b.1 Exploration, gas	CO_2	-	-
1.B.2.b.2 Production, gas	CO_2	-	-
1.B.2.b.4 Transmission and storage, gas	CO_2	-	-
1.B.2.b.5 Distribution, gas	CO_2	-	-
1.B.2.c.1.ii Venting, gas	CO_2	-	-
1.B.2.c.2.i Flaring, oil	CO_2	-	-
1.B.2.c.2.ii Flaring, gas	CO_2	Level (1990 & 2015)	-
1.B.2.a.1 Exploration, oil	CH_4	-	-
1.B.2.a.2 Production, oil	CH_4	-	-
1.B.2.a.3 Transport, oil	CH_4	-	-
1.B.2.a.4 Refining/storage	CH_4	-	-
1.B.2.b.1 Exploration, gas	CH_4	-	-
1.B.2.b.2 Production, gas	CH_4	-	-
1.B.2.b.4 Transmission and storage, gas	CH_4	-	-
1.B.2.b.5 Distribution, gas	CH_4	-	-
1.B.2.c.1.ii Venting, gas	CH_4	-	-
1.B.2.c.2.i Flaring, oil	CH_4	-	-
1.B.2.c.2.ii Flaring, gas	CH_4	-	-
1.B.2.a.1 Exploration, oil	N_2O	-	-
1.B.2.b.1 Exploration, gas	N_2O	-	-
1.B.2.c.2.i Flaring, oil	N_2O	-	Level (1990 & 2015) Trend (1990-2015)

Calculations of fugitive emissions are to the highest degree possible based on Tier 2 and Tier 3 methodologies. The methodological Tiers 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 2 Tier 1	PS CS D
1 B 2 a ii	Production of oil, Land-based activities	CO_2 CH_4	Tier 1 Tier 1, Tier 2	D CS, OTH (EMEP/EEA 2013)
1 B 2 a ii	Production of oil, Offshore activities	CO_2 CH_4	Tier 1 Tier 1, Tier 2	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 2 Tier 1	PS CS D
1 B 2 b ii	Production of gas, Offshore activities	CO_2 CH_4	Tier 1 Tier 1	D D
1 B 2 b iii	Transmissions and storage	CO_2 CH_4	Tier 2 Tier 2	CS CS
1 B 2 b iv	Distribution	CO_2 CH_4	Tier 2 Tier 2	CS CS
1 B 2 c 1 ii	Venting in gas storage	CO_2 CH_4	Tier 2, Tier 3 Tier 1	CS(1990-1994), PS(1995 onwards) D
1 B 2 c 2 i	Flaring in oil refinery	CO_2 CH_4 N_2O	Tier 2, Tier 3 Tier 1 Tier 1	CS(1990-2006), PS(2007 onwards) D D
1 B 2 c 2 ii	Flaring in gas storage, transmission and distribution	CO_2 CH_4 N_2O	Tier 2, Tier 3 Tier 1 Tier 1	CS(1990-2006), PS(2007 onwards) D D
1 B 2 c 2 iii	Flaring in oil and gas extraction	CO_2 CH_4 N_2O	Tier 2, Tier 3 Tier 2 Tier 1	CS(1990-2007), PS(2008 onwards) CS D

Note: PS: plant specific. CS: country specific, D: default (IPCC, 2006), OTH: other.

3.5.2 Source category description

According to the IPCC sector definitions the category *fugitive emissions from fuels* is a sub-category under the main-category Energy (Sector 1). The category *fugitive emissions from fuels* (Sector 1B) is segmented into sub-categories covering emissions from solid fuels *(coal mining and handling (1B1a), solid fuel transformation (1B1b) and other (1B1c))*, oil *(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. Accordingly greenhouse gas emissions from solid fuels are not occurring in Denmark.
- 1B2a: Fugitive emissions from oil include emissions from exploration, production, 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, production, transmission of natural gas and distribution of natural gas and town gas.

- 1B2c: Venting and flaring include activities onshore and offshore. Flaring occur both offshore in upstream oil and gas production, and onshore in gas treatment and storage facilities, in refineries and in natural gas transmission and distribution. Venting occurs in gas storage facilities. Venting of gas is assumed to be negligible in oil and gas production and in refineries as controlled venting enters the gas flare system.

Table 3.5.4 summarizes the Danish fugitive greenhouse gas emissions in 2015. Information on other pollutants are included in the Informative Inventory Reports (IIRs) reported annually to UNECE CLRTAP (Nielsen et. al., 2017).

Table 3.5.4 Summary of the Danish fugitive emissions 2015. P refers to point source and A to area source.

IPCC code	Source	Type*	Pollutant	Emission	Unit
1.B.2.a.1	Exploration of oil	A	CH_4	<0.01	Mg
1.B.2.a.1	Exploration of oil	A	CO_2	0.75	Gg
1.B.2.a.1	Exploration of oil	A	N_2O	<0.01	Mg
1.B.2.a.2	Offshore activities	A	CH_4	5.35	Mg
1.B.2.a.2	Offshore activities	A	CO_2	<0.01	Gg
1.B.2.a.3	Land-based activities	A	CH_4	484.21	Mg
1.B.2.a.3	Land-based activities	A	CO_2	<0.01	Gg
1.B.2.a.3	Offshore activities	A	N_2O	66.77	Mg
1.B.2.a.4	Petroleum products processing	P	CH_4	617.30	Mg
1.B.2.b.1	Exploration of gas	A	CH_4	0.31	Mg
1.B.2.b.1	Exploration of gas	A	CO_2	0.08	Gg
1.B.2.b.1	Exploration of gas	A	N_2O	0.05	Mg
1.B.2.b.2	Offshore activities	A	CH_4	1718.36	Mg
1.B.2.b.2	Offshore activities	A	CO_2	0.06	Gg
1.B.2.b.4	Transmission and storage of gas	A	CH_4	31.25	Mg
1.B.2.b.4	Transmission and storage of gas	A	CO_2	<0.01	Gg
1.B.2.b.5	Distribution of gas	A	CH_4	154.70	Mg
1.B.2.b.5	Distribution of gas	A	CO_2	<0.01	Gg
1.B.2.c.1.ii	Venting in gas storage	P	CH_4	31.24	Mg
1.B.2.c.1.ii	Venting in gas storage	P	CO_2	<0.01	Gg
1.B.2.c.2.i	Flaring in oil refinery	P	CH_4	4.54	Mg
1.B.2.c.2.i	Flaring in oil refinery	P	CO_2	12.85	Gg
1.B.2.c.2.i	Flaring in oil refinery	P	N_2O	0.12	Mg
1.B.2.c.2.ii	Flaring in oil and gas extraction	A	CH_4	942.50	Mg
1.B.2.c.2.ii	Flaring in oil and gas extraction	A	CO_2	232.58	Gg
1.B.2.c.2.ii	Flaring in oil and gas extraction	A	N_2O	142.62	Mg
1.B.2.c.2.ii	Flaring in gas storage	P	CH_4	0.19	Mg
1.B.2.c.2.ii	Flaring in gas storage	P	CO_2	0.68	Gg
1.B.2.c.2.ii	Flaring in gas storage	P	N_2O	<0.01	Mg
1.B.2.c.2.ii	Flaring in gas transmission and distribution	A	CH_4	0.32	Mg
1.B.2.c.2.ii	Flaring in gas transmission and distribution	A	CO_2	0.07	Gg
1.B.2.c.2.ii	Flaring in gas transmission and distribution	A	N_2O	<0.01	Mg

* A: area source, P: point source.

3.5.3 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, upstream 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, which is the case for the EU ETS reports regarding fugitive emission sources. 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 Section *1.4.10 Use of EU Emission Trading Scheme data*. 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.

EU ETS reports for refineries

Activity data are measured with flow meters and rates 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.

EU ETS reports for offshore installations

Activity data are measured with flow meters and rates 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.

3.5.4 Activity data, emission factors and emissions for fugitive sources

The following paragraphs describe the methodology for emission calculation for fugitive sources, including activity data, emission factors and annual emissions. The order follow the IPCC structure (1B2a Oil, 1B2b Natural gas, 1B2c Venting and flaring), with the exception that exploration and production of gas are include in the paragraphs for exploration and production of oil, due to similar methodologies and data providers.

Fugitive emissions from oil (1B2a)

The emissions from oil derive from exploration, production, onshore and offshore loading of ships, onshore oil tanks, service stations and refineries. Exploration and production of both oil and gas are described in this paragraph.

Exploration (1B2a1, 1B2b1)

Activity data

Activity data for oil and gas exploration are provided annually by the Danish Energy Agency (Andersen, 2016). Exploration of oil and gas is given separately for each exploration drilling, and fluctuate significantly over the time series. The largest oil rates are seen for 1990, 2002 and 2005, while relatively large gas rates are seen for more years of the time series. Explored rates are shown in Figure 3.5.1.

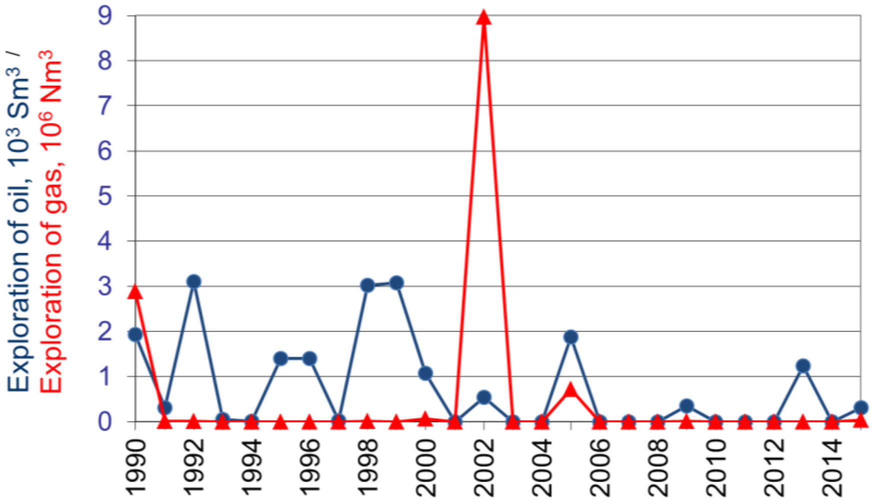

Figure 3.5.1. Exploration of oil and gas.

Emission factors

Annual CO_2 emission factors are based on composition data, calorific values and densities for explored oil and gas provided by the Danish Energy Agency. Composition data are available for the exploration and appraisal wells (E/A wells) separately, except for a few E/A wells, for which the compositions for the previous E/A well are used for emission calculation. As calorific values and densities are not available per drilling, data from a gas test in 1992 are used. CO_2 emission factors are listed in Table 3.5.5. The emission factors used to calculate emissions from offshore flaring in upstream oil and gas production are applied for the remaining pollutants (refer to the Section *Fugitive emissions from venting and flaring (1B2c)* belowe).

Table 3.5.5 Annual CO_2 emission factors for selected years for exploration of oil and gas.

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
EF_{CO2}, exploration of oil, kg/Sm3	2433	2449	2449	2444	NO	NO	NO	2449	NO	2449
EF_{CO2}, exploration of gas, kg/Nm3	2.85	2.94	2.94	2.89	NO	NO	NO	2.82	NO	2.82

Emissions

Calculated CH4 emissions for exploration of oil and gas are shown in Figure 3.5.2. There is no correlation between emissions from oil and gas, as the individual exploration drillngs have different ratios between oil and gas rates.

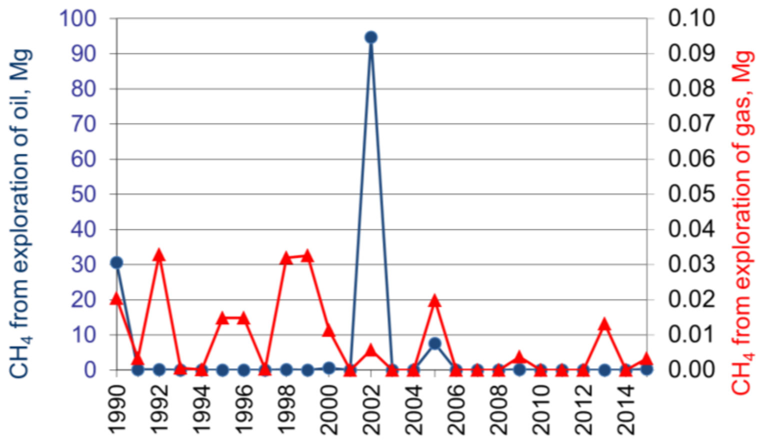

Figure 3.5.2 CH_4 emissions from exploration of oil and gas.

Production (1B2a2, 1B2b2)

Activity data

Activity data used for oil and gas production are provided by the Danish Energy Agency (DEA 2016a). As seen in Figure 3.5.3 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.

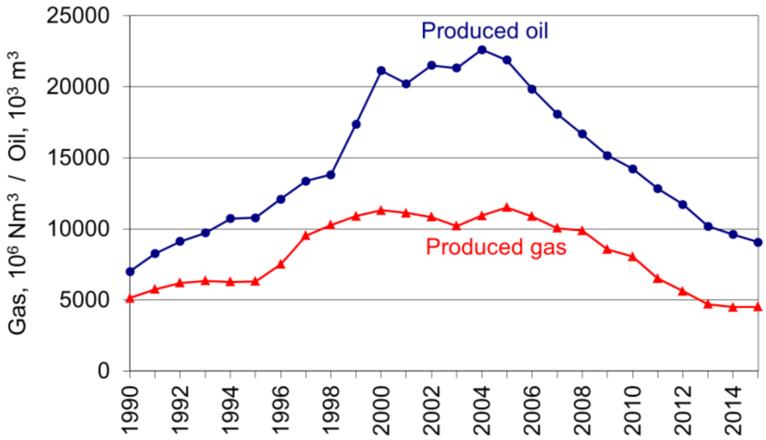

Figure 3.5.3 Production of oil and gas.

Emission factors

Standard emission factors from the 2006 IPCC Guidelines (IPCC, 2006) are used to calculate emissions from production of oil and gas (see Table 3.5.6).

Table 3.5.6 Emission factors for exploration of oil and gas.

	CO_2	CH_4	Reference
Production of oil, Gg/1000m^3	4.30E-08	5.90E-07	IPCC 2006
Production of gas, Gg/Mm3	1.40E-05	3.80E-04	IPCC 2006

Emissions

Calculated CH_4 emissions from oil and gas production are shown in Figure 3.5.4. The annual variations follow the production rates.

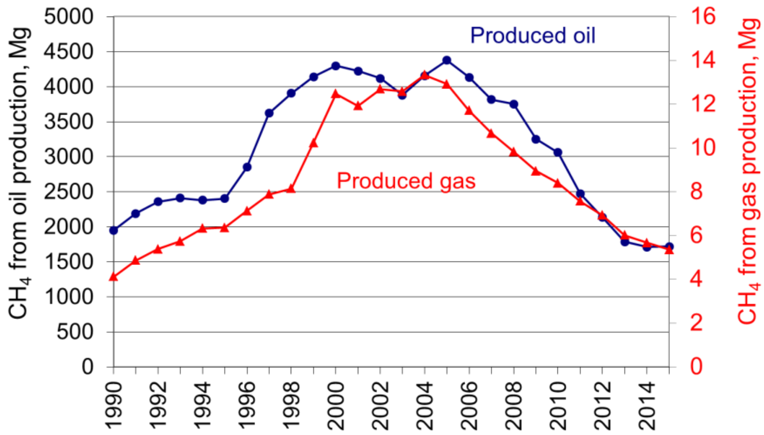

Figure 3.5.4 CH_4 emissions from production of oil and gas.

Transport (1B2a3)

Activity data

Fugitive emissions of oil transport include loading of ships from storage tanks or directly from the wells, and storage and handling at the oil terminal. Activity data for loading offshore and onshore are provided by the Danish Energy Agency (DEA 2016a) and from the annual self-regulating reports from DONG Oil Pipe A/S (DONG Oil Pipe A/S 2016), respectively. The latter also provide annual emissions from storage and handling at the oil terminal.

The rates of oil loaded on ships roughly follow the trend of the oil production (see Figure 3.5.5). Offshore loading of ships was introduced in 1999. In earlier years the produced oil was transported to land via pipeline.

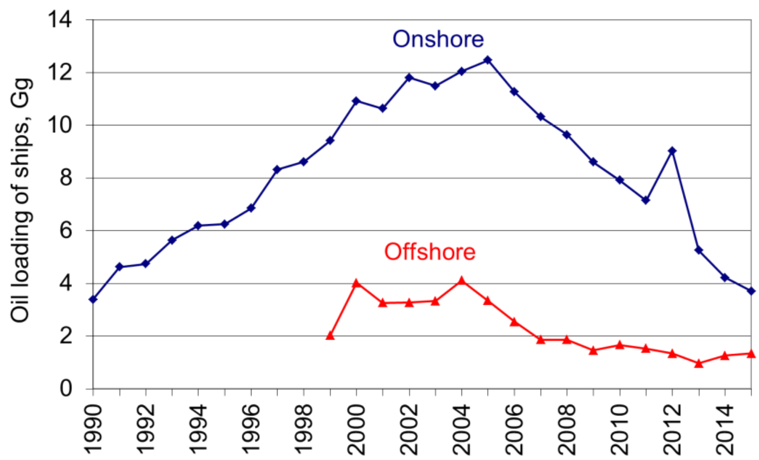

Figure 3.5.5 Onshore and offshore loading of ships.

Emission factors

The standard CO_2 emission factor for oil transport from the 2006 IPCC Guidelines (IPCC, 2006) is used to calculate emissions from storage and handling at the oil terminal (Table 3.5.7).

The EMEP/EEA Guidebook provide standard emission factors for loading of ships onshore and offshore for different countries (EMEP/EEA, 2013). In the Danish 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 from loading of ships (Miljøcenter Odense, 2010). The reduced emission factors used for 2010 onwards are included in Table 3.5.7.

Table 3.5.7 Emission factors for the oil terminal and for onshore and offshore loading of ships.

Source	Pollu-tant	Unit	Emission factor	
			1990-2009	2010 on-wards
Oil terminal	CO_2	Gg/1000m^3 oil transported by pipeline	4.9E-07	4.9E-07
Offshore loading of ships	CH_4	fraction of loaded	5E-05	5E-05
Onshore loading of ships	CH_4	fraction of loaded	1E-05	7.9E-06

Emissions

CH_4 emissions from transport of oil are shown in Figure 3.5.6.

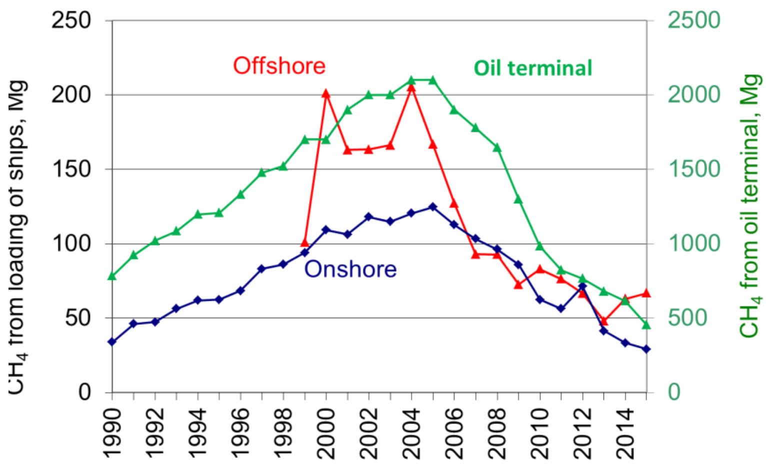

Figure 3.5.6 CH_4 emissions from the oil terminal and from onshore and offshore loading of ships.

Refining (1B2a4)

Activity data

Emissions from oil refinery processes include non-combustion emissions from handling and storage of feedstock (raw oil), from the petroleum product processing and from handling and storage of products. Emissions from flaring in refineries are included in the Section *Fugitive emissions from venting and flaring (1B2c)*. Emissions related to process furnaces in refineries are included in stationary combustion.

Rates of crude oil processed in the two Danish refineries are given in their annual environmental report (A/S Dansk Shell, 2016 and Statoil A/S, 2016). Until 1996 a third refinery was in operation, leading to a decrease in the crude oil rate from 1996 to 1997. Activity data are shown in Figure 3.5.7.

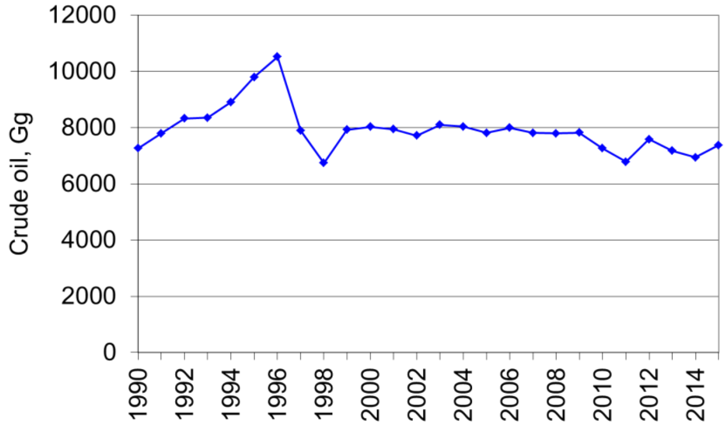

Figure 3.5.7 Crude oil processed in Danish refineries.

Emission factors

VOC emissions are provided 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 (Hjerrild & Rasmussen, 2014).

Both the non-combustion processes including product processing and sulphur recovery plants emit SO_2. For descriptions regarding fugitive emissions of SO_2 and other pollutants from refining, please refer to the Danish Informative Inventory Report (Nielsen et al., 2017).

Emissions

Figure 3.5.8 shows CH_4 emissions from the Danish refineries for selected years in the time series. The increase from 2005 to 2006 owes a new measurement campaign at one refinery, which showed larger emissions than the previous. According to the environmental department at the refinery, fugitive emissions from oil processing in refineries are not correlatable to any measured parameters, but are expected to follow a more random pattern. The refinery has chosen to report the latest measured emission for the years between measurement campaigns, and as no better methodology are available, the same approach is used in the national emission inventories.

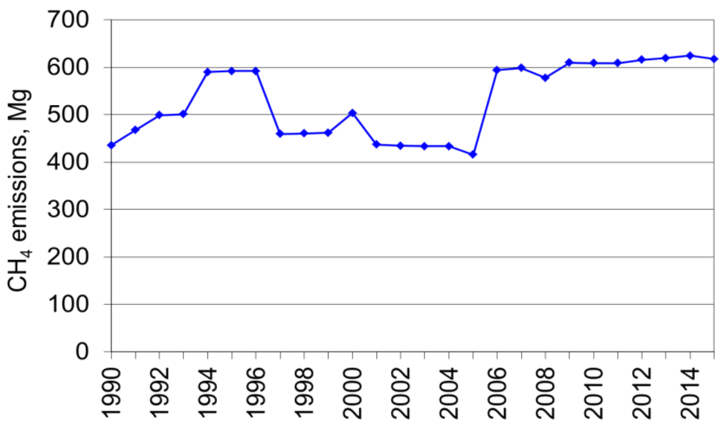

Figure 3.5.8 CH_4 emissions from crude oil processing in Danish refineries.

Service stations (1B2a5)

Fugitive emissions from service stations cover only NMVOC. For a description on methodology and data basis, please refer to the Danish Informative Inventory Report (Nielsen et. al., 2017).

Fugitive emissions from natural gas (1B2b)

The emissions from natural gas derive from exploration, transmission, storage and distribution. Descriptions of exploration and production of natural gas are included in the sections covering exploration and production of oil *Exploration (1B2a1, 1B2b1)* and *Production (1B2a2, 1B2b2)*.

Exploration (1B2b1)

See Section *Exploration (1B2a1, 1B2b1)*.

Production (1B2b2)

See Section *Production (1B2a2, 1B2b2)*.

Transmission and storage (1B2b4)

Activity data

The fugitive emissions from transmission and storage of natural gas are based on information from the gas transmission companies, which provide data on transported rate, pipeline losses, and length and material of the pipeline systems. In 2015 the length of the transmission pipelines is approximately 900 km.

The activity data used in the calculation of the emissions from transmission of natural gas are shown in Figure 3.5.9. 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 (2016b). 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.

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.

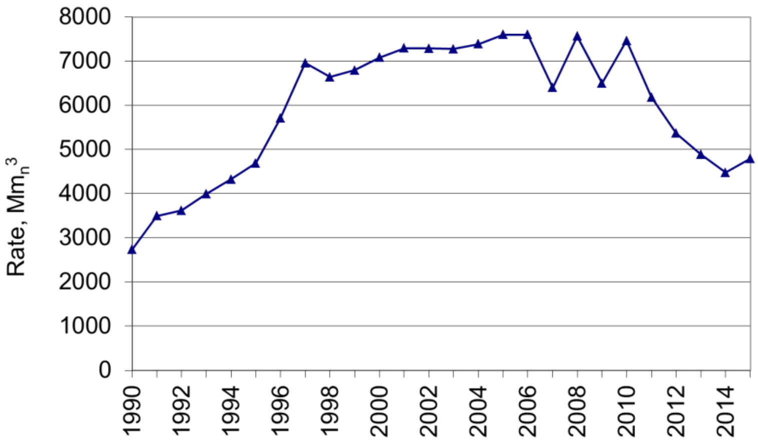

Figure 3.5.9 Rates for transmission of natural gas.

Emission factors

The fugitive emissions from transmission and storage 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 (2016c) (Table 3.5.8).

Table 3.5.8 Annual gas composition, lower heating value and density for Danish natural gas.

		Unit	1990	2000	2005	2010	2015
Methane	CH_4	molar-%	90.92	86.97	88.97	89.95	88.80
Ethane	C_2H_6	molar-%	5.08	6.88	6.14	5.71	6.08
Propane	C_3H_8	molar-%	1.89	3.17	2.50	2.19	2.47
i-Butane	i-C_4H_{10}	molar-%	0.36	0.43	0.40	0.37	0.39
n-Butane	n-C_4H_{10}	molar-%	0.50	0.61	0.55	0.54	0.59
i-Petane	i-C_5H_{12}	molar-%	0.14	0.11	0.11	0.13	0.13
n-Petane	n-C_5H_{12}	molar-%	0.10	0.08	0.08	0.08	0.10
n-Hexane and heavier hydrocarbons	C^{6+}	molar-%	0.09	0.06	0.05	0.06	0.05
Nitrogen	N_2	molar-%	0.31	0.34	0.29	0.31	0.32
Carbon dioxide	CO_2	molar-%	0.60	1.35	0.90	0.66	1.07
Lower heating value	H_n	MJ/m^3_n	39.176	40.154	39.671	39.461	39.635
Density	ρ	kg/m^3_n	0.808	0.846	0.825	0.816	0.828

Emissions

The gas transmission company reports emissions of CH_4 for the years 1999 and onwards, based on registered loss in the transmission grid and the emission from the natural gas consumption in the pressure regulating stations. 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 leaks during construction and maintenance. This leads to large annual fluctuations in emissions which are not correlated to the transmission rates. E.g. the large emission in 1995 owe to a large construction work covering four different locations. The increase in 2011 owe to venting for drainage of the pipes in preparation for construction work on a new compressor station, and the increase in 2014 owe to the construction of a new major railway line.

Emissions of CH_4 from transmission of natural gas are shown in Figure 3.5.10. Emissions of CO_2 from transmission and storage are very limited and not included in the figure. For information on emissions of NMVOC, please refer to Chapter 3.4 in the Danish Informative Inventory Report (Nielsen et. al., 2017).

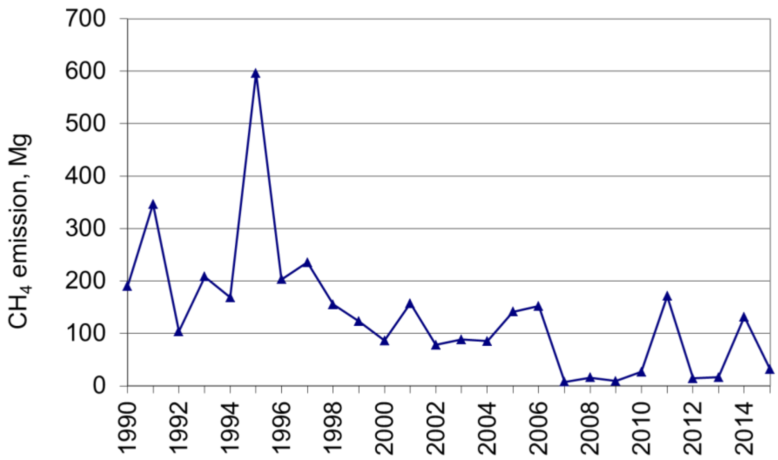

Figure 3.5.10 CH_4 emissions from transmission of natural gas.

Distribution (1B2b5)

Activity data

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. The fugitive losses from distribution of natural gas are only given for some companies. The average of the available "loss/distribution"-ratios is used for the remaining companies too.

Activity data for distribution of town gas is rather scarce, and calculations are based on the available data from the town gas distribution companies on losses from the pipelines. At present, there are two areas with town gas distribution and correspondingly two distribution companies. Two other 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 rate is assumed to decrease linearly to cero over these years, and the share ("distribution loss/distribution rate") is assumed equal to the value for 1995.

Data on the distribution network are given by Energinet.dk, DGC and the distribution companies concerning length and material. In 2015 the length of the distribution network was around 20.000 km. Because the distribution network in Denmark is relatively new most of the pipelines are made of plastic (approximately 90 %). 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). Distribution rates are shown in Figure 3.5.11.

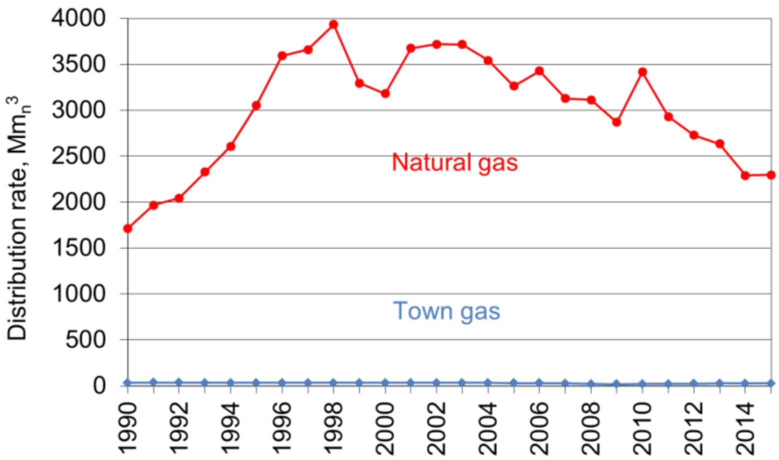

Figure 3.5.11 Distribution rates of natural gas and town gas.

Emission factors

Emissions from natural gas distribution are calculated from the fugitive losses from pipelines and the gas quality measured by Energinet.dk (see Table 3.5.8). The same approach is used for town gas, which is natural gas admixed ~ 50 % ambient air. From 2014 one town gas distribution company has started to admix biogas to. In 2014 the share of biogas is 10.1 % which is expected to increase in the coming years. The admixed biogas has not been upgraded as tests of different appliances have shown that up to 40 % non-upgraded biogas can be added to the town gas without causing problems with the appliances' combustion. The composition of biogas is given in Table 3.5.9.

Table 3.5.9 Composition of biogas admixed to towngas (Jeppesen, 2014; Ea Energianalyse, 2014).

Methane	CH_4	molar-%	60.98
Nitrogen	N_2	molar-%	0.001
Carbon dioxide	CO_2	molar-%	39.02
Lower heating value	H_n	MJ/m^3_n	21.53
Density	ρ	kg/m^3_n	0.808

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

Emissions of CH_4 from distribution of natural gas and town gas are shown in Figure 3.5.12. Emissions of CO_2 are very limited amounts and not included in the figure. For information on emissions of NMVOC, please refer to Chapter 3.4 in the Danish Informative Inventory Report (Nielsen et. al., 2017).

Emissions from the natural gas network are variable and are associated with renovation to the network and excavation damages.

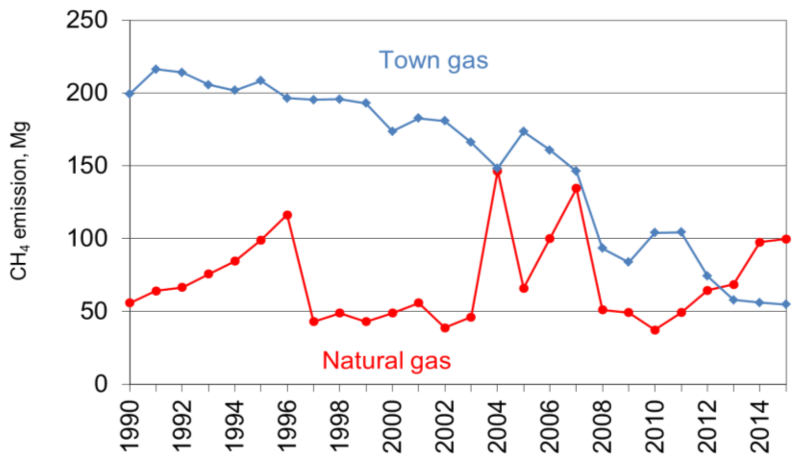

Figure 3.5.12 CH_4 emissions from transmission of natural gas.

Fugitive emissions from venting and flaring (1B2c)
Venting occur in the two Danish natural gas storage facilities. Flaring occurs in oil and gas production, in gas treatment and storage facilities, in refineries, and in gas transmission and distribution.

Venting
Activity data
The natural gas storage facilities are obligated to make environmental reports on an annual basis, including data on venting. 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 3.4.13. Data are not available for the years 1990-1994 for the one gas storage facility that was in operation over the entire time series, and the average for 1995-1998 is applied. The second gas storage facility was opened in 1994, leading to increasing venting rates.

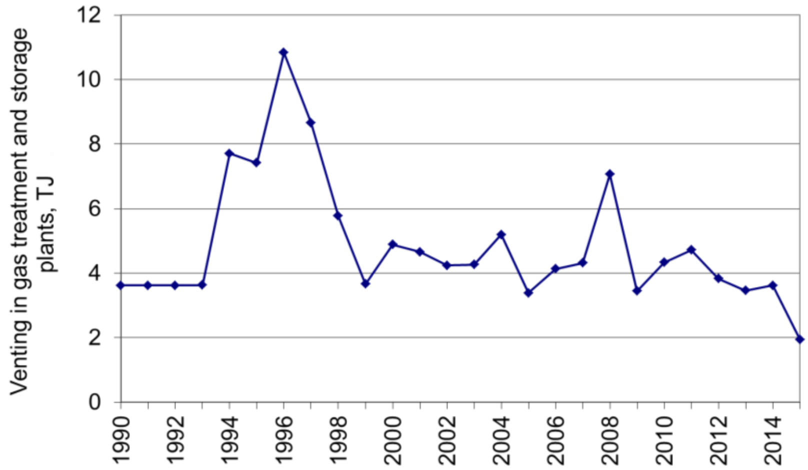

Figure 3.5.13 Venting rates in gas storage facilities.

Emission factors
Emissions of CH_4 and NMVOC from venting are given in the environmental reports for the gas storage facilities (DONG Energy, 2016a; Energinet.dk, 2016a). CO_2 emissions from venting are calculated from country specific emission factors based on annual natural gas composition published by Energinet.dk.

Emissions

Venting is limited to the gas storage facilities and the emissions are of minor importance to the total fugitive emissions. Venting emissions are included in Figure 3.5.17.

Flaring

Flaring in refineries

Activity data

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 rates are given in the EU ETS reporting. Data are not available for the years 1990-1993, why the flaring rate for 1994 has been adopted for the previous years. Flaring rates are shown in Figure 3.5.14.

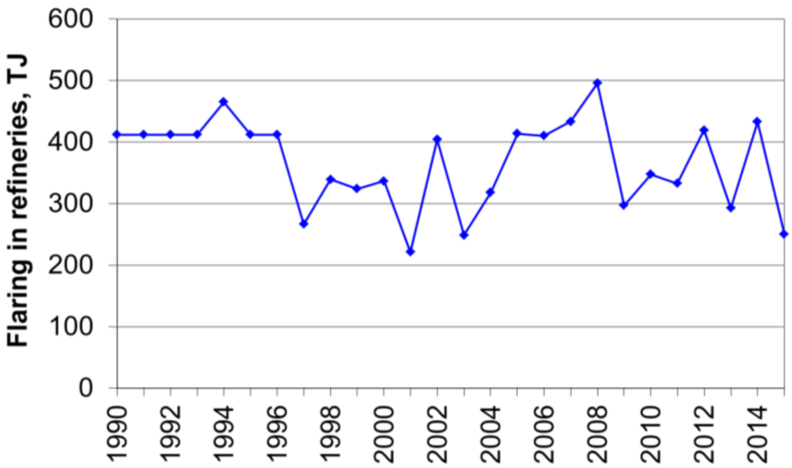

Figure 3.5.14 Flaring rates in refineries.

Emission factors

The composition of refinery gas is given for 2008 by one of the two refineries. As the composition for refinery gas is very different from than the composition of natural gas, the 2008 refinery gas composition is used in calculations for both Danish refineries. The CH_4 and NMVOC emission factors based on the 2008 refinery gas composition 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 2007-2011 for each refinery is applied. The emission factor applied for N_2O is based on 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 3.5.10. For information on emissions of other pollutants, please refer to Chapter 3.4 in the Danish Informative Inventory Report (Nielsen et. al., 2017).

Table 3.5.10 Emission factors for flaring in refineries for 2015.

Pollutant	Emission factor	Unit
CH_4	18.1	g per GJ
CO_2 *	50.76 / 57.34	kg per GJ
N_2O	0.47	g per GJ

** The CO_2 emission factors are based on the refineries reports for EU ETS and are plant specific.

Emissions

Emissions of CH_4 and CO_2 are shown in figure 3.5.15. The variation over the time series follow the flaring rates, with small variations for CO_2 from 2006 onwards, when annual plant specific CO_2 emission factors became available in EU ETS reportings.

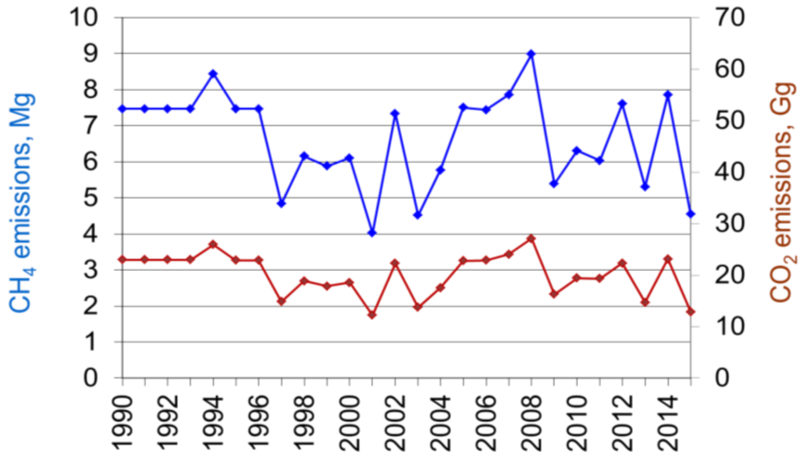

Figure 3.5.15 CH_4 and CO_2 emissions from flaring in refineries.

Flaring in upstream oil and gas production

Activity data

From 2006 data on flaring in upstream oil and gas production is given in the reports for the EU ETS and thereby emission calculation can be made for the individual production units. Before 2006 only the total flared amount is available in the annual report Denmark's oil and gas production (Danish Energy Agency, 2016a). Flaring rates (and CO_2 emissions) are shown in Figure 3.5.16. Flaring rates in upstream oil and gas production have been decreasing over the last 10 years period in accordance with the decrease in production as seen in Figure 3.5.3. Further, there is focus on reducing the amount being flared for environmental reasons.

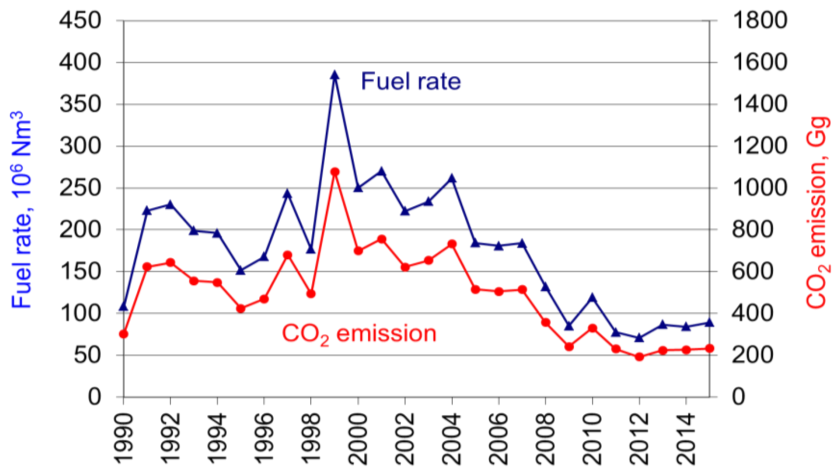

Figure 3.5.16 Fuel rate and CO_2 emission from flaring in upstream oil and gas production.

Emission factors

The emission factors for flaring in upstream oil and gas production are shown in Table 3.5.11. Since 2006 the CO_2 emission factor is calculated according to the reporting for EU ETS. As corresponding data are not available for earlier years, the average CO_2 EF for the years 2008-2012 is applied for the years 1990-2007. The emission factor for CH_4 is estimated from flare gas quality data for one offshore production platform, assuming a flare efficiency of 98 % in agreement with IPCC (2006) and API (2009). Emission factors for N_2O are based on IPCC (2006). For information on emissions of other pollutants, please refer to Chapter 3.4 in the Danish Informative Inventory Report (Nielsen et. al., 2017).

Table 3.5.11 Emission factors for flaring in upstream oil and gas production for 2015.

Pollutant	Emission factor	Unit
CH_4	10.56	g per Nm^3
CO_2	2.606	kg per Nm^3
N_2O	1.598	g per Nm^3

Emissions

The time series for the emission of CO_2 from flaring in upstream oil and gas production 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 3.5.16, there was a marked increase in the rate of flaring in upstream oil and gas production 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 CH_4 and N_2O emissions from flaring in upstream oil and gas production 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 are shown in Figure 3.5.17.

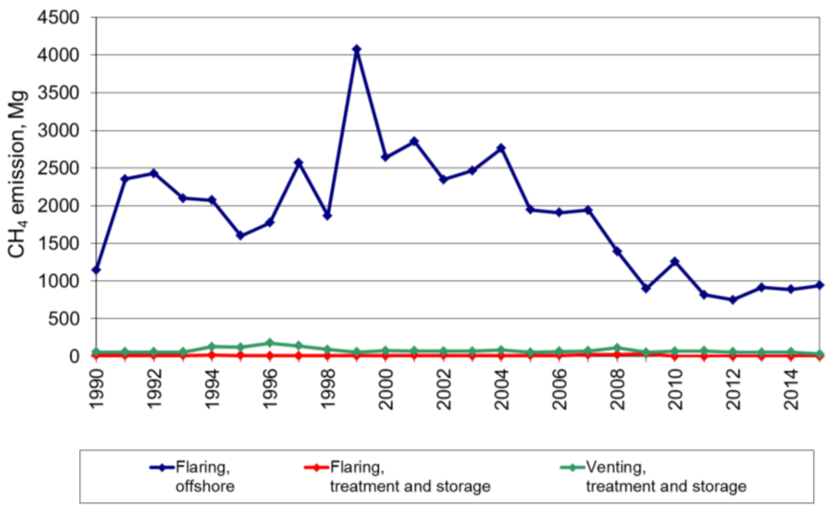

Figure 3.5.17 CH_4 emissions from flaring in upstream oil and gas production.

Flaring in gas treatment and storage facilities

Activity data

Activity data for flaring in gas treatment and storage facilities are given in DONG Energy's environmental reports (Dong Energy, 2016a; Dong Energy, 2016b; Energinet.dk, 2016a). Flaring rates in gas treatment and gas storage facilities 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. Note that one of the two gas storage facilities was not opened before 1994. The large amount of gas flared in 2007 owe to a larger maintenance work at the gas treatment plant.

Emission factors

Emissions from flaring in gas treatment and storage facilities are calculated from the same emission factors which are used for flaring in upstream oil and gas production, except for CO_2. The natural gas flared in the treatment and storage facilities are natural gas with the same composition as natural gas distributed in Denmark, and the CO_2 emission factors are based on the gas composition given by Energinet.dk.

Emissions

Emissions from flaring in gas treatment and storage facilities are of minor importance to the total fugitive emissions. Emissions from gas treatment and storage facilities 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. CH_4 emissions are included in Figure 3.5.18.

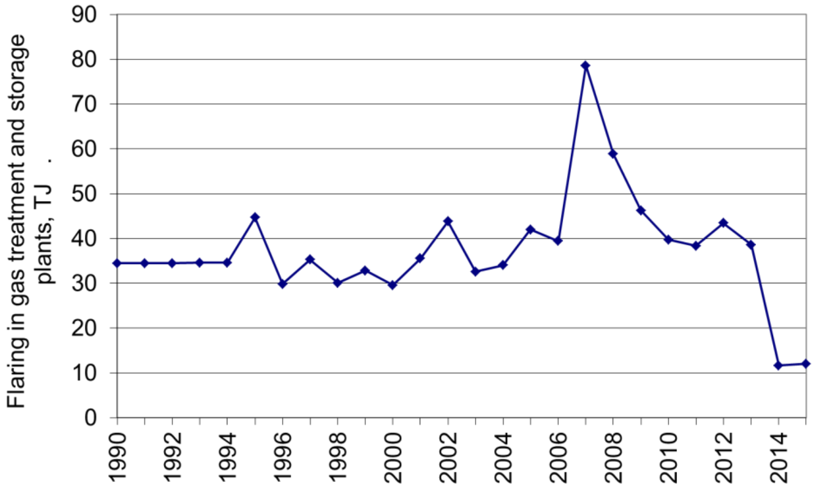

Figure 3.5.18 Flaring in gas treatment and storage facilities.

3.5.5 Uncertainties and time series consistency

Until 2016, two sets of uncertainty estimates were 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. From the 2017 submission, the Tier 2 uncertainty estimation has not been carried out due to a lack of ressources.

Uncertainty estimates are made for total emissions in the latest inventory year and for the emission trend for the corresponding time series. Uncertainty estimates are made for the CO_2, CH_4 and N_2O 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. Emission data, activity data and emission factors are described in Section *3.5.4 Activity data, emission factors and emissions for fugitive sources*.

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 DCE 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 3.5.12. Uncertainty levels are given in percentage related.

Table 3.5.12 Uncertainty levels for activity rates and emission factors.

Pollutant	Source	Activity data uncertainty level, %	Emission factor uncertainty level, %
CO_2	Exploration, oil	2 A	10 A
CO_2	Off-shore activities, oil	2 A	100 I
CO_2	Land based activities, oil	2 A	40 S
CO_2	Exploration, gas	2 A	10 A
CO_2	Off-shore activities, gas	2 A	100 S
CO_2	Transmission of natural gas	15 G	2 Q
CO_2	Distribution of natural gas	25 G, A	10 Q, A
CO_2	Venting in gas storage	15 G, A	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 A	125 A
CH_4	Off-shore activities, oil	2 A	100 I
CH_4	Land based activities, oil	2 A	40 S
CH_4	Petroleum product processing	1 E, A	200 A
CH_4	Exploration, gas	2 A	125 A
CH_4	Off-shore activities, gas	2 A	100 I
CH_4	Transmission of natural gas	15 G	2 Q
CH_4	Distribution of natural gas	25 G, A	10 Q, A
CH_4	Venting in gas storage	15 G, A	2 Q
CH_4	Flaring, refinery gas	11 E	15 H, A
CH_4	Flaring, natural gas	7,5 E	125 G
N_2O	Exploration, oil	2 A	1.000 A
N_2O	Exploration, gas	2 A	1.000 A
N_2O	Flaring, refinery gas	11 E	1.000 I
N_2O	Flaring, natural gas	7,5 E	1.000 I

A: 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 in upstream oil and gas production 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, and the uncertainty interval for the N_2O emission factors given for flaring in oil and gas production is -10 % to +1 000 %. An uncertainty level of 1 000 % is adopted in the Danish uncertainty model for all fugitive sources in the Danish inventory (exploration and flaring of oil and gas).

Results

The results of the Tier 1 uncertainty model for 2015 are shown in Table 3.5.13. In 2015, N_2O has the largest uncertainty for both the total emission and the trend followed by CH_4 and CO_2. The estimated uncertainty for the total GHG emission is 110 % and the GHG emission trend is -24 % ± 9 %-point.

Table 3.5.13 Uncertainty estimates for total emissions and emission trends from the Tier 1 uncertainty model.

	Emission, kt CO_2 eqv Base year	Emission, kt CO_2 eqv 2014	Uncertainty, % Lower and upper (±)	Trend 1990-2015, %	Uncertainty, % Lower and upper (±)
CO_2	341	247	7	-27	7
CH_4	123	101	60	-17	11
N_2O	53	43	999	-20	30
GHG	516	391	110	-24	9

3.5.6 Source specific QA/QC and verification

The elaboration of a formal QA/QC plan started in 2004 and was updated in 2013 (Nielsen et al., 2013). The plan describes the concepts of quality work and definitions of sufficient quality, Critical Control Points (CCP) and a list of Points of Measuring (PM) (Figure 3.5.20). Please refer to the general Section *1.6 Information on QA/QC plan including verification and treatment of confidential issues where relevant* for further information.

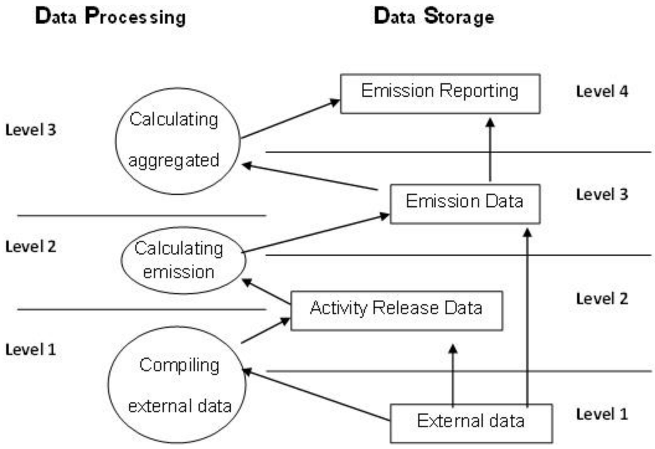

Figure 3.5.20 The general data structure for the Danish emission inventory (Nielsen et al., 2013).

Data storage level 1

Data storage level 1 refers to the data collected by DCE before any processing or preparing. Table 3.5.15 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 3.5.15 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 exploration of oil and gas, including rates and composition.	Activity data	The Danish Energy Agency	Jan H. Andersen	Data agreement
Production of oil and gas	Gas and oil production. Dataset, including rates of offshore loading of ships.	Activity data	The Danish Energy Agency	Jan H. Andersen	Not necessary due to obligation by law
Offshore flaring	Flaring in upstream oil and gas production (EU 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 transmission rates from the transmission company, sales and losses.	Activity data	Energinet.dk	Christian Friberg B. Nielsen	Not necessary due to obligation by law
Onshore activities	Rates 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 and town gas distribution rates from the distribution company, sales and losses (meter differences)	Activity data	Naturgas Fyn, HMN Dong Energy Aalborg Forsyning	Hanne Mochau, Søren K. Andersen Grethe Andersen Andreas Bech Jensen	No formal data agreement.
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.
Treatment and storage 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 (EU 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 Section *3.5.4 Activity data, emission factors and emissions for fugitive sources* regarding emission factors		

The following lists the CCPs and the PMs in the Danish QA/QC plan, relevant for the emission inventory for the fugitive sector.

Level	CCP	PM	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.

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 behind 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 Section *3.5.5 Uncertainties and time series consistency*.

Level	CCP	PM	Description
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 in Section *1.6 Information on QA/QC plan including verification and treatment of confidential issues where relevant*.

Level	CCP	PM	Description
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 include energy statistics from the Danish Energy Agency, EU ETS reports and annual environmental reports from a number of plants and companies. Further, supplementary information are gathered annually from some companies. Only one national data set is found for most fugitive sources, and all data sets are expected to be complete and include all activities/emissions form the sources. Data on flaring in upstream oil and gas production, in refineries and in gas treatment and storage facilities 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 suppliers. Minor differences may owe to the allocation of fuels, e.g. if pilot gas are included in the flare gas or the fuel gas rate.

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 production and flaring in upstream oil and gas production, 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 e.g. fuel consumption and emissions. 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 information are used. All information is compared with data for previous years.

Reports for the European Union Greenhouse Gas Emission Trading System (EU ETS)

CO_2 emission factors for offshore in upstream oil and gas production and in refineries are taken from the EU ETS reports since 2006 when the EU ETS reports became available. EU ETS reports are available individually for the Danish oil/gas production fields and refineries.

Emission factors from a wide range of sources

For specific references, see Section *3.5.4 Activity data, emission factors and emissions for fugitive sources*.

Level	CCP	PM	Description
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 to ensure that the external data are always available in the original form. Data sources are referenced in the spread sheets. Refer to Section *1.3. Brief description of the process of inventory preparation. Data collection and processing, data storage and Archiving*.

Level	CCP	PM	Description
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. The remaining data are published or delivered by the companies on voluntary basis. See Table. 3.5.15.

Level	CCP	PM	Description
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 3.5.15.

Data Processing Level 1

Level	CCP	PM	Description
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 General uncertainty evaluation, including data on the overall uncertainty for the inventory totals* in the Danish NIR and Section *3.5.6 Source specific QA/QC and verification*.

Level	CCP	PM	Description
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.

Level	CCP	PM	Description
Data Processing	3.Completeness	DP.1.3.1	Identification of data gaps with regard to

level 1			data sources that could improve quantitative knowledge.

Data gaps are found for distribution of town gas, as more companies are closed before this 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. Also further information regarding VOC emissions from refineries would be preferred, but are not available. DCE continue the collaboration with the refineries update the methodology and emission estimates if new information become available.

Level	CCP	PM	Description
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 Section *3.5.4 Activity data, emission factors and emissions for fugitive sources*.

Level	CCP	PM	Description
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/or emissions on SNAP level are used to identify possible errors in the calculation procedure.

Level	CCP	PM	Description
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. For sources where activity data is available in more data sources (e.g. in both EU ETS and annual reports), data are compared and reasons for any differences are clarified.

Level	CCP	PM	Description
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 Section *3.5.4 Activity data, emission factors and emissions for fugitive sources*.

Level	CCP	PM	Description
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.

Level	CCP	PM	Description
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

Level	CCP	PM	Description
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

Level	CCP	PM	Description
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.

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 facilities) 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 (production and flaring rates in upstream oil and gas production).
- 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 CRF and SNAP source categories. Significant dips and jumps are controlled and explained.

External review

In 2015 a documentation report for the sector "Fugitive emissions from fuels" was published, including detailed information on the methodology used in the emission inventories for greenhouse gases and air pollution (Plejdrup et al., 2015). The report was reviewed by Glen Thistlethwaite from Ricardo Energy & Environment, Oxfordshire, UK.

3.5.7 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., 2017).

Oil production (1B2a2)

Activity data for the oil terminal are updated for 2011-2014 according to the annual environmental report. The recalculation is of minor importance (<0.001 % of the total CH_4 emission from 1B2b2).

Venting and flaring (1B2c)

Flaring in gas transmission has been updated for 2014 according to information from the Danish gas transmission company Energinet.dk.

Activity data and emissions are updated for one of the gas storage plants; for 2014 as the 2014 environmental report has become available, and for 2012 due to updated values in the 2015 environmental report.

Emission factors for N_2O have been updated for flaring in oil/gas production and exploration for the entire time series.

The recalculations have only minor influence on the emissions from 1B2c. The largest change is in 2014 where the CH_4 and N_2O emissions have changed by -0.9 tonnes and +0.7 tonnes respectively, corresponding -0.1 % and +0.5 % of the total CH_4 and N_2O emissions from 1B2c.

3.5.8 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 Overview of methodologies used for the 2015 data (or the latest active year for activities that have ceased).

IPCC code	Process	Substance	Tier	EF	Key category 1990/2015/trend
2A1	Cement production*	CO_2	T3	PS	Yes/Yes/Yes
2A2	Lime production	CO_2	T3	CS	No/No/No
2A3	Glass production	CO_2	T3	PS	No/No/No
2A4a	Ceramics	CO_2	T2	CS	No/No/No
2A4b	Other uses of soda ash	CO_2	T3	D	No/No/No
2A4d	Other process uses of carbonates	CO_2	CS/T3	D	No/No/No
2B2	Nitric acid production	N_2O	T2	PS	Yes/No/Yes
2B10	Catalyst production	CO_2	T2	PS	No/No/No
2C1	Iron and steel production	CO_2	T1	D	No/No/No
2C4	Magnesium production	SF_6	T2	D	No/No/No
2C5	Secondary lead production	CO_2	T1	D	No/No/No
2D1	Lubricant use	CO_2	T1	D	No/No/No
2D2	Paraffin wax use	CO_2, N_2O, CH_4	T2	OTH/D	No/No/Yes
2D3	Paint application	CO_2	CS/T2	CS	No/No/No
2D3	Degreasing, dry cleaning and electronics	CO_2	CS/T2	CS	No/No/No
2D3	Chemical products manufacturing or processing	CO_2	CS/T2	CS	No/No/No
2D3	Other use of solvents and related activities	CO_2	CS/T2	CS	No/No/No
2D3	Road paving with asphalt	CO_2, CH_4	T2	D/OTH	No/No/No
2D3	Asphalt roofing	CO_2	T2	D/OTH	No/No/No
2D3	Urea from fuel consumption	CO_2	T3	D	No/No/No
2E5	Other electronics industry	PCFs	T2	D	No/No/No
2F1	Refrigeration and air conditioning	HFCs, PFCs	T2	D	No/Yes/Yes
2F2	Foam blowing agents	HFCs	T2	D	Yes/No/Yes
2F4	Aerosols	HFCs	T2	D	No/No/No
2F5	Solvents	PFCs	T2	D	No/No/No
2G1	Electrical equipment	SF_6	T3	D	No/No/No
2G2	SF_6 and PFCs from other product use	SF_6	T2	D	No/No/No
2G3a	Medical application	N_2O	T1	D	No/No/No
2G3b	Propellant for pressure and aerosol products	N_2O	T1	D	No/No/No
2G4	Other product uses	CO_2, CH_4, N_2O	T2	D/CS/OTH	No/No/No

* The methodology used for this category varies over the time series, see Table 4.1.2.

Table 4.1.2 Overview of implemented methodologies for categories where the methodology varies over the time series.

Process	Years	Available activity data	Available emission factors	Resulting methodology
2A1 Cement production	1990-1997	Production of white cement and production of three types of grey clinker.	Plant specific factors for the three individual grey clinker types and for white cement.	Tier 1/PS
	1998-2015	Consumption of raw materials.	Plant specific measured carbonate content of raw materials.	Tier 3/PS

4.1.2 Key categories

A Key Category Analysis (KCA) for the years 1990 and 2015 as well as for the trend has been carried out. The result for the IPPU sector is shown in Table 4.1.3. A detailed KCA is presented in Chapter 1.5 and Annex 1. The calculations are based on national emissions including LULUCF but excluding Greenland and the Faeroe Islands.

The analysis is carried out using both an Approach 1 and Approach 2 method. Five categories are identified as key categories in IPPU in this submission, some for level, some for trend and some for both level and trend.

Table 4.1.3 Key Category Analysis for *Industrial Processes and Product Use*.

IPCC code	Process	Substance	Approach 1 1990	Approach 1 2015	Approach 1 1990-2015	Approach 2 1990	Approach 2 2015	Approach 2 1990-2015
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

Only source categories identified as key categories are presented in Table 4.1.3, for a full overview of the source categories included in this inventory please refer to Table 4.1.1.

4.1.3 Emission overview

An overview of the six most significant sources in 2015 covered by IPPU is presented in Table 4.1.4; these six source categories compile more than 90 % of emissions in CO_2 equivalents (CO_2e) from IPPU. The table below also gives an indication of the contribution to the total emission of greenhouse gases in 2015 in the IPPU sector. The emissions are extracted from the CRF tables.

Table 4.1.4 Overview of the largest sources to greenhouse gas emissions in the IPPU sector in 2015.

Process	IPCC Code	Substance	Emission Gg CO_2 eq.	%*
Cement production	2A1	CO_2	932	46.8
Refrigeration and air conditioning	2F1	HFCs, PFCs	596	29.9
SF_6 from other product uses	2G2	SF_6	91	4.6
Paraffin wax use	2D2	CO_2, CH_4, N_2O	73	3.7
Solvent use	2D3	CO_2, CH_4	68	3.4
Other uses of carbonates	2A4	CO_2	61	3.1
Total of six largest sources			1820	91.4

*of total CO_2 equivalent emissions from the IPPU sector.

For 2015, the subsector Mineral Industry (2A) constitutes 53 % of the GHG emissions from the IPPU sector and Product Uses as Substitutes for ODS (2F) constitutes 32 %. Non-Energy Products from Fuels and Solvent Use (2D) and Other Product Manufacture and Use (2G) constitutes 9 and 6 % respectively, while Chemical Industry (2B), Metal production (2C) and Electronics Industry (2E) together constitutes below 0.1 %. The total emission of greenhouse gases (excl. LULUCF) in Denmark in 2015 is estimated to 51.7 Tg CO_2 equivalents of which IPPU contribute with 2.0 Tg CO_2 equivalents (3-9 %). The emissions of GHG from IPPU from 1990-2015 are presented in Figure 4.1.1.

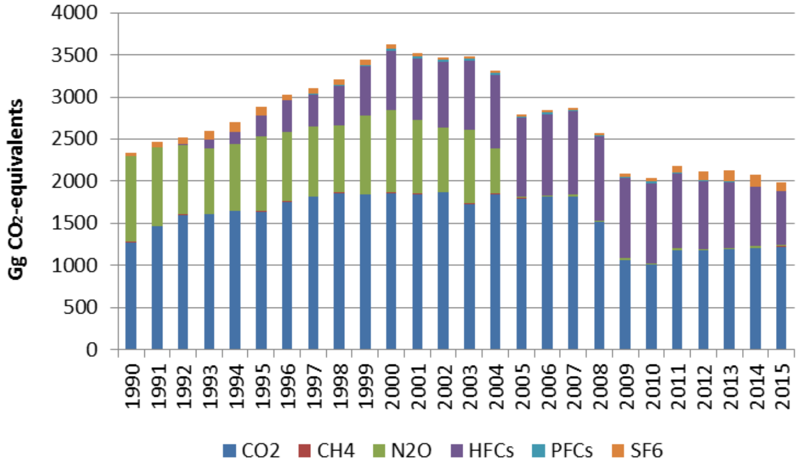

Figure 4.1.1 Emission of individual- and total greenhouse gases from IPPU (CRF Sector 2) from 1990-2015.

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 during the time series.

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) covers 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 Stone 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 2015 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 how much the individual source categories contribute throughout the time series.

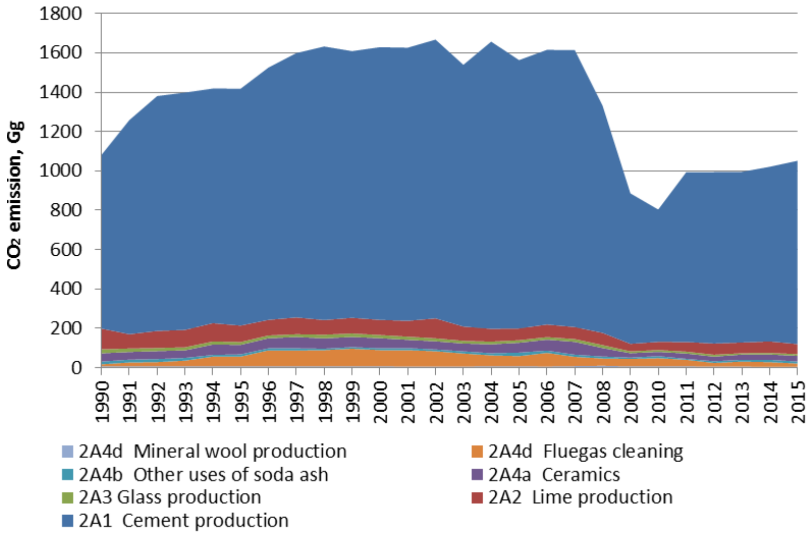

Figure 4.2.1 Emission of CO_2 from the individual source categories compiling *2A Mineral Industry*, Gg.

Greenhouse gas emissions from *Mineral Industry* are made up mostly by CO_2 emissions from the production of cement; min. 82 % (1990) to max. 89 % (2015).

Emissions from *Mineral Industry* increased with 54 % from 1990 to the time series peak in 2002 (2002 emission: 1667 Gg CO_2e). The overall development in the CO_2 emission for 1990 to 2015 shows a decrease from 1080 Gg CO_2e to 1052 Gg CO_2e, i.e. -3 %.

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 fuel combustion in cement kilns are estimated and reported in the energy sector. Only emissions related to the calcination of non-fuel feedstock to cement kilns are reported under category 2A.

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 are no further information available. Data for white cement is therefore used as an estimate for white clinker making the methodology used for the years 1990-1997 a Tier 1.

From 1998-2004 carbonate content of the raw materials has been determined by loss on ignition methodology. Determination of loss on ignition takes into account all the potential raw materials leading to release of CO_2 based on full oxidation 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). Clinker data are available.

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, 2016a). The reporting to EU-ETS also provides detailed information of alternative fuels used in the production of clinker and the amount of clinker produced.

Activity data

Activity data for cement (measured in total cement equivalents (TCE)) and clinker production are presented in Table 4.2.1 and Annex 3C-1. Emissions are based on clinker production alone, cement production data are used for verification.

Table 4.2.1 Production statistics for cement and clinker production, Gg (Aalborg Portland, 2008, 2016a, b).

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
Gg TCE	1620	2274	2613	2706	1454	1767	1818	1825	1819	1902
Gg clinker[1]	1406	2353	2452	2521	1314	1582	1629	1613	1644	1715

[1] 1990-1997: Clinker production is estimated as grey clinker plus white cement (Aalborg Portland, 2008).

Emission factors

The calculated implied emission factors (IEF) for cement production are presented in Table 4.2.2 and Annex 3C-2.

Table 4.2.2 Implied emission factors for CO_2 for cement production.

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
IEF Mg CO_2 per Mg TCE[1,2,3]	0.545	0.529	0.530	0.504	0.462	0.488	0.479	0.475	0.488	0.490
IEF Mg CO_2 per Mg clinker[3,4]	0.628	0.512	0.565	0.541	0.512	0.545	0.535	0.538	0.540	0.543

[1] 1990-1997: IEF based on information provided by Aalborg Portland, 2005.
[2] 1998-2004: IEF based on information provided by Aalborg Portland (Aalborg Portland, 2008).
[3] 2005-2015: IEF based on emissions reported to EU-ETS (Aalborg Portland, 2016a).
[4] 1998-2015: IEF based on clinker production statistics provided by Aalborg Portland (Aalborg Portland, 2016b).

The IEF for CO_2 from the calcination process is expressed per Mg of cement or 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 products 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 used for 1990-1997 (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 grey clinker
FKH clinker	0.459	Mg CO_2/Mg FKH grey clinker
SKL/RKL clinker	0.610	Mg CO_2/Mg SKL/RKL grey 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 (1998-2015). Determination of loss on ignition means that there is no need to consider uncalcined cement kiln dust (CKD) not recycled to the kiln; further detail is given above under methodology.

The company reporting to the EU ETS applies the following EFs for the most important raw materials used in 2015, similar data are available back to 2006 (Aalborg Portland 2016a) and to a less detailed degree back to 1998 (Aalborg Portland, 2016b).

Table 4.2.4 Emission factors for raw materials used in 2015 (Aalborg Portland, 2016a).

Raw material	Mg CO_2 per Mg raw material
Limestone	0.44
Magnesium carbonate	0.522
Sand	0.005-0.028
Fly ash	0.124
CKD	0.381-0.525

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 Annex 3C-3 and is also presented in Figure 4.2.2 below.

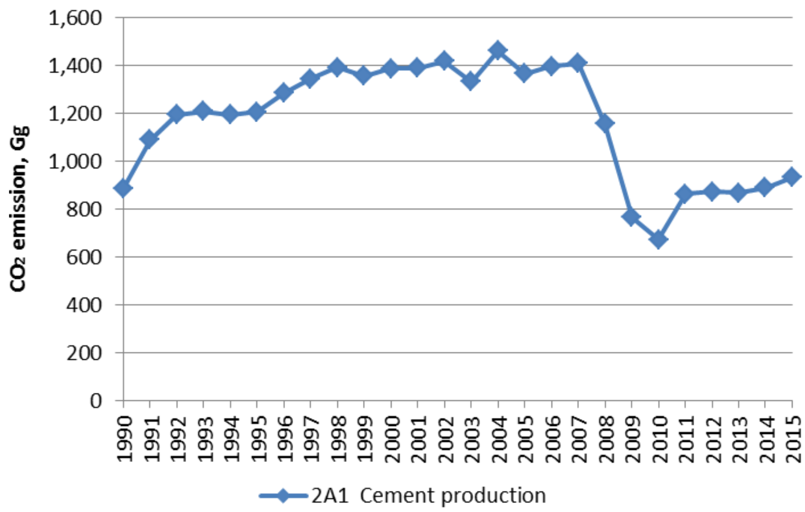

Figure 4.2.2 Emission of CO_2 from cement production.

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 2011-2015, but the emissions are still far below the pre-recession levels. However, the overall development in the CO_2 emission from 1990 to 2015 is an increase from 882 to 932 Gg CO_2, i.e. by 5.6 %. The maximum emission occurred in 2004 and constituted 1 459 Gg CO_2.

EU-ETS data for cement production

Cement production applies the Tier 3 methodology for calculating the CO_2 emission for 1998-2015.

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 – 2015.

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

The ratios in cement:/clinker production data from Aalborg Portland (presented in Table 4.2.1) shows that for most years the cement is 102-115 % (109 % in average) higher than the clinker data. This is as expected since Aalborg Portland only uses their own produced clinker, but for 1995 and 1996 the ratios are 97 %. In the comparison against the cement data from Statistics Denmark (presented in Annex 3C-5) these two years are where the data from Statistics Denmark are notably higher than those from Aalborg Portland (310 and 210 Gg respectively). If a corresponding ratio is calculated for 1995-1996 with clinker data from Aalborg Portland (Table 4.2.1) and cement data from Statistics Denmark (Annex 3C-5) the resulting ratios are 106-110%, as with the rest of the time series. This indicates that the used activity data for cement given by Aalborg Portland might be a little low for these years. It does however not affect the emission estimates.

Information on production, import and export of cement and clinker for the years 1990–1997 was investigated in order to ensure that the Tier 1 method is being implemented in accordance with the IPCC Good Practice Guidance (IPCC, 2006).

The supply of cement clinker, grey cement and white cement in Denmark is shown in Table 4.2.5 and Annex 3C-4; 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, 2016).

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
Cement clinker										
Production	NAV	NAV	103	43	4	0.03	24	0	9	0
Import	0.4	0.0	0.0	31	22	27	25	26	30	90
Export	17	281	90	56	12	3	25	0.6	17	0.1
Supply	-	-	12	18	14	24	24	26	22	90
Portland cement, white										
Production	412	531	551	715	482	514	496	531	558	614
Import	0	0.02	11	15	23	30	29	22	7	8
Export	367	473	546	508	501	497	498	506	543	562
Supply	44	58	17	222	3	47	26	47	22	60
Portland cement, grey										
Production	1,244	2,053	1,985	2,166	1,085	1,338	1,321	1,322	1,318	1,414
Import	190	272	238	215	160	214	183	183	202	198
Export	19	790	634	732	201	251	271	249	238	264
Supply	1,414	1,535	1,589	1,650	1,044	1,301	1,233	1,256	1,282	1,348

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 (Aalborg Portland, 2013a).

The data presented in Table 4.2.5 have verification purposes only and are not used in the emission calculations.

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 4.2.5 and Table 4.2.1 show the produced amount of cement (grey and white) according to Statistics Denmark and the amount of cement 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 an average 1.3 % (22.8 Gg) through the time series (1990-2015). The most comprehensive activity data is believed to be the information on yearly produced amount of cement obtained from the Danish producer. A comparison between the two datasets is presented in Annex 3C-5.

Table 4.2.6 compares the default emission factor from IPCC (2006)[1] with the measured/calculated implied emission factor for 1992-2015. The average IEF for these years is 0.54 Mg per Mg clinker. The comparison shows good agreement between the two methods.

Table 4.2.6 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]	0.51-0.57	Mg/Mg clinker	Aalborg Portland (2008, 2016a, b)

[1]1992-2015.

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.

[1] Volume 3: Industrial Processes and Product Use, Chapter 2.2: Cement production, Equation 2.4, page 2.12.

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 % of mass produced) 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.

CO_2 emission factors are therefore consistent but the methodology behind the chosen activity data for cement production is not. Due to extensive verification, however, the methodology is believed to be consistent.

The inventory on cement production is considered complete in accordance with IPCC (2006) as the sole producer of cement in Denmark is fully included.

4.2.4 Lime production

The production of limestone ($CaCO_3$) and lime/burned lime/quicklime (CaO) 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. 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 has been estimated from the annual production figures registered by Statistics Denmark, and emission factors. Since 2006, point source data for Faxe Kalk have been applied but the total production always sums up to the national statistics. Plant specific activity data for marketed lime from Faxe Kalk are available from PRTR and EU-ETS for the years 2006-2015. Faxe Kalk constitutes 36-83% (59 % in average) of the Danish activity in 2006-2015. The plant specific activity data are available back to 1995 from the environmental reports but these are not applied as a point source. A number of smaller companies account for the remaining of the Danish production.

Since 2006, process CO_2 emissions from Faxe Kalk have been calculated by the company and reported to EU-ETS and since 2008 Faxe Kalk has measured and included the content of $MgCO_3$ in the process emissions reported to EU-ETS. For the sake of consistency, the same method has been applied for the entire time series and for all producers, i.e. assuming the same $CaCO_3/MgCO_3$ ratio as the measured average from Faxe Kalk in 2007-2013.

Limestone consumption data for production of sugar are available from the company's environmental reports (Nordic Sugar, 2016; Nordic Sugar Nykøbing, 2010; Nordic Sugar Nakskov, 2010; Danisco Sugar Assens, 2007) back to 1996 and sugar sales statistics are available from Statistics Denmark (2016) for the entire time series. Limestone consumption data are used when available and national sugar sales statistics are used as surrogate data the remaining years (1990-1995). Raw material consumption data are given in amount of limestone and calculated into amount of burnt lime (CaO) equivalents using the stoichiometric relation between $CaCO_3/CaO$ and the average measured $CaCO_3$ content in limestone of 10.83 % from Faxe Kalk.

Activity data

The production data for burnt lime are presented in Table 4.2.7 and Annex 3C-6.

Table 4.2.7 Production of burnt lime, Gg.

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
From Faxe Kalk	-	46.3	62.5	57.3	25.6	21.3	29.8	30.3	39.1	30.1
From other producers	-	54.4	29.5	13.9	24.8	38.1	39.3	36.5	33.9	33.4
From sugar production	5.8	5.1	5.8	4.7	2.0	2.6	2.9	2.2	1.3	0.7
Total lime production	133.8	105.9	97.8	75.9	52.4	62.0	72.0	69.0	74.2	64.2

[1] Faxe Kalk (2016a, b).

[2] Non-ETS producers of marketed lime, calculated as national statistics data minus Faxe Kalk.

[3] Data from the sugar factories.

Emission factors

The emission factor for calcination of both marketed and non-marketed calcium carbonate is based on measurements from Faxe Kalk in 2008-2012; the emission factor applied is 0.788 kg CO_2 per kg CaO Faxe Kalk 2016a). These measurements include a small impurity of MgO. It is assumed that the degree of calcination is 100 % and that no lime kiln dust (LKD) emits the process.

Emission trends

The trend for the CO_2 emission from lime production, including sugar production; is available in Annex 3C-7 and Figure 4.2.3.

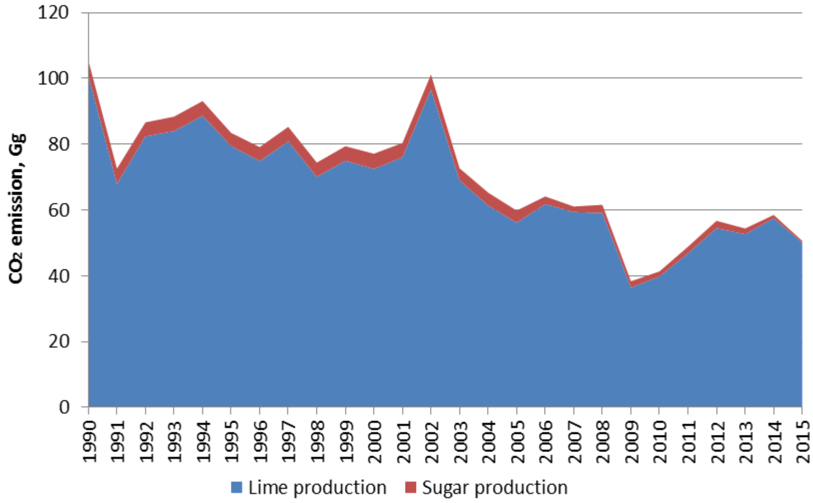

Figure 4.2.3 Emission of CO_2 from lime production.

The emission from sugar production only comprise 1 % (2015) to 6 % (1991) of the total CO_2 emission from lime production; 5 % in average over the time series.

The activity data are based on the official statistics from Statistics Denmark and there is no immediate explanation to the peak in 2002. There are very few producers in Denmark and therefore it will not be possible to obtain more detailed information from Statistics Denmark.

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 – 2015.

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; these are constant at 0.788 Mg CO_2 per Mg lime for all years and for both marketed lime production and production of lime in the sugar industry.

If the simple Tier 2 methodology had been used instead of using plant specific emission factors from EU-ETS data; i.e. assuming that the MgO impurity is negligible by applying the default 0.7848 Mg CO_2 per Mg lime produced, then the emission from lime production would be 0.1 % (2006) to 0.5 % (2010) lower; average of 1990-2015 is 0.4 %, proving that the impurity is in fact insignificant..

Time series consistency and completeness

The chosen methodology, activity data and emission factor for calculation of CO_2 emissions from marketed lime are consistent throughout the time series.

All though the activity data for non-marketed lime production at the sugar factories are based on actual carbonate consumption from 1996 onward and on estimated consumptions for 1990-1995, the methodology and applied emission factor are both constant and this source category is therefore considered to be consistent.

With regards to completeness concerning production of other lime products than burnt lime, dolomitic lime is not produced in Denmark and 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 statistical data on which the calculations are based, and adding the production of slaked lime to the activity data would therefore result in double counting.

Other industries that typically use lime as an intermediate product are chemical-, metal-, production for emissions abatement etc. have been searched with respect to completing this source but nothing was found. Regarding industries producing lime as intermediate products only one was identified (i.e. Nordic Sugar). Denmark has virtually no chemical or metal industry, so the need for lime in the Danish industry is non-existing with the exception of the sources listed, and the sector must therefore be considered to be complete.

4.2.5 Glass production

Glass production in Denmark includes production of:

- Container glass
- Industrial art glass
- Glass wool

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.

Information on consumption of carbon containing raw materials in the glass industry is available from the environmental reports since

1997 (Ardagh, 2015) and from EU-ETS since 2006 (Ardagh, 2016). For the years prior to 1997 the production of glass is based on information contained in Illerup et al. (1999). 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.

Information on consumption of carbon containing raw materials is available from the environmental reports of the plant since 1996 (Saint-Gobain Isover, 2015) and EU-ETS since 2006 (Saint-Gobain Isover, 2016). For the years prior to 1996 the production of glass wool and consumption of carbonates are estimated.

Activity data

The activity data for glass production are presented in Table 4.2.8 and Annex 3C-8.

Table 4.2.8 Production of glass, activity data, Gg.

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
Production of glass[1, 2]	164.0	140.0	183.3	168.2	172.9	186.5	209.6	159.9	162.9	155.7
Consumption of soda ash[3, 4]	17.8	15.2	16.4	13.0	c	c	c	c	c	c
Consumption of limestone[3,4]	14.4	12.3	7.7	5.7	c	c	c	c	c	c
Consumption of dolomite[3,4]	1.0	0.8	9.1	6.1	c	c	c	c	c	c

[1] 1990-1997: Illerup et al. (1999).
[2] 1998-2015: Estimated based on Illerup et al. (1999) and consumption of raw materials.
[3] 1990-1996: Estimated based on Illerup et al. (1999) and the consumption of raw materials in 1997.
[4] 1997-2015: Environmental reports and EU-ETS data; Ardagh (2015, 2016)
c Confidential: data from EU-ETS (Ardagh, 2016)

The activity data for glass wool production are presented in Table 4.2.9 and Annex 3C-9.

Table 4.2.9 Production of glass wool, activity data, Gg.

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
Production of glass wool	35.6	35.6	39.7	37.3	24.9	29.8	26.8	27.9	28.8	33.0
Consumption of soda ash[2]	3.6	3.6	3.0	3.6	c	c	c	c	c	c
Consumption of limestone[2]	0.8	0.8	0.2	0.6	c	c	c	c	c	c
Consumption of dolomite[3]	1.0	1.0	1.0	1.0	c	c	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.
[4] Environmental reports (Saint-Gobain Isover, 2015)
c Confidential: data from EU-ETS (Saint-Gobain Isover, 2016)

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, 2016; Saint-Gobain Isover, 2016), but the applied emission factors remain the same for the entire time series.

Emission trends

For the years from 2006 onward, information on CO_2 emission has been available in the company's reports to the EU ETS (Ardagh, 2016; Saint-Gobain Isover, 2016). However, this information is confidential and therefore not presented individually.

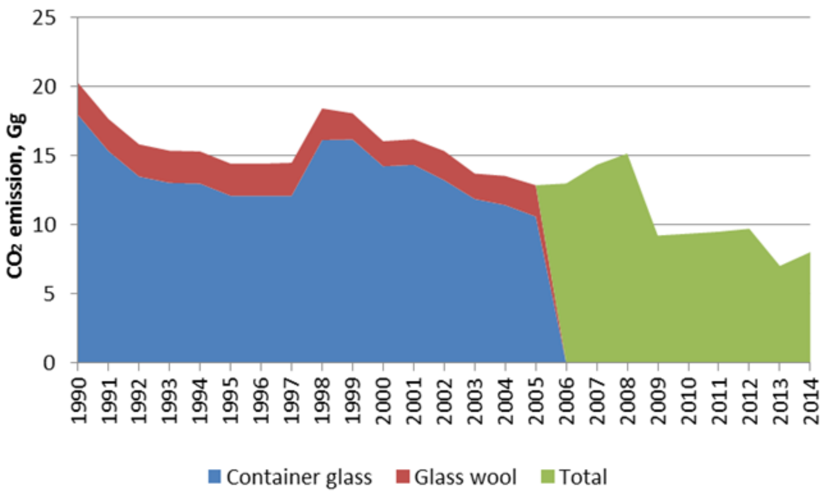

Figure 4.2.4 CO_2 emissions from glass production.

EU-ETS data for glass production

The applied methodologies for Ardagh Glass Holmegaard and Saint-Gobain Isover are specified in the individual monitoring plan that is approved by Danish authorities (DEA) prior to the reporting of the emissions.

Glass production applies the Tier 3 for both methodology and emission factors as the calculations are based on individual carbonates used as raw materials.

The CO_2 emission from glass production is based on consumption of carbonate raw materials (based on invoices and corrected for changes in inventory by measures on the storage silos; Tier 2: 1.10-1.37 % depending on the silo) and standard emission factors except for dolomite where Ca/Mg analysis are performed for each new batch (Ardagh, 2012)

The CO_2 emission from glass wool production is based on weight measures of carbonate raw materials (Tier 1: ± 2.5 %) and standard emission factors (Saint-Gobain Isover, 2012).

Verification

For verification purposes, the implied emission factors for glass production are presented in Figure 4.2.5.

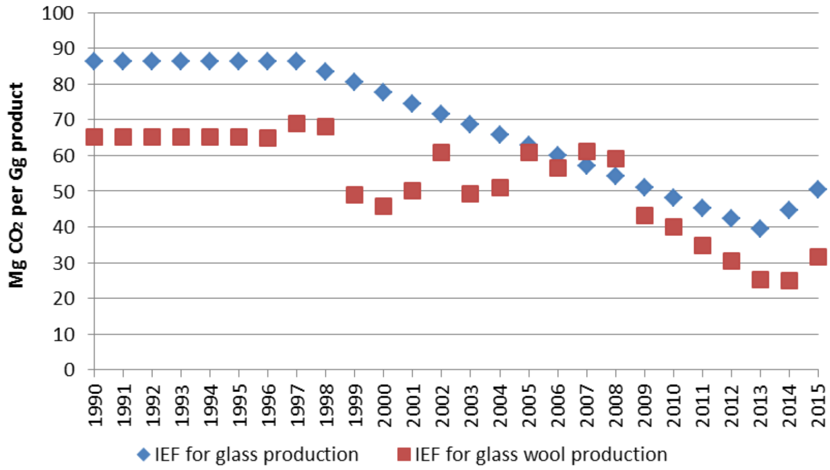

Figure 4.2.5 Implied emission factors for glass production.

Figure 4.2.5 shows that improvements in both glass production processes have lowered the IEFs significantly during the time series.

CO_2 emissions from container glass production are calculated using a Tier 1 and Tier 2 method respectively and compared with the applied Tier 3 method, see Figure 4.2.6. The following assumptions are used for the two lower Tiers:

- Tier 1: 0.2 Mg CO_2 per Mg product and 0.5 cullet ratio (IPCC, 2006[2])
- Tier 2: 0.21 kg CO_2 per kg container glass (IPCC, 2006[3]) and the actual annual cullet ratios (0.34-0.76)

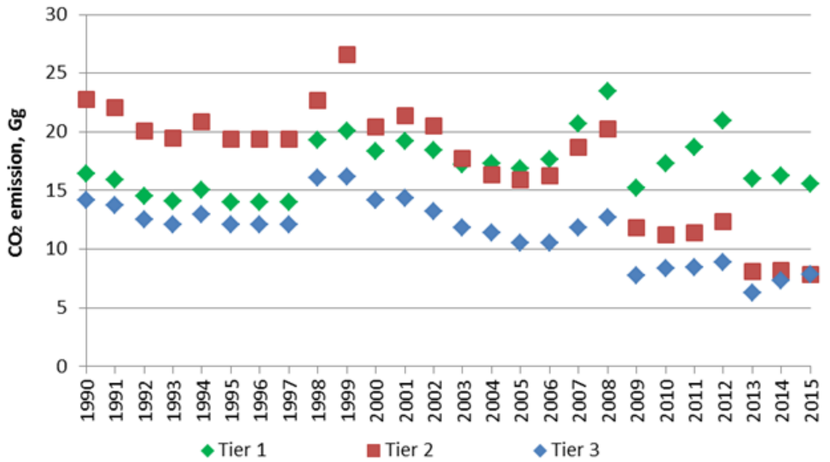

Figure 4.2.6 Comparison of CO_2 emission from container glass production calculated using different methods.

The Tier 1 method is a pretty good match in the beginning of the 90's, but as the Danish production betters over the years, the basis of the Tier 1 estimate is unvarying. The Tier 2 calculations (including the actual cullet ratios known for 1997-2002 and 2004-2013) are in good agreement with the Tier 3 calculations with a similar decrease in emis-

[2] Volume 3 Industrial Processes and Product Use, Chapter 2.4.1.2 page 2.29 and chapter 2.4.1.3, page 2.30.
[3] Volume 3 Industrial Processes and Product Use, Chapter 2.4.1.2 page 2.30 (Table 2.6).

sions; however Tier 2 generally results in an overestimation of emissions up until 2015.

A similar verification using different method Tiers is not possible for glass wool since there are no default estimation methods available.

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.

In relation to completeness, 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.

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 (2016) 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/tiles and expanded clay products (used as surrogate data) and the consumption of lime in the production (calculated for 1990-2005) are presented in Table 4.2.10 and Annex 3C-10.

Table 4.2.10 Statistics for production of bricks/tiles and expanded clay products.

		1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
Bricks and tiles											
Produced[1]	mil. pieces	315.2	385.6	436.3	426.5	223.0	234.2	196.3	186.7	199.3	226.7
Consumed lime	Gg $CaCO_3$	58.8	71.9	81.4	79.5	35.1	46.0	39.7	36.7	38.7	46.2
Expanded clay products											
Produced[1]	Gg	331.8	340.9	316.2	310.9	157.4	172.3	153.3	139.8	137.7	155.0
Consumed lime	Gg $CaCO_3$-eq	37.1	38.1	35.3	34.7	13.7	15.1	13.4	23.8	22.5	19.4

[1] Statistics Denmark (2016).

[2] 1990-2005: Calculated from production data and the average implied emission factor for 2006-2013.

Emission factors

The emission factor for lime is 0.43971 kg CO_2 per kg $CaCO_3$. The calcination factor is assumed to be 1 for all years and all producers.

For 2006-2015 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 2006-2015 (Damolin, 2016; Saint-Gobain Weber, 2016). 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/tiles and expanded clay products is available in Annex 3C-11 but is also presented in Figure 4.2.7.

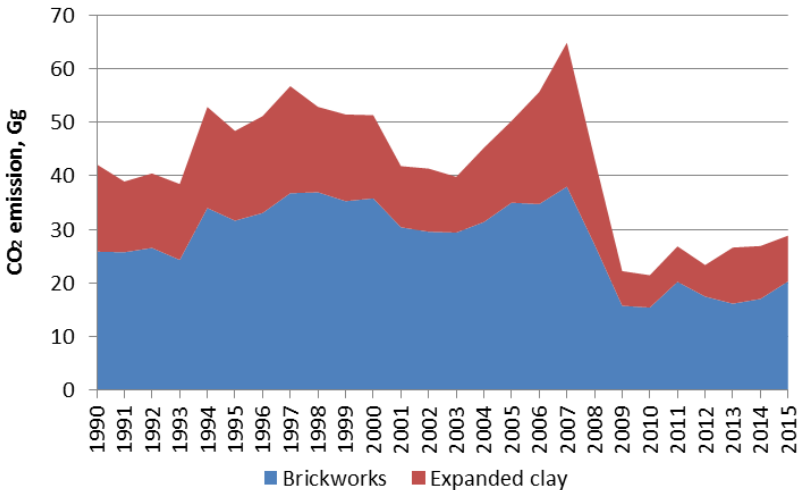

Figure 4.2.7 CO_2 emissions from the production of ceramics.

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.

Verification

For 2013-2015, the brickwork companies have reported production of brick/tile products (Mg) and thereby making it possible to verify the applied production data from Statistics Denmark for these years. A comparison of the two datasets is presented in Table 4.2.11.

Table 4.2.11 Verification of production data from Statistics Denmark against EU-ETS data.

	Unit	2013	2014	2015
Statistics Denmark[1]	Mg product	466790	498335	566685
EU-ETS	Mg product	465865	492557	558242
Difference	Mg product	925	5778	8443
Difference	%	0.2	1.2	1.5

[1] Data are calculated into Mg (from pieces) using the assumption of 2.5 kg/brick and tile

The data presented in Table 4.2.11 shows a good agreement between the two data sources. All though it is difficult to conclude anything with only three data years, this comparison indicates that all Danish brickworks report to EU-ETS and that this source is therefore complete.

Figure 4.2.8 presents the calculated implied emission factors for ceramics and for the individual product types bricks/tiles and expanded clay products.

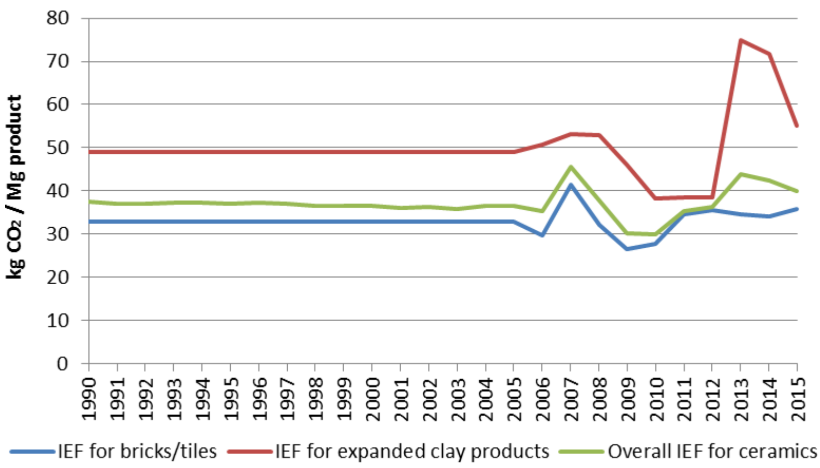

Figure 4.2.8 Implied emission factors for ceramics.

The IPCC (2006)[4] default emission factor for ceramics is 49.0 kg CO_2 per Mg product which is within reasonable compliance with the IEFs of Figure 4.2.8.

The IEF for expanded clay products displays a significant increase for from 2012 to 2013. This is caused by a strong increase in carbonate consumptions from Saint-Gobain Weber (Hinge) (EU-ETS) in spite of a decreasing production (national statistics). The company has explained that the estimates made by the company prior to 2013 did not take into account the carbonate content of the clays used but only the pure carbonates.

Figure 4.2.9 shows the CO_2 emissions from production of ceramics calculated by the Tier 1 method (IPCC, 2006) and the applied Tier 2 method.

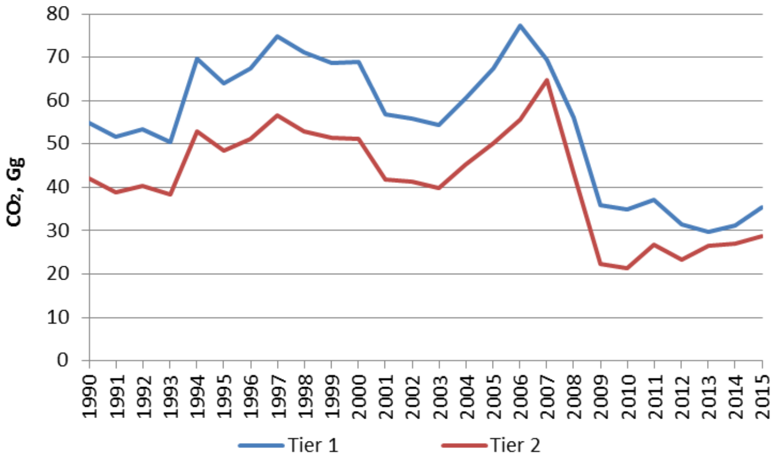

Figure 4.2.9 Comparison of emissions calculated by Tier 1 and Tier 2 method.

Time series consistency and completeness

Emissions from 2006-2015 are known from the EU-ETS reports and emissions for 1990-2005 are estimated. However, due to the various performed verifications, the ceramics source category is considered to be consistent.

The inventory is based on companies reporting to EU-ETS and national sales statistics, but clay is also burned in minor scale e.g. ceramic art workshops and school art classes. These miniscule 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

[4] Volume 3 Industrial Processes and Product Use, Chapter 2.5.1.3 page 2.36, Chapter 2.5.1.1 page 2.34 and Chapter 2.1 page 2.7 (Table 2.1).

Methodology

Emissions from other uses of soda ash (Na_2CO_3) are calculated based on national statistics on import/export (subtracted the amount used in the glass industry) and the stoichiometric emission factor.

Activity data

National statistics on import/export and the calculated activity data (supply) are presented in Table 4.2.12 and Annex 3C-12.

Table 4.2.12 Statistics for other uses of soda ash, Gg.

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
Import	54.6	47.6	42.0	59.5	36.5	23.0	32.3	29.9	36.1	33.1
Export	0.09	2.13	0.31	0.01	0.06	0.09	0.08	0.10	0.10	0.09
Glass production	21.4	18.8	19.4	16.6	10.7	10.9	11.2	8.2	7.2	8.6
Supply	33.2	26.7	22.3	42.9	25.7	12.1	21.0	21.6	28.8	24.4

Emission factors

The applied emission factor for other uses of soda ash is 414.92 kg 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 Figure 4.2.10 and Annex 3C-13.

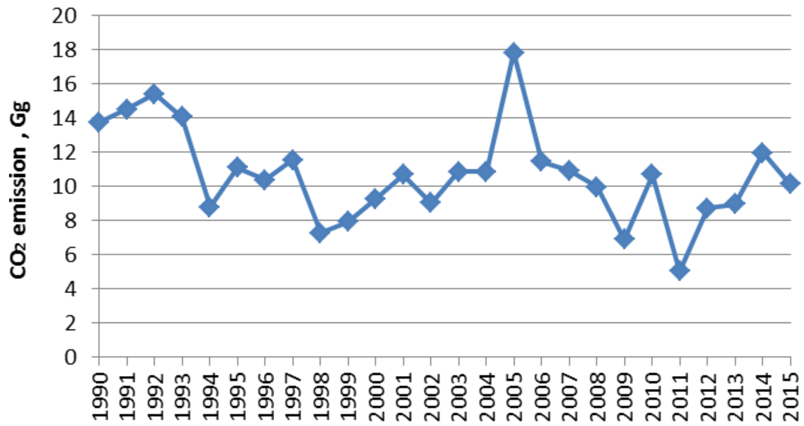

Figure 4.2.10 CO_2 emissions from other uses of soda ash.

Information on the uses of soda ash outside the glass industry is scarce, and descriptions of the trend development are therefore not available.

Verification

Annex 3C-14 presents a comparison of the applied national data from Statistics Denmark with that of Eurostat for the years 2000-2013. The two datasets are in good agreement with each other.

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 consistent. Calculations are based on national import/export statistics and are therefore also complete as there is no production of soda ash in Denmark.

There is no information available on how the soda ash in this source category is used, and there is therefore no way of knowing if the use is emissive. It is fair to assume that this source category contains an unknown overestimation as it is unlikely that all soda ash uses are emissive as this applied worse case methodology assumes.

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. Information on limestone consumption is available from EU-ETS for 2006-2015.

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 1990-2013. 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. For 1990-2005, the generation of gypsum data have been used as surrogate data.

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, four of the nine coal fired power plants have changed to alternative fuels 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.

The activity data are presented in Table 4.2.13 and Figure 4.2.11.

Table 4.2.13 Activity data for fluegas desulphurisation, Gg.

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
Gypsum production[1]	41.6	211.5	354.3	220.4	185.8	147.6	100.9	153.3	-	-
$CaCO_3$ consumption[2, 3]	22.0	111.8	187.3	116.6	94.0	75.8	41.0	57.9	53.3	36.2

[1] Energinet.dk (2014)

[2] 1990-2005: Estimated from surrogate data and stoichiometric relations

[3] 2006-2015: EU-ETS of the individual plants

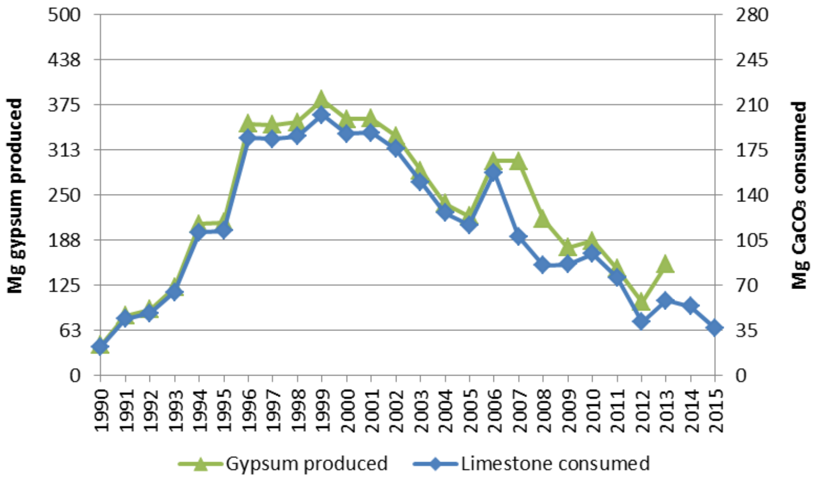

Figure 4.2.11 Activity data for flue gas desulphurisation.

The activity data level varies with the coal consumption that again varies greatly with electricity import/export.

Emission factors

The emission factor applied to the limestone consumption is the stoichiometric emission 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 Annex 3C-15 but is also presented in the "Verification" section below.

Verification

Three datasets are available, the gypsum generation from Energinet.dk and the limestone (equivalent) consumption from the environmental reports and EU-ETS respectively. The consumption data from the environmental reports (1998-2005) are not applied in the emission calculations but are displayed in the Figure below for verification purposes. CO_2 emissions are calculated from all three datasets which generally display a good agreement, see Figure 4.2.12.

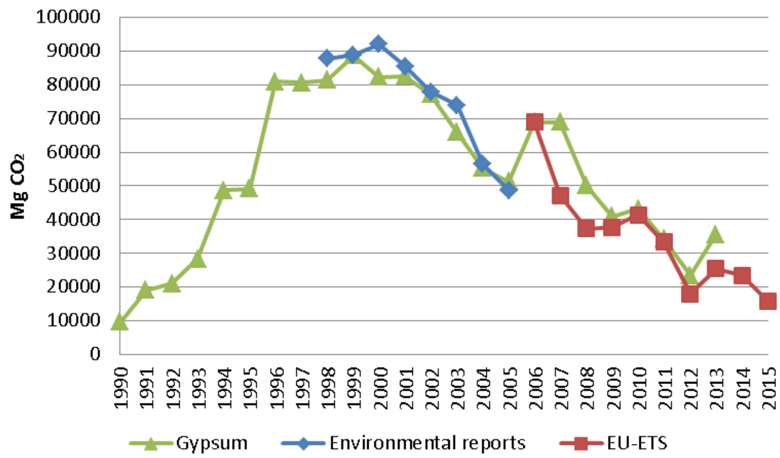

Figure 4.2.12 CO_2 emissions from flue gas desulphurisation calculated from gypsum consumption and limestone consumption compiled by environmental reports and EU-ETS respectively.

Emissions calculated from the limestone consumption data provided by the environments reports vary with -5 % (2005) to +12 % (2003) from the emission based on gypsum production. And emissions calculated from the limestone consumption data provided by the EU-ETS vary with -31 % (2007) to +0.1 % (2006) 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 Stone wool production

Only one company produces stone wool in Denmark, Rockwool situated at three localities: Hedehusene[5], Vamdrup and Øster Doense. The following SNAP-code is covered:

- 04 06 18 Limestone and dolomite use – Stone wool production

Emissions associated with the fuel use are estimated and reported in the energy sector.

Methodology

Stone 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 stone wool is confidential.

Information on emissions from 2006-2015 has in combination with yearly total 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 (Rockwool, 2016). CO_2 process emissions are available for the years 2006-2015 (EU-ETS) and the consumption of raw materials for 1995-2013 (environmental reports).

[5] The melting of minerals (cupola) has been closed down in 2002.

Emissions for 1990-1994 are estimated as the constant average of 1995-1999.

Calculations are performed for the three factories individually.

Activity data

The consumption of limestone equivalents are presented in Table 4.2.14 and Annex 3C-16.

Table 4.2.14 Activity data for stone wool production, Gg $CaCO_3$ equivalents.

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
Carbonate consumption	17.9	18.0	17.3	18.0	17.1	16.8	15.0	13.8	11.6	13.5

Emission factors

The applied emission factor for stone 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 stone wool production is presented in Figure 4.2.13 below.

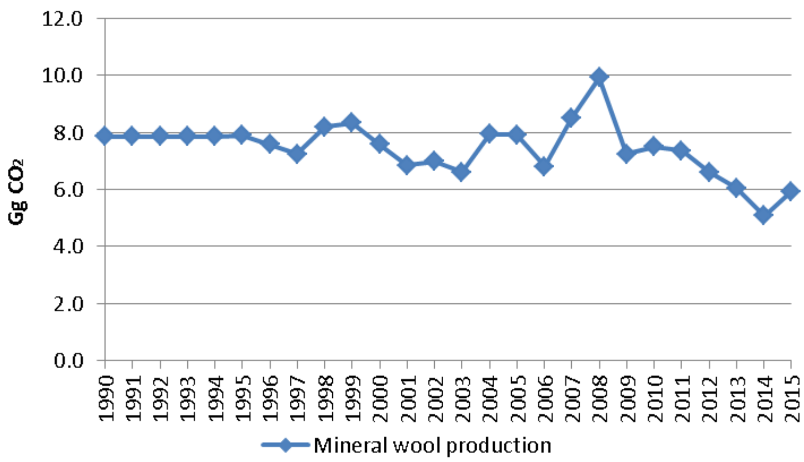

Figure 4.2.13 CO_2 emissions from stone wool production.

Time series consistency and completeness

The source category of stone wool production is complete but inconsistent, the inconsistency occurs because emissions for 2006 onward are known (EU-ETS) but emissions for 1990-2005 are estimated via surrogate data.

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 4.3.1 and individually in the subsections below (Sections 4.4.3 – 4.2.4). The following figure gives an overview of which source categories contribute the most throughout the time series.

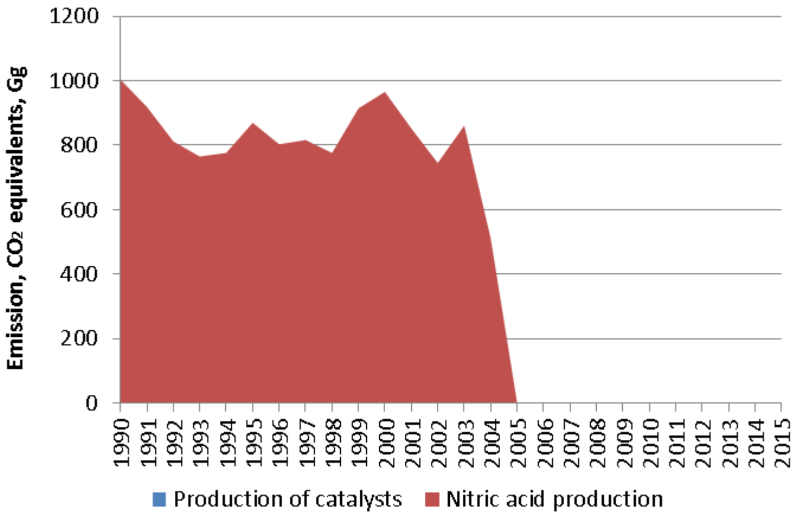

Figure 4.3.1 Emission of CO_2 equivalents from the individual source categories compiling *2B Chemical Industry*, Gg.

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 implied emission factor based on 2002.

Specific information on applied technology is not available; however, the emission factor measured by the Danish nitric acid plant is in accordance with the default emission factor for a medium pressure plant (IPCC, 2006).

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	1998	1999	2000	2001	2002	2003	2004
Nitric acid	450	412	364	343	348	390	360	366	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 375 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[6]) 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 Figure 4.3.1 and Annex 3C-17.

The trend for N_2O emission 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 are based on information from the specific company/plant. 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.

[6] Volume 3 Chemical Industry, Chapter 3.3.2.2 page 3.23 (Table 3.3).

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, 2016b) and the CO_2 emission from energy consumption reported to EU-ETS (Haldor Topsøe, 2016a). 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 and Annex 3C-18.

Table 4.3.3 Production of catalysts and potassium nitrate, Gg.

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
Catalysts	17.0	17.0	17.2	23.2	20.5	22.3	22.9	25.1	27.0	29.5
Potassium nitrate	18.4	18.4	19.2	23.3	25.9	25.3	32.9	31.9	34.3	35.2
Catalysts+KNO_3	35.4	35.4	36.4	46.5	46.4	47.5	55.8	57.1	61.2	64.7

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 2015, the emission of CO_2 from the production of catalysts/fertilisers has increased from 0.9 to 1.5 Gg with maximum in 2015, due to an increase in the production 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 Annex 3C-19 and in Figure 4.3.2.

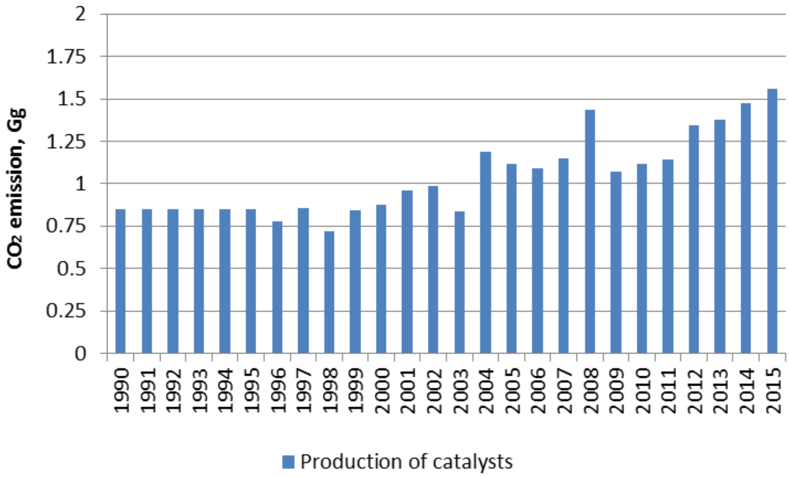

Figure 4.3.2 Emission of CO_2 catalyst/fertiliser production Gg.

Time series consistency and completeness

There is an inconsistency between the methodology applied for 1997-2015 and the one applied for 1990-1996 as the latter is estimated by simply keeping is constant. The source category of catalyst production is complete.

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 greenhouse gasses from *Metal production* (2C) is presented in the CRF tables and in Figure 4.4.1 below.

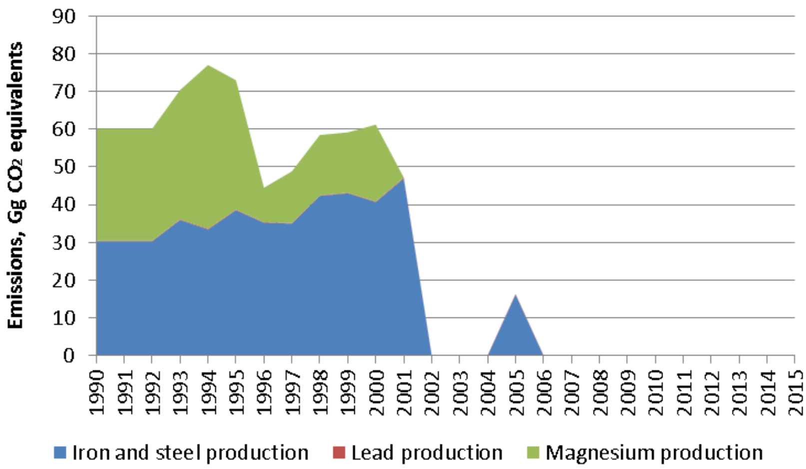

Figure 4.4.1 Emission of greenhouse gasses from the individual source categories compiling *2C Metal Industry*, Gg CO_2 equivalents.

From 1990 to 2001, the CO_2 emission from the electro-steelwork increased by 55 % whiles the SF_6 emission from magnesium production decreased with 32 % (1990-2000). 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 % of CO_2e emissions 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.

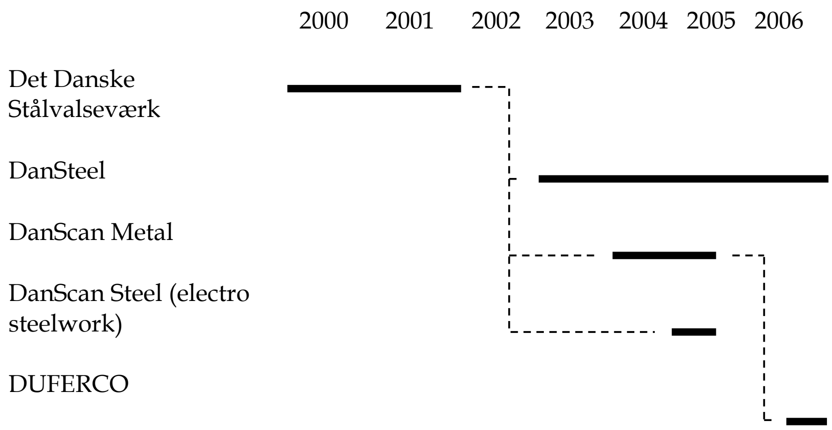

Figure 4.4.2 Timeline for production at the Danish steelwork.

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 1993 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 of 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 and Annex 3C-20.

Table 4.4.1 Overall mass flow for Danish steel production, Gg.

		1990	1995	2000	2005
Det danske stålvalseværk					
Raw material	Iron and steel scrap	-	657	731	-
Intermediate product	Steel slabs etc.	-	654	803	-
Product	Steel sheets	444[1]	478	380	-
	Steel bars	170[1]	239	251	-
	Products, total	614[1]	717	631	250[2]
Raw material	Metallurgical coke	8.3	10.5	11.1	4.4

[1]Extrapolation, [2]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 Figure 4.4.3 and Annex 3C-21. The production ceased in 2001 and reopened and closed again in 2005; see Figure 4.4.2.

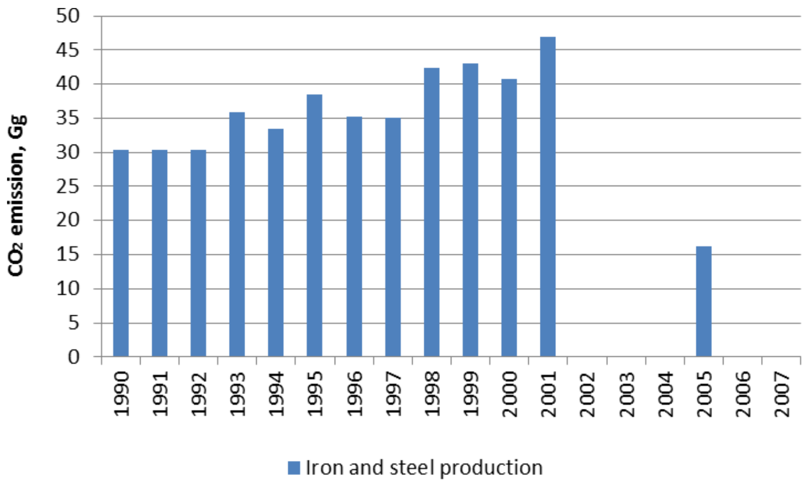

Figure 4.4.3 Emission of greenhouse gasses from the production of steel from scrap.

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 (2016). Activity data can be calculated from the SF_6 consumption and the default Tier 1 emission factor.

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[7]).

Emission trends

The greenhouse gas emissions from the production of magnesium are presented in Figure 4.4.4 below. The consumption of SF_6 ceased in 2000.

[7] Volume 3: Industrial Processes and Product Use, Chapter 4.5.2.2: Magnesium Production, Choice of emission factors, Table 4.20, page 4.66.

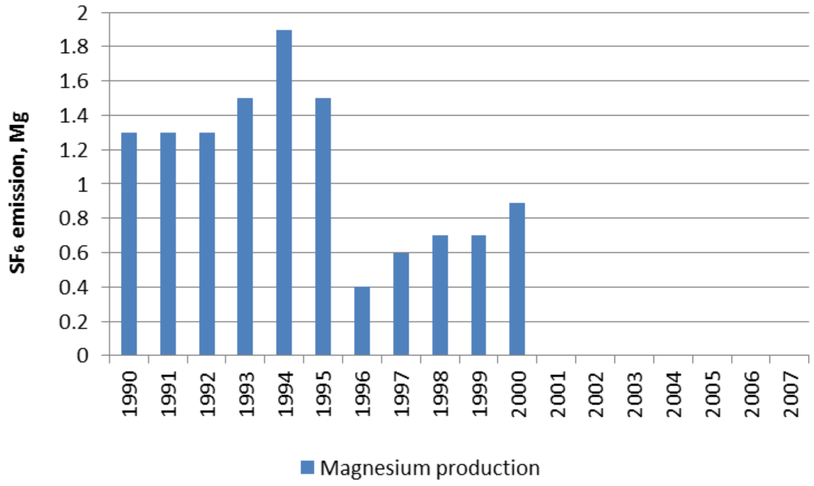

Figure 4.4.4 Emission of greenhouse gasses from the production of magnesium.

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 are 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 production is shown in Table 4.4.3 and Annex 3C-22.

Table 4.4.3 Activity data for secondary lead production (Hals metal, 2015 and Lassen et al., 2004), Mg.

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
Hals metal	540	750	540	691	635	938	412	533	625	625
Lead tiles	250	250	250	250	250	250	250	250	250	250
Total	790	1000	790	941	885	1188	662	783	875	875

Emission factors

The applied CO_2 emission factor for secondary lead production is the default Tier 1 factor of IPCC (2006)[8]; 0.2 Mg per Mg product.

Emission trends

The greenhouse gas emissions from the production of secondary lead are presented in Figure 4.4.5 below.

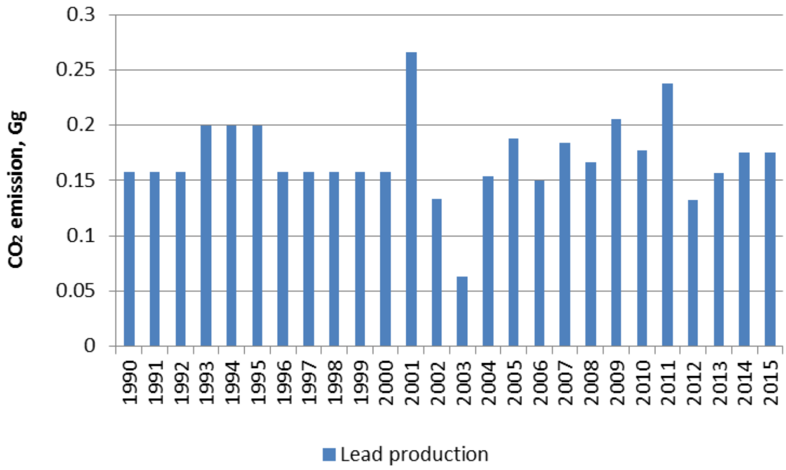

Figure 4.4.5 Emission of greenhouse gasses from secondary lead production.

Time series consistency and completeness

The time series for secondary lead production is considered to be both consistent and complete.

4.5 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, SNAP 060607)

The CO_2 emission from paraffin wax use is identified as key category 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

[8] Volume 3: Industrial Processes and Product Use, Chapter 4.6.2.2: Choice of emission factors, Table 4.21, page 4.73.

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	2014
Lubricants	3 372	3 314	2 693	2 550	2 251	2 150	2150	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	2014
Lubricants	49.7	48.8	39.7	37.6	33.2	31.7	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 2014.

The applied methodology has been the same for all years (1990 to 2014) 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 (2015). Complete time series can be seen in Annex 3C-3

Table 4.5.3 Use of paraffin wax candles (Gg) (Statistics DK, 2015).

2D2	1990	1995	2000	2005	2010	2011	2012	2013	2014
Paraffin wax use	7.4	9.1	16.9	34.4	35.3	30.2	27.9	29.1	30.3

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	2014
CO_2 (Gg)	21.7	26.5	49.3	100	103	87.8	81.1	84.7	88.3
N_2O (Mg)	0.18	0.22	0.41	0.83	0.85	0.72	0.67	0.70	0.73
CH_4 (Mg)	0.90	1.10	2.05	4.17	4.27	3.65	3.37	3.52	3.67

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. (2016) Chapter 4.5.1.

Activity data

Description of compilation of activity data can be found in Nielsen et al. (2016) 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	2014
Paint application (SNAP 0601)	83.2	82.2	91.1	104	74.2	45.8	42.8	42.3	46.3	40.3
Degreasing, dry cleaning (SNAP 0602)	1.41	1.41	1.53	0.59	0.37	0.25	0.22	0.055	0.097	0.19
Chemical products manufacturing or processing (SNAP 0603)	406	406	504	567	740	641	640	516	517	485
Other use of solvents and related activities (SNAP 0604)	197	206	256	239	213	178	176	176	190	155

Emission factors

Description of derivation of emission factors can be found in Nielsen et al. (2016) 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	2014
Paint application (SNAP 0601)	0.19	0.16	0.16	0.16	0.14	0.14	0.16	0.16	0.16	0.16
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	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	0.023
Other use of solvents and related activities (SNAP 0604)	0.31	0.31	0.29	0.29	0.24	0.25	0.25	0.25	0.26	0.26

Emission trends

Table 4.5.8 and Figure 4.5.1 show the emissions of CO_2 from 1985 to 2014. 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 2014, with a slight increase in 2013. Further information can be found in Nielsen et al. (2016) 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	2014
Paint application (SNAP 0601)	12.8	12.8	14.6	15.8	10.3	6.47	6.83	6.80	7.40	6.30
Degreasing, dry cleaning (SNAP 0602)	3.8E-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	5.2E-06
Chemical products manufacturing or processing (SNAP 0603)	19.4	19.4	22.0	17.0	15.6	12.5	12.0	12.2	11.6	10.9
Other use of solvents and related activities (SNAP 0604)	61.4	61.4	72.1	67.6	49.9	44.7	44.0	43.7	49.3	40.3
Total CO_2	93.6	93.6	109	100	75.8	63.7	62.9	62.7	68.3	57.5

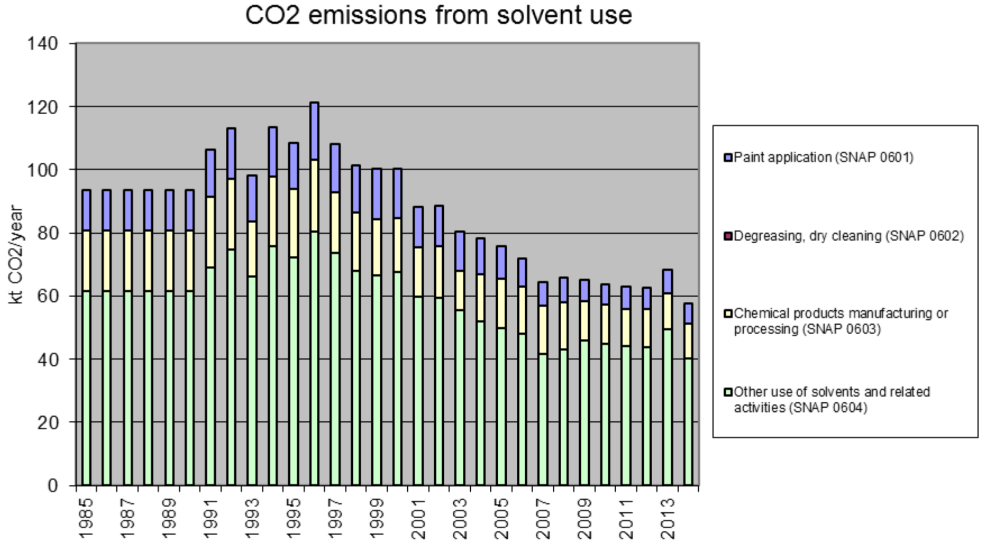

Figure 4.5.1 CO_2 emissions in Gg CO_2 per year. Figures can be seen in Table 4.5.8 and in Annex 3C-7.

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 (2015).

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	2014
Road paving with asphalt	2370	2370	3144	2933	3879	3005	3896	3233	3339	3429

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	2014
CO_2	0.093	0.123	0.115	0.115	0.118	0.152	0.126	0.131	0.134
CH_4	0.011	0.015	0.014	0.019	0.015	0.019	0.016	0.016	0.017
CO	0.178	0.236	0.220	0.291	0.225	0.292	0.242	0.250	0.257

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 (2015).

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	2014
Asphalt roofing (NFR 2D3c)	120	120	123	204	187	105	134	131	125	152

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	2014
CO_2	0.0282	0.0282	0.0290	0.0478	0.0439	0.0247	0.0315	0.0307	0.0294	0.0357
CO	0.00114	0.00114	0.00117	0.00194	0.00178	0.00100	0.00128	0.00124	0.00119	0.00144

There is a 26% increase in emissions from 1990 to 2014, 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 – 2014) can be seen in Annex 3C-12.

	2001	2005	2010	2011	2012	2013	2014
Urea (CRF 2D3 Other)	0.00217	0.0367	10.201	15.286	20.187	24.961	28.825

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	2014
CO_2	0.00052	0.0087	2.433	3.646	4.815	5.954	6.876

There is a significant increase in urea consumption and CO_2 emissions from 2001 to 2010, and a smaller increase from 2010 to 2014.

4.5.8 Source specific recalculations and improvements

Emissions from use of spray cans (CRF 3D3 Other-Solvent Use) have been updated. Previously only the propellant (propane and butane) was included but now, solvents are included as well as adjusted propellant amounts. Propellants comprise, according to communication with "Aerosol Industriens Brancheforening" and FORCE (2009), approx. 33 vol-% (24 weight-%) of a can. According to Rambøll (2004) the remaining amount is solvents (VOCs), 71 weight-% for spray paint and 51 weight-% for cosmetics, and non-VOCs, 5 weight-% for spray paints and 25 weight-% for cosmetics. 3% of the Danish marked is spray paints. The rest is cosmetics, which comprises deodorants, hairspray and foam products. 90% of the use in Denmark is imported. It is assumed that approx. 5% remains in the can and is destroyed in waste handling. Based on these assumptions the total VOC emissions from use of spray cans in Denmark is 1788 tonnes per year, which is an increase of 454 tonnes per year. This amount is assigned to all years as no detailed consumption trend is available. The specific compounds are propane and butane as propellants and ethanol, tert-butanol, acetone, butanone, butylacetate, ethylacetate, propanol, toluene and xylene as solvents.

Rambøll, 2004: Kortlægning af kemiske stoffer i forbrugerprodukter. Kortlægning nr. 45 fra Miljøstyrelsen.

FORCE, 2009: Revision af beregninger af danske VOC emissioner fra opløsningsmidler og husholdninger. Arbejdsrapport fra Miljøstyrelsen nr. 5.

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

The sector *Electronic Industry* (CRF 2E) covers the 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) and PFC-318 (c-C_4F_8) from Fibre optics

The description of consumption and emission of F-gases given below is based on an inventory published as Poulsen (2016). 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 2006-2015; however, no emissions occurred in 2015. The emission time series for *Electronics Industry* (2E) is available in the CRF tables but is also presented in Figure 4.6.1.

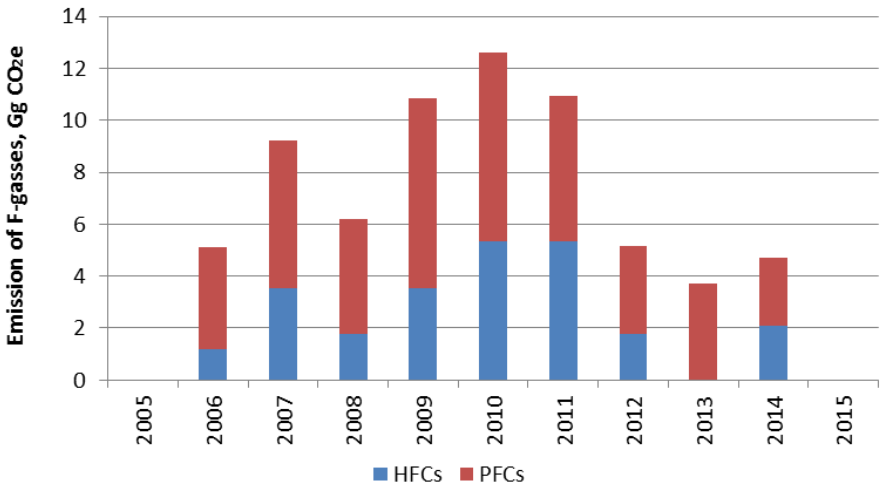

Figure 4.6.1 Emissions of HFCs and PFCs from *Electronics Industry.*

4.6.3 Other electronics industry

As mentioned above, optic fibre production is the only source category relevant for the Danish inventory on electronic industries.

Methodology

Both HFCs (HFC-23) and PFCs (PFC-14 & PFC-318) are used for technical purposes in Danish optics fibre production for protection and as cleaning gases in the production process. Information on consumption of HFCs and PFCs in production of fibre optics is derived from annual importers' sales report with specific information on the amount used for production of fibre optics. This is thought to represent 100% of the Danish consumption of F-gases for that purpose. The emission factor is 1, i.e. 100 % release in the production year (i.e. year of consumption). The methodology corresponds to the IPCC Tier 2 method.

Activity data

The consumption of PFCs from fibre optics production was 0.3 Mg in 2014 and HFCs 0.1 Mg. There was no use of HFC-23 in 2013 and no use of either PFCs or HFCs in 2015. The consumption data are provided in Table 4.6.1 below.

Table 4.6.1 Consumption of F-gases in the production of fibre optics, Mg.

	2006	2007	2008	2009	2010	2011	2012	2013	2014
HFC-23	0.08	0.24	0.12	0.24	0.36	0.36	0.12	NO	0.14
PFC-14 (CF_4)	0.25	0.14	0.11	0.36	0.36	0.20	0.18	0.50	0.08
PFC-318 (c-C_4F_8)	0.20	0.45	0.35	0.45	0.45	0.40	0.20	NO	0.20

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 % release during production.

Emission trends

Emission trends are presented in Table 4.6.2 below.

Table 4.6.2 Emissions from Electronics industry.

	Unit	2006	2007	2008	2009	2010	2011	2012	2013	2014
HFC-23	Gg CO_2e	1.18	3.55	1.78	3.55	5.33	5.33	1.78	0	2.07
PFC-14 (CF_4)	Gg CO_2e	1.86	1.03	0.80	2.66	2.66	1.48	1.33	3.70	0.59
PFC-318 (c-CF_4F_8)	Gg CO_2e	2.06	4.635	3.605	4.635	4.635	4.12	2.06	0	2.06
Total	Gg CO_2e	5.11	9.22	6.18	10.85	12.62	10.93	5.17	3.70	4.72

Time series consistency and completeness

The estimates are based on information directly from the importer supplying this sector in Denmark. As Denmark is a small country with a limited consumption of F-gasses, there are only few importers. Data collection for the F-gas report (Poulsen, 2016) is done in close corporation with the industry associations enabling inclusion of any new importers of F-gases or F-gas containing products. The time-series is therefore considered both complete and consistent.

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, -143a, -152a, unspecified mix of HFCs, 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 level in 2014 and for trend (both Approach 1 and Approach 2) and foam blowing agents for level in the base year and for trend (Approach 2).

The description of consumption and emission of F-gases given below is based on an inventory published as (Poulsen, 2016). 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 Figure 4.7.2 below.

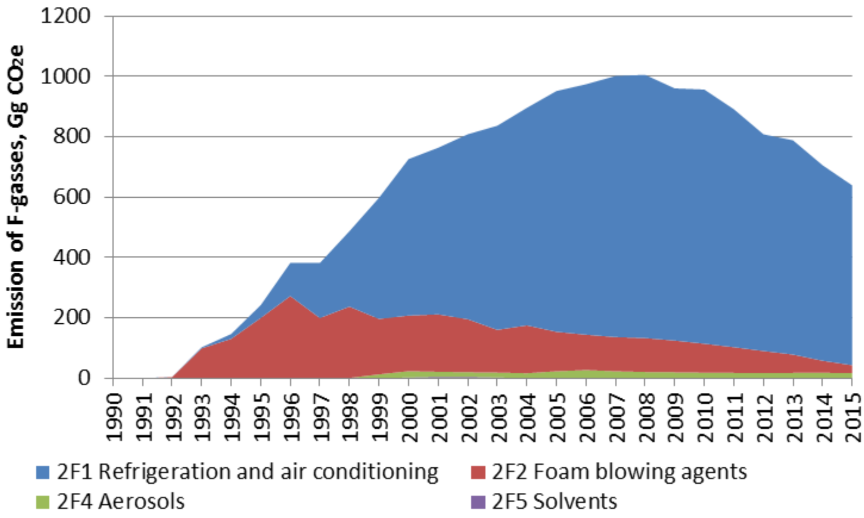

Figure 4.7.1 Emission of F-gases from the individual source categories within *2F Product uses as substitutes for ODS*, Gg CO_2e.

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.

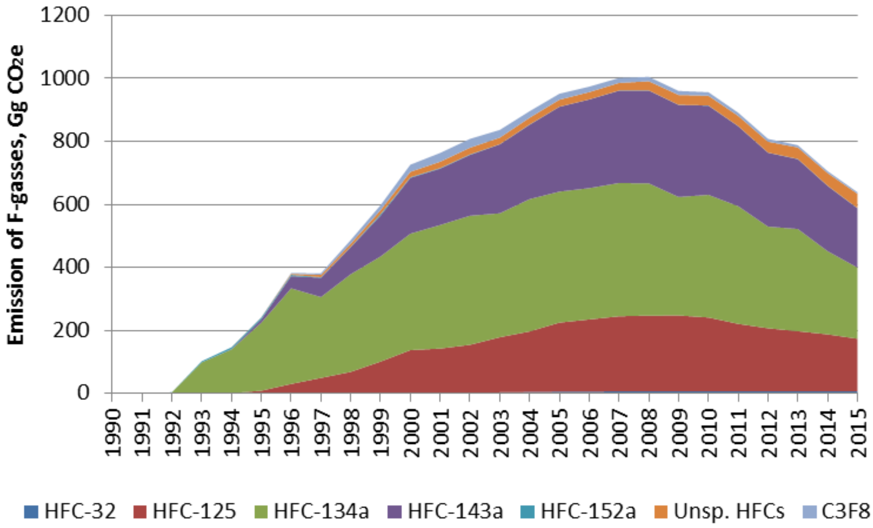

Figure 4.7.2 Emission of F-gases from the individual gases within *2F Product uses as substitutes for ODS*, Gg CO_2e.

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 closed cell and open cell foam production, during the period 2001-2004. Especially the phase-out of HFCs in open cell foam is significant for the emission in this period.

Since the introduction of taxes on HFCs in 2001, the consumption decreased from foams, but the emission of HFCs for refrigeration continued to increase until 2008, 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 are now introduced and available for customers.

The import of PFC-218 (C_3F_8) has been very low since 2008, and it is expected that this refrigerant will be phased out of the marked. The vast majority of emissions occurs from the existing stock but is naturally decreasing. The use of PFC-218 (C_3F_8) as a solvent only occurred from 2000 to 2003.

A quantitative overview is given below for each of these source categories, showing their emissions in Mg CO_2e through the times-series.

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, 2016), 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 the 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 (2016).

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 is based on 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.

Whenever possible, consumption and emissions of F-gases are 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.

The substances have been accounted for in the annual 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 4.7.1 have been used.

Table 4.7.1 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-407c	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 national inventories for F-gases are provided and documented in an annual report (Poulsen, 2016). 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 (2016).

According to Danish law, refrigerators and air-conditioning equipment must be emptied before decommissioning by recovery, reuse or destruction of the remaining gases. It is reasonable to assume that this law is upheld in Denmark since waste collection is mandatory and there are no extra charges for e.g. getting rid of a used refrigerator. In addition, to recycling plants where companies and individuals can deliver their waste there is also a collection scheme, where e.g. used refrigerators are collected at the sidewalks and disposed of. Due to this there is no reason why people would chose to illegally dispose of an appliance when the legal disposal is both free and easy.

Activity data

The data collection is described in the Chapter 4.7.4 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 emission factors are presented in Table 4.7.2. The emission factors for commercial refrigerators, mobile A/C (MAC), 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, 2016).

Table 4.7.2 Applied EFs for refrigeration and air-condition systems (Poulsen, 2016).

	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 and applied for the years 2009 - 2011, and therefore, a new approach has been implemented in the calculation of emissions from these years onward. 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, 2016):

Consumption of HFC for MAC = refilled stock = emission

Emission trends

Figure 4.7.3 present the emissions of F-gases from consumption of HFCs and PFCs in the individual sub-categories of refrigeration and air-conditioning systems.

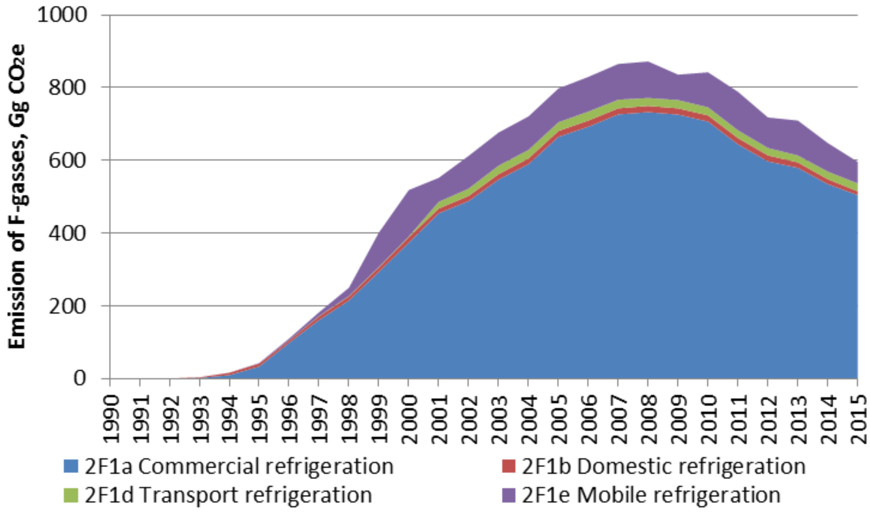

Figure 4.7.3 Emissions from refrigeration and air-conditioning.

F-gas emissions from commercial refrigeration are dominating the overall emissions from this source. Hence. the increasing trend from the mid-1990s to 2008 and the subsequent decrease in emissions are explained in Chapter 4.7.3.

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 IPCC (2006). 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 (2016).

Activity data

The data collection is described in the Chapter 4.7.4 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 emission factors for foam blowing agents are presented in Table 4.7.3.

Table 4.7.3 Applied EFs for foam blowing agents (2F2) (Poulsen, 2016 – appendix 3).

	Consumption	Stock	Lifetime
	%	%	years
Foam in household fridges and freezers (closed cell)	10[4]	4.5[4]	15[5]
Soft foam (open cell)[1]	100[4]		
Joint filler (open cell)[1]	100[4]		
Foaming of polyether for shoe soles (closed cell)	15[5]	4.5[5]	3[5]
System foam (for panels, insulation, etc.)	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. [4] IPCC (2006) default, [5] Danish default.

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 emission factors for foam in fridges and freezers, soft foam and joint filler are default values from (IPCC, 2006[1]). The emission factors for foaming of polyether are country-specific (Poulsen, 2016).

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 4.7.4 presents the emissions of F-gases from consumption of HFCs in foam blowing agents.

[1] Volume 3: Industrial Processes and Product Use, Chapter 7.4.2.1: Foam blowing agents, Choice of method, Table 7.5, page 7.35 and Chapter 7.4.2.3: Foam blowing agents, Choice of activity data, page 7.38.

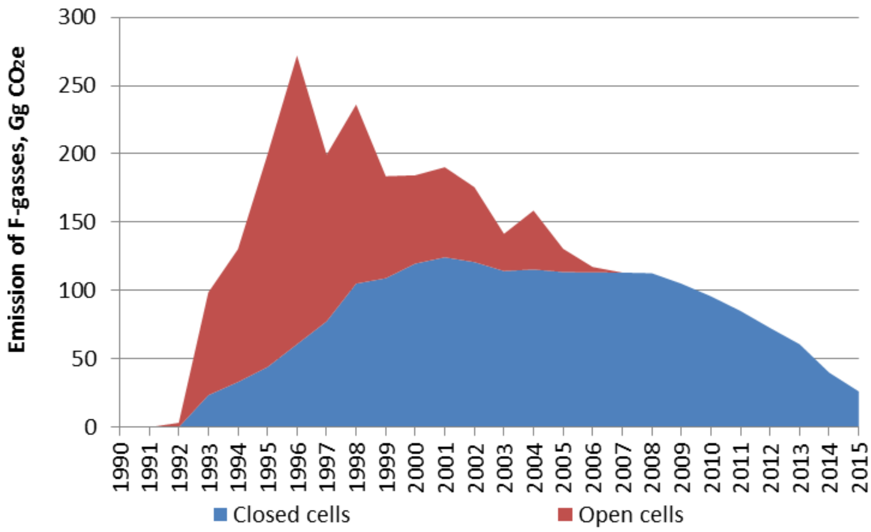

Figure 4.7.4 Emissions from foam blowing agents.

The sharp fluctuations in the time-series are caused by fluctuations in the consumption of HFCs in production of open cell foam, with an emission factor of a 100 % in the given year. For the later part of the time-series the trend reflects the limited use of HFCs 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 (2006) 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 4.7.4.

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 emission factors are presented in Table 4.7.4.

Table 4.7.4 Applied EFs for aerosols/medical dose inhalers (Poulsen, 2016).

	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 4.7.5 presents the emissions of F-gases from consumption of HFCs in aerosols.

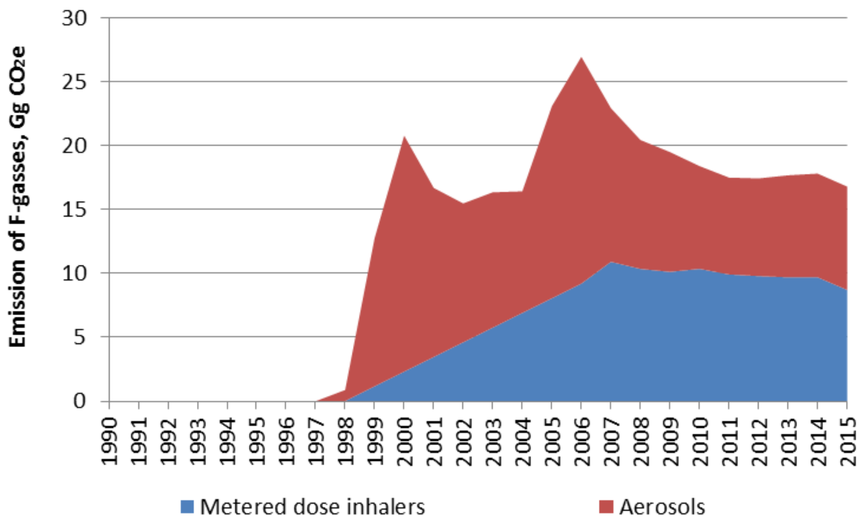

Figure 4.7.5 Emissions from aerosols.

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 Gg CO_2 equivalents.

4.7.8 Solvents

C_3F_8 was used as cleaner from 2000 to 2002 (emissions in 2000-2003) and the use then ceased following the ban in accordance with the Executive Order (MIM, 2002).

Methodology

The methodology used is the IPCC (2006) 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 4.7.4.

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 IPCC (2006)[2], the emission factor is 50 % in year 1 and 50 % in year 2.

Emission trends

Figure 4.7.6 presents the emissions of F-gases from consumption of PFCs used as solvents.

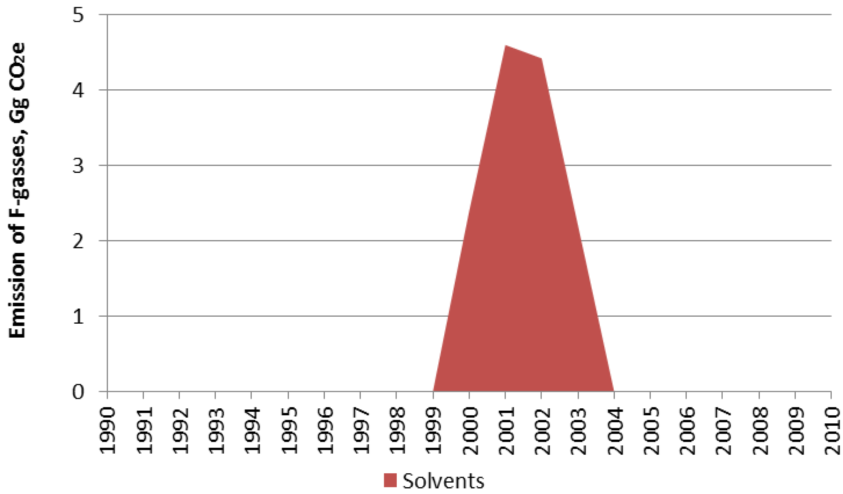

Figure 4.7.6 Emissions from PFCs used as solvents.

As mentioned the use of PFCs as solvent only occurred from 2000 to 2002 and hence emissions only occurred from 2000 to 2003.

4.8 Other Product Manufacture and Use

4.8.1 Source category description

The sector *Other Product Manufacture and Use* (CRF 2G) covers the following processes relevant for the Danish air emission inventory:

- 2G1 Electrical equipment (SNAP 060507); see section 4.8.4
- 2G2 SF_6 from other product uses (SNAP 060508); see section 4.8.5
- 2G3a Medical applications (SNAP 060501); see section 4.8.6
- 2G3b N_2O used as propellant for pressure and aerosol products (SNAP 060506); see section 4.8.7
- 2G4 Other product uses (SNAP 060601, 060602, 060605); see section 4.8.8

4.8.2 Emissions

Total greenhouse gas emissions from the *Other Product Manufacture and Use* (2G) sector are available in the CRF Table 10. The emission time series for the source categories within 2G are presented in Figure 4.8.1 and individually in the subsections below (Sections 4.8.4 – 4.8.8). The following figure gives an overview of which source categories contribute the most throughout the time series.

[2] Volume 3: Industrial Processes and Product Use, Chapter 7.2.2.1: Solvents (non-aerosol), Choice of method, Equation 7.5, page 7.23 and Chapter 7.2.2.2: Solvents (non-aerosol), Choice of activity data, page 7.24.

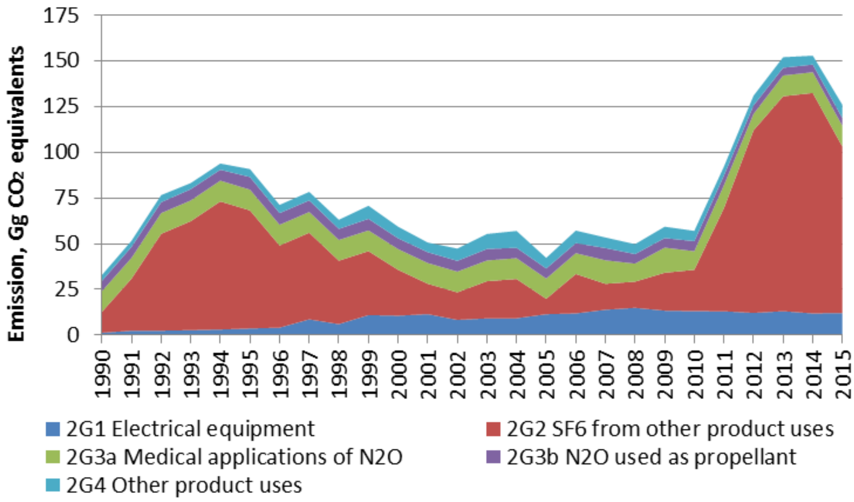

Figure 4.8.1 Emission of CO_2 equivalents from the individual source categories compiling *2G Other Product Manufacture and Use*.

4.8.3 Electrical equipment

Use of electrical equipment (2G1b) is the only source relevant for the Danish inventories in the sub sector of 2G1 *Electrical equipment*.

Methodology

High voltage 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 3c methodology of IPCC (2006).

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 sole Danish supplier (Siemens) or appropriately disposed of through waste collection schemes.

Activity data

The data collection is described in the Chapter 4.7.4 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 for this purpose.

The electricity sector also provides information on the installation of new plants and thus whether the stock is increasing.

Emission factors

The applied emission factors are presented in Table 4.8.1. Special attention has been given to use of SF_6 as insulation in high-voltage plants (Poulsen, 2001; ELTRA, 2004).

Table 4.8.1 Applied emission factors for other processes (Poulsen, 2016).

	Consumption/filling	Stock, per annum	Lifetime
Insulation 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.

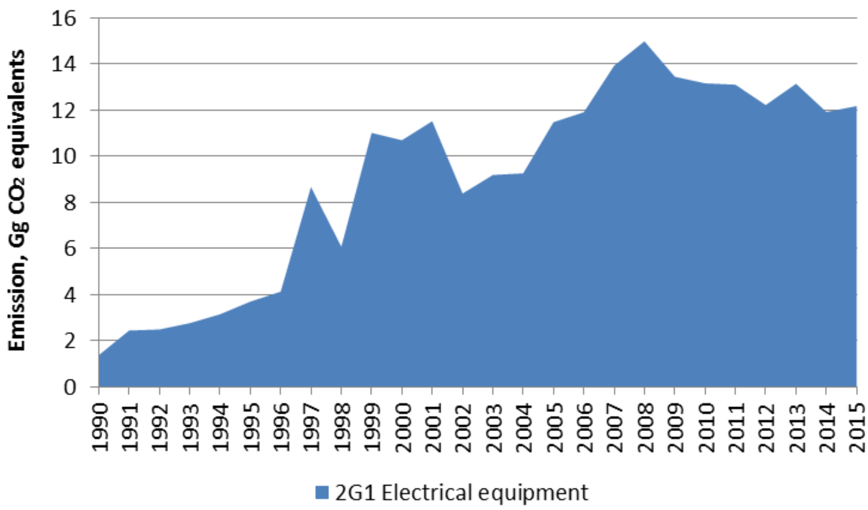

Figure 4.8.2 Emissions from SF_6 from electrical equipment.

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 (2016).

Activity data

The data collection is described in the Chapter 4.7.4 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.

Importers have estimated imports to Denmark of SF_6 in training footwear.

Emission factors

The applied emission factors are presented in Table 4.8.2.

Table 4.8.2 Applied EFs for SF_6 from other product use (Poulsen, 2016).

	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 emissions have been estimated to 0.11 Mg (Poulsen, 2016).

Emission trends

Figure 4.8.3 presents the emissions of SF_6 from shoes, double glazed windows and other uses (laboratories etc.).

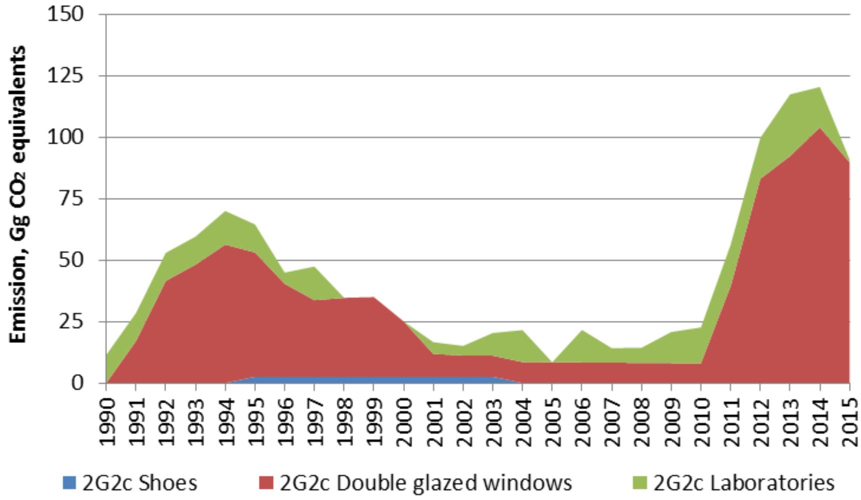

Figure 4.8.3 Emissions from SF_6 from other product uses.

Double-glazed windows using SF_6 was introduced in 1991. While there is annual emissions, the lifetime is assumed to be 20 years meaning that all remaining SF_6 contained in the windows is assumed to be emitted 20 years after production, i.e. first in 2011. Emissions of SF_6 from this source will therefore be quite high in the coming years. However, since the use of SF_6 in double glazed windows was banned in 2002, by 2021 all emissions are assumed to have taken place.

4.8.5 Medical applications of N_2O

The category *Medical applications* of N_2O (CRF 2G3a) covers the following SNAP-code:

- 06 05 01 Anaesthesia

Methodology

N_2O has been used as anaesthetics for more than a hundred years but has also had other smaller applications in newer times. 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-1990s, 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 hospitals, dentists and veterinarians 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 2013-2015 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	2013-2015
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 presented in Figure 4.8.4 below.

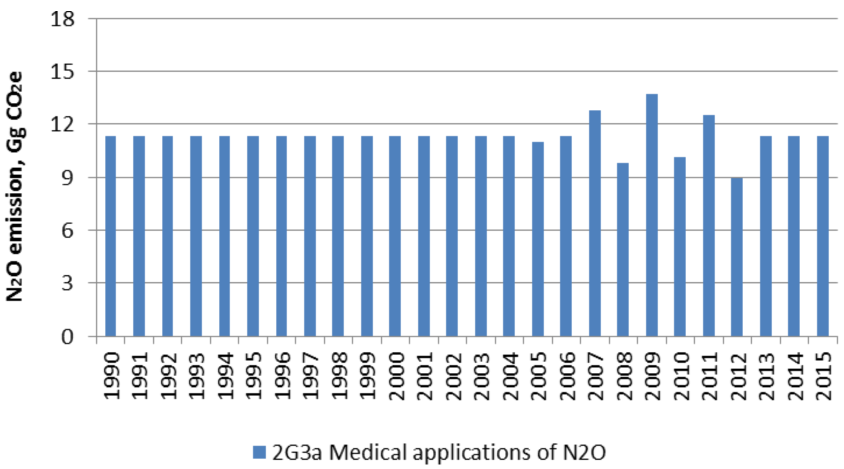

Figure 4.8.4 N_2O emissions from the use of anaesthetics.

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 considered to be complete although uncertainties going back from 2005 are increasing.

4.8.6 N_2O used as propellant for pressure and aerosol products

The category *N_2O used as propellant for pressure and aerosol products* (CRF 2G3b) covers the following SNAP-code:

- 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 and in Annex 3C-36.

Table 4.8.4 Consumption of cream in Denmark, Mg.

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
Cream[1]	37378	46279	39380	37333	37009	35386	31278	28314	29492	31772
Canned cream	374	463	394	373	370	354	313	283	295	318

[1] Statistics Denmark (2016).

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 used as propellant is available in Annex 3C-37 but is also presented in Figure 4.8.5 below.

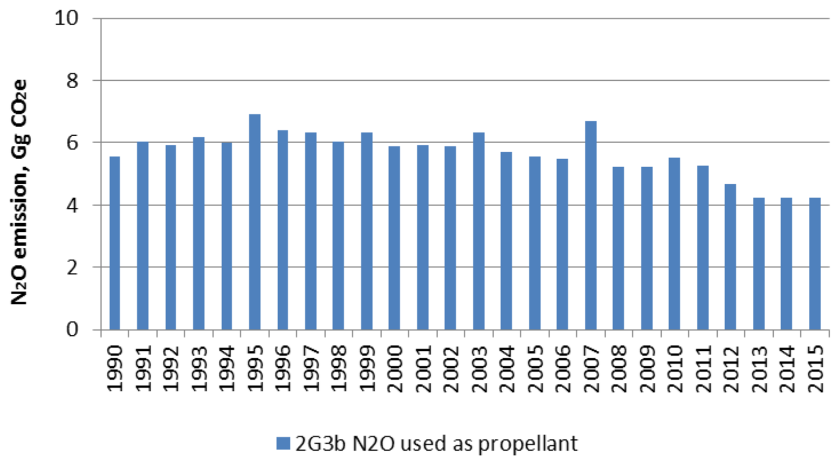

Figure 4.8.5 N_2O emissions from the use of canned whipped cream (Emission 2A from Figure 4.8.6).

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 one can contains 250 ml (250 g) cream and releases 100 % of the propellant.

Table 4.8.5 N_2O released as propellant (2012), Gg.

	Assumption 1	Assumption 2
	1 can 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 can	0.013	0.005

Using the four assumptions presented in the table above, the time series are calculated; see Figure 4.8.6.

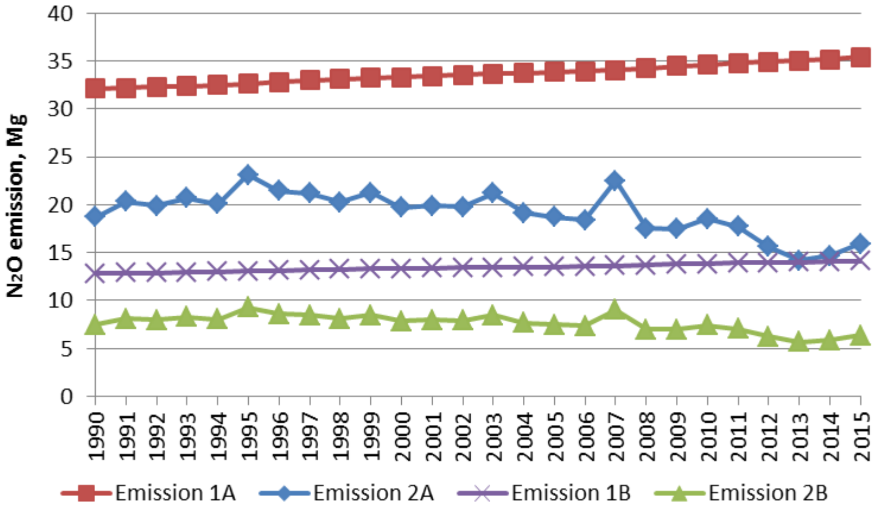

Figure 4.8.6 N_2O emissions from the use of canned whipped cream.

Although the calculated emissions vary over the four estimates 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 2014 "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. The estimate is considered too rough to be certain of completeness.

4.8.7 Other product uses

The category *Other Product Uses* (CRF 2G4) covers the following SNAP-codes:

- Use of fireworks (SNAP 060601): CO_2, N_2O and CH_4
- Use of tobacco (SNAP 060602): N_2O and CH_4
- Use of charcoal for barbequing (SNAP 060605): N_2O and CH_4

Methodology

Methane and nitrous oxide emissions are calculated for all three product uses but carbon dioxide is only relevant for fireworks since emissions from the two remaining product uses are considered to be biogenic.

The applied methodology follows a Tier 2 technology-specific approach from EMEP/EEA (2013)[3] is used for calculating emissions from fireworks, tobacco and charcoal for barbeques (BBQ).

Activity data

Activity data are derived from import, export and production data from Statistics Denmark (2016) and are available in Table 4.8.6 and Annex 3C-38.

Table 4.8.6 Activity data for other product uses, Gg.

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
Fireworks	1.3	3.0	4.9	3.7	5.4	4.7	3.5	4.2	3.6	5.8
Tobacco	13.0	11.6	11.4	10.4	9.2	8.3	8.2	8.4	7.1	7.0
Charcoal for BBQs	7.2	7.9	13.4	14.9	7.8	6.8	14.2	14.2	11.5	18.2

The assumption of the weight of cigarettes and cigars of 1 g and 5 g respectively was made to derive the activity data from Table 4.8.6.

Emission factors

Emission factors for use of fireworks, tobacco and charcoal are found through literature studies and are presented in Table 4.8.7.

Table 4.8.7 Emission factors for other product uses.

	Unit	Fireworks[1]	To-bacco[2]	BBQ[3]
CO_2	kg/Mg	43.25	NA	NA
N_2O	kg/Mg	1.935	0.064	0.030
CH_4	kg/Mg	0.825	3.187	6.0

[1] Netherlands National Water Board (2008).

[2] 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).

[3] IPCC (2006), calculated using default EFs[4] a net calorific value[5].

Emission trends

The emission trend for the greenhouse gases from other product uses is available in Annex 3C-39 and in Figure 4.8.7 below.

[3] 2.D.3.i, 2.G Other solvent and product use, Chapter 3.3 Tier 2 technology-specific approach.

[4] Volume 2: Energy, Chapter 2.3.2.1 Stationary combustion, Tier 1, Table 2.4, page 2.21, solid biofuels, charcoal.

[5] Volume 2: Energy, Chapter 1.4.1.3 Introduction, Activity data sources, Table 1.2, page 1.19, solid biofuels, charcoal.

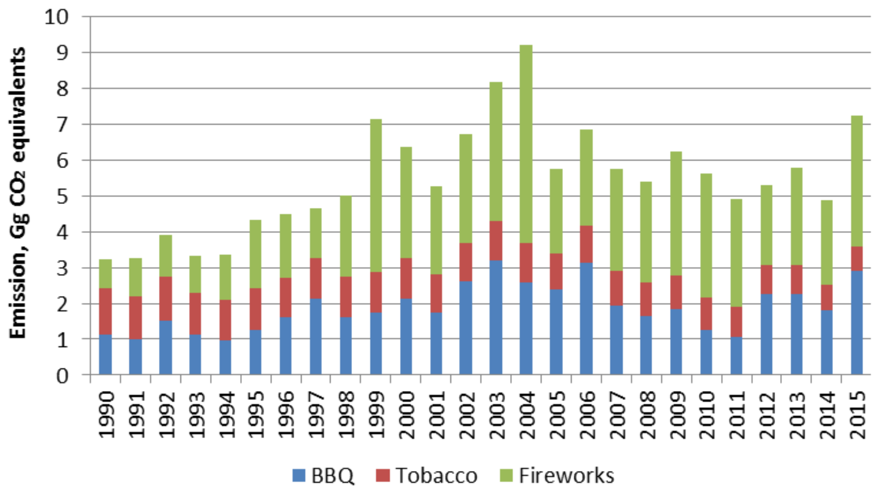

Figure 4.8.7 Greenhouse gas emissions from other product uses.

The consumption of charcoal for BBQs is highly influenced by the summer season weather and the number of smokers has been decreasing throughout the time series.

For fireworks, two peaks are visible in the time series, the peak in 1999 is caused by the celebration of the new millennia and the peak in 2004 by the Seest incident where 284 Mg net explosive mass (NEM) corresponding to a gross weight of about 1,500 Mg of fireworks exploded (Report Seest, 2005). From 2005, the new restrictions put on fireworks meant a lower general consumption than before 2004, but the increasing trend continued.

Time series consistency and completeness

Activity data for fireworks is based on import/export data. There is no firework production industry in Denmark and the use of illegal products is assumed negligible. Cross-border shopping of fireworks is also considered negligible since most fireworks from e.g. Germany is illegal in Denmark due to the strict Danish laws on the content of net explosive mass (NEM).

Activity data for tobacco includes cross-border shopping. Data for cross-border shopping is known for 2000-2010 and estimated for the remaining years of the time series. From 2000 to 2010 the cross-border shopping of tobacco decreased from 14 % of retail sale to 5 %, most likely due to decreases in the Danish tax.

The activity data for charcoal for barbeques are determined from import/export data and includes

- Charcoal, including coal of nutshells or nuts, also agglomerated
- Bamboo, including coal of nutshells or nuts, also agglomerated (except for medical use, charcoal mixed with incense, activated charcoal and charcoal for drawing)
- Charcoal, including coal of nutshells or nuts, also agglomerated (except bamboo, charcoal dosed or packaged as medicines, charcoal mixed with incense, activated charcoal and charcoal for drawing).

The product called Heat Beads® BBQ briquettes have won marked shares from regular charcoal for some years now but the use of this product is still small compared to regular coal for barbequing. Heat Beads® consist of a certain blend of hardwood charcoal and mineral carbon made by carbonising brown coal and is therefore emitting some non-biogenic CO_2. Due to confidentiality it is not possible to determine neither the marked share of this product nor if/how much its composition differs from other products. The amount of non-biogenic CO_2 from barbequing is assumed to be negligible. It is further more assumed that the cross-border shopping of charcoal is negligible.

The time series is considered to be complete for the included sources, the time series is also consistent.

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 (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). Activity data have fulfilled the Tier 3 methodology since 1998 and is assumed to have an uncertainty of 1 %. Since uncertainties cannot vary over time in Approach 1 uncertainty calculations, the activity data uncertainty is assumed to be 1 % for the entire time series. The estimation of emission factors fulfils the Tier 3 methodology for the entire time series and uncertainties are therefore assumed to be 2 %.

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 4 %.

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), since uncertainties cannot vary over time in Approach 1 calculations, 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 and 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 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 activity data uncertainty is assumed to be 2 %. The measurement of N_2O is problematic and is only carried out for one year. Therefore, the emission factor 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 (2016) 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 (2016). 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 (2016) 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. However, a change in distribution of pollutants between industrial sectors and households will 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.

Electronic Industry

Uncertainty estimates for HFCs and PFCs from electronic industries are 10 % and 50 % for activity data and emission factors respectively.

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 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 activity data for "Other Product Use" are collection of data for quantifying production, import and export of products. Some data, like private import (cross-border shopping) of fireworks, are not available in Statistics Denmark. Other missing data like the composition of mineral containing charcoal for barbequing are unobtainable due to confidentiality. The uncertainty for activity data for all three product uses (fireworks, tobacco and BBQs) is estimated to be 10 %. Reliable emission factors are difficult to obtain for the other product use categories. Some chosen emission factors apply to countries that are not directly comparable to Denmark, and hereby is introduced an increased uncertainty. The uncertainties for emission factors are estimated to be 50 % for fireworks, 50 % for tobacco and 100 % for barbeques.

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 for activity data and emission factors and the calculated total emission and uncertainty for Approach 1 for the individual pollutants. The total CO_2 equivalent greenhouse gas emission from the IPPU sector in 2015 is 1992 Gg CO_2e and the calculated Approach 1 uncertainty for the year is 15.6 %. The trend decreases with 24.7 % and the trend uncertainty is 13.5 %.

Table 4.9.1 Input uncertainties and calculated Approach 1 emission and uncertainties.

		Activity data uncertainty	Emission factor uncertainty					
			CO_2	CH_4	N_2O	HFCs[2]	PFCs[2]	SF_6[2]
CRF	Category	%	%	%	%	%	%	%
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					
2E5	Other electronics industry	-						
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	10	50	50	50			
2G4	Tobacco	10		50	50			
2G4	Barbeques	10		100	100			
Emission 2015, Gg			1226	0.2	0.1	634[4]	4.9[4]	103[4]
Overall uncertainty in 2015			4.2	71.2	47.5	47.6	51.0	45.4
Trend 1990-2015 (1995-2015)			-4.1	59.6	-98.1	162.5	681	0.7
Trend uncertainty			3.1	49.9	1.2	146.8	110.5	20.9

[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 this source category because the activity occurs in neither 1990 nor 2015.

[4] CO_2 equivalents.

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 level by using default and country specific uncertainty factors. The applied uncertainty factors are presented in Chapter 4.9.

The sources of data described in the methodology sections 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 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 and is described in verification sections under each source category as they are performed.

The applied data sets are presented in Table 4.9.1.

Production and import/export data from Statistics Denmark for single products/chemicals can be directly compared with data from Eurostat for other countries. This has been done for a few chosen products/chemicals and countries. Furthermore, chosen Danish data from Eurostat have been validated with data from Statistics Denmark in order to check the consistency in data transfer from national to international databases.

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.

Regarding Non-energy products from fuels and solvent use, 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.
- SPIN database.
- 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) and after the removal of the requirement (i.e. after 2014).

For 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, e.g. 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 industries may give valuable information on specific production processes, chemicals and/or products and industrial activities. By considering both sources a verification as well as optimum reliability and accuracy is obtained.

Statistics Denmark is used as source for activity data as they are able to provide consistent data for the entire time series. In the cases where the statistics do not contain transparent data, statistics from industrial organisations are used to generate to required activity data. Statistics Denmark 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.

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.

For many of the processes, the default emission factors are based on chemical equations (stoichiometric) and are, therefore, the best choice. In some cases, the default emission factor 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, 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:

O:\ST_ENVS-Luft-Emi\Inventory\2014\2_Industrial_Processes\Level_1a_Storage.

All data extracted from the internet (e.g. Statistics Denmark and SPIN) 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: O:\ST_ENVS-Luft- Emi\Inventory\2015\2_Industrial _Processes\Level_1a_Storage)

\Grønne regnskaber\	Dansteel 2015
	Ardagh Glass Holmegaard GR 2015
	Faxe Kalk 2015
	Haldor Topsøe 2015
	Nordic Sugar Nykøbing/Grindsted 2015
	Rockwool Vamdrup 2015
	Rockwool Doense 2015
	Koppers 2015
\CO2 kvote indberetninger\	Ceramics (folder)
	Industri (folder)
	Aluminium
	Animal feed
	BBQ
\Danmarks Statistik\	Beverages
	Bread
	Bricks and tiles
	Cast iron
	Cement
	Coffee
	Construction BYGV04 Samlet byggeaktivitet
	Demolition BYGB33 Bygningsbestand
	Dolomite and soda ash
	Expanded clay
	Fats
	Fireworks
	Fløde
	Grain drying
	Meat
	Slaughterhouse waste
	Soda ash – KN8Y
	Stenbrud og minedrift
	Sugar production
	Termometre
	Tobacco

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 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 (2016). 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. 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. Some are presented in the "Verification" sections, some are available in the sector report (Hjelgaard et al., 2015) and some are only used internally.

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 (Hjelgaard et al., 2015).

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 (Hjelgaard et al., 2015) 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 regarding both level and trend. The level is compared to relevant emission factors to ensure correctness. Large dips/jumps in the time series are explained.

The implied emission factors 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).

4.11 Recalculations and improvements

Table 4.11.1 shows recalculations of the CO_2, CH_4, N_2O, HFCs, PFCs and SF_6 emissions. Emissions reported this year have been compared to emissions reported last year.

Sector specific recalculations for 2015 are shown in Table 4.11.2.

The main recalculations are discussed below.

Table 4.11.1 Recalculations (emissions reported this year / emissions reported last year), %.

	1990	1995	2000	2005	2010	2011	2012	2013	2014
CO_2	100.15	100.00	100.00	100.00	100.02	100.02	100.02	100.01	100.02
CH_4	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
N_2O	99.94	99.93	99.94	100.00	99.85	99.86	100.84	98.72	98.95
HFCs	-	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
PFCs	-	100.00	100.00	100.00	99.94	99.50	99.42	99.42	100.00
SF_6	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Table 4.11.2 Recalculations for industrial processes and product use, 2014.

	CO_2, Gg CO_2	CH_4, Gg CO_2e	N_2O Gg CO_2e	F-gasses Gg CO_2e	CO_2 %	CH_4, %	N_2O %	F-gasses %
2A1 Cement production	NO				NO			
2A2 Lime production	NO				NO			
2A3 Glass production	NO				NO			
2A4 Other process uses of carbonates	0.29				0.43%			
2B10 Catalysts/fertiliser production	NO				NO			
2C5 Secondary lead production	NO				NO			
2D1 Lubricant use	NO				NO			
2D2 Paraffin wax use	NO	NO	NO		NO	NO	NO	
2D3 Other	-0.01	NO			-0.02%	NO		
2E5 Other electronics industry				NO				NO
2F1 Refrigeration and air conditioning				0.00				0.00%
2F2 Foam blowing agents				NO				NO
2F4 Aerosols				NO				NO
2G1 Electrical equipment				NO				NO
2G2 SF_6 from other product use				NO				NO
2G3 N_2O from product uses			-0.19				-1.22%	
2G4 Other	NO	NO	NO		NO	NO	NO	

NO Not occurring

4.11.1 Other uses of soda ash

A calculation error in soda ash consumption in the glass industry was corrected. This correction has no influence for emissions from the glass industry but influences the calculated amount of soda ash used for other purposes. The recalculation is between -0.0002 Gg (1996) and 1.97 Gg (1990).

4.11.2 Refrigeration and air conditioning

Two changes were made in this category. For HFC-134a from mobile air-conditioning (2F1e) a shift in methodology is introduced from 2009 onward, the resulting recalculations in emissions are small but the change places all emissions to "from stocks" including emissions from manufacture. It was found that no C_3F_8 was used in commercial refrigeration (2F1a) in 2010, this change removed emission from manufacture in 2010 and lowers emissions from stocks in 2011-2013.

HFC emissions from Refrigeration and air conditioning were recalculated for 2009 (changes for 2011-2014 are miniscule) and PFC emissions for 2010-2013. The recalculations are between -0.1 Gg CO_2e (-0.01 %) in 2011 and 7.1 Gg CO_2e (0.9 %) in 2009.

4.11.3 N_2O from product uses

The historical data (1990-2004) for consumption of N_2O for medical use is now estimated as the average of 2005-2012 instead of only 2005-2009. This change reduces the emissions from 2G3 in each of the historical years with 0.6 Gg CO_2e (3 %).

In addition, Statistics Denmark updated their data for consumption of cream in the years 2009-2014 resulting in yearly recalculations for 2G3 in these years of -1.5 % to 1.0 %.

4.12 References

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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 fertilisers
- For emission of NVMOC, CO and NO_x see the Danish Informative Inventory Report (Nielsen et al, 2016).

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 21 % of the overall greenhouse gas emission (GHG) in 2015 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 2015 with 88 % and 80 % respectively of the total Danish emissions of N_2O and CH_4.

From 1990 to 2015, the emissions decreased from 12.6 million tonnes CO_2 equivalent to 10.3 million tonnes CO_2 equivalent, which corresponds to an 18 % reduction (Table 5.1). CH_4 is the largest contributor to the overall agricultural greenhouse gas emission, in 2015 accounting for 54 % 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 – 2015.

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
CH_4, kt CO_2 eqv.	5 585	5 831	5 719	5 682	5 633	5 579	5 588	5 556	5 590	5 524
N_2O, kt CO_2 eqv.	6 429	5 713	5 241	4 884	4 537	4 584	4 494	4 475	4 569	4 597
CO_2, kt CO_2 eqv	619	537	268	222	156	165	192	246	240	177
Total, kt CO_2 eqv.	12 633	12 081	11 228	10 788	10 326	10 328	10 274	10 278	10 400	10 299

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 1990-2015 has decreased by 28 % 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 fertiliser and a decrease of emission per produced kg meat, which all has reduced the overall GHG emission.

The CH_4 emissions from 1990 to 2015 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 2015 has increased by 1 %.

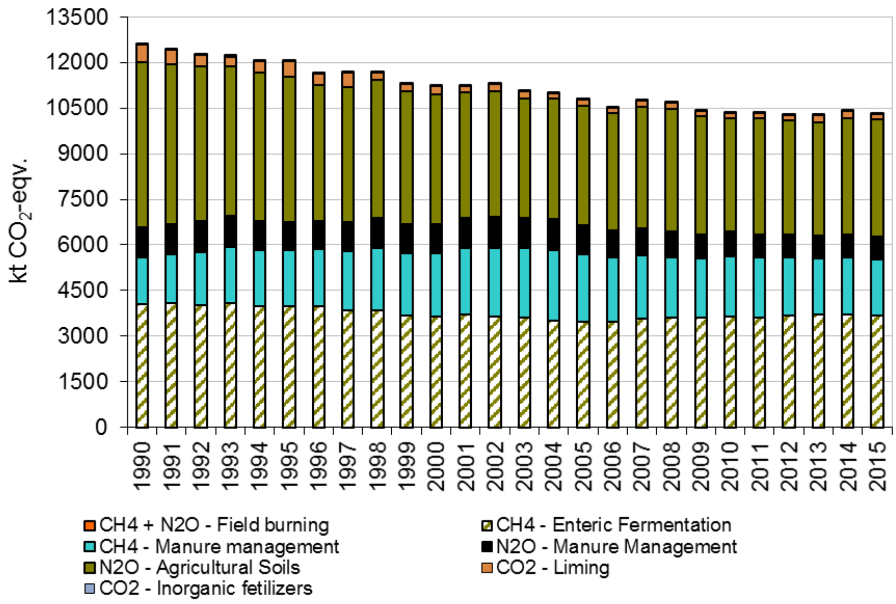

Figure 5.1 Danish greenhouse gas emissions 1990 – 2015.

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 2015, 6 of the sources are listed as key categories according to level and trend for Approach 1 and 10 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 fertilisers.

Table 5.2 Key category identification Tie1 and Tier 2 from the agricultural sector 1990 and 2015.

CRF table	Compounds	Emission source	Key category identification	
2015			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	Level
3.Da.1	N_2O	Inorganic N fertilisers	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 fertiliser 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		Trend
3.Da.6	N_2O	Cultivation of organic soils	Level	Level
3.Db.1	N_2O	Atmospheric deposition	Level	Level/trend
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/trend	Level/trend
3.H	CO_2	Urea application	-	-
3.I	CO_2	Other carbon-containing fertilisers	-	-
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 fertilisers	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 fertiliser 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 fertilisers	-	-

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, SEGES, 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 - acidification of slurry
Danish Environmental Protection Agency	www.mst.dk	EPA	- sewage sludge used as fertiliser (until 2004) - industrial waste used as fertiliser
The Danish AgriFish Agency	http://naturerhverv.fvm.dk	DAFA	- inorganic N fertiliser (consumption and type) - housing type (from 2005) - sewage sludge used as fertiliser (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.

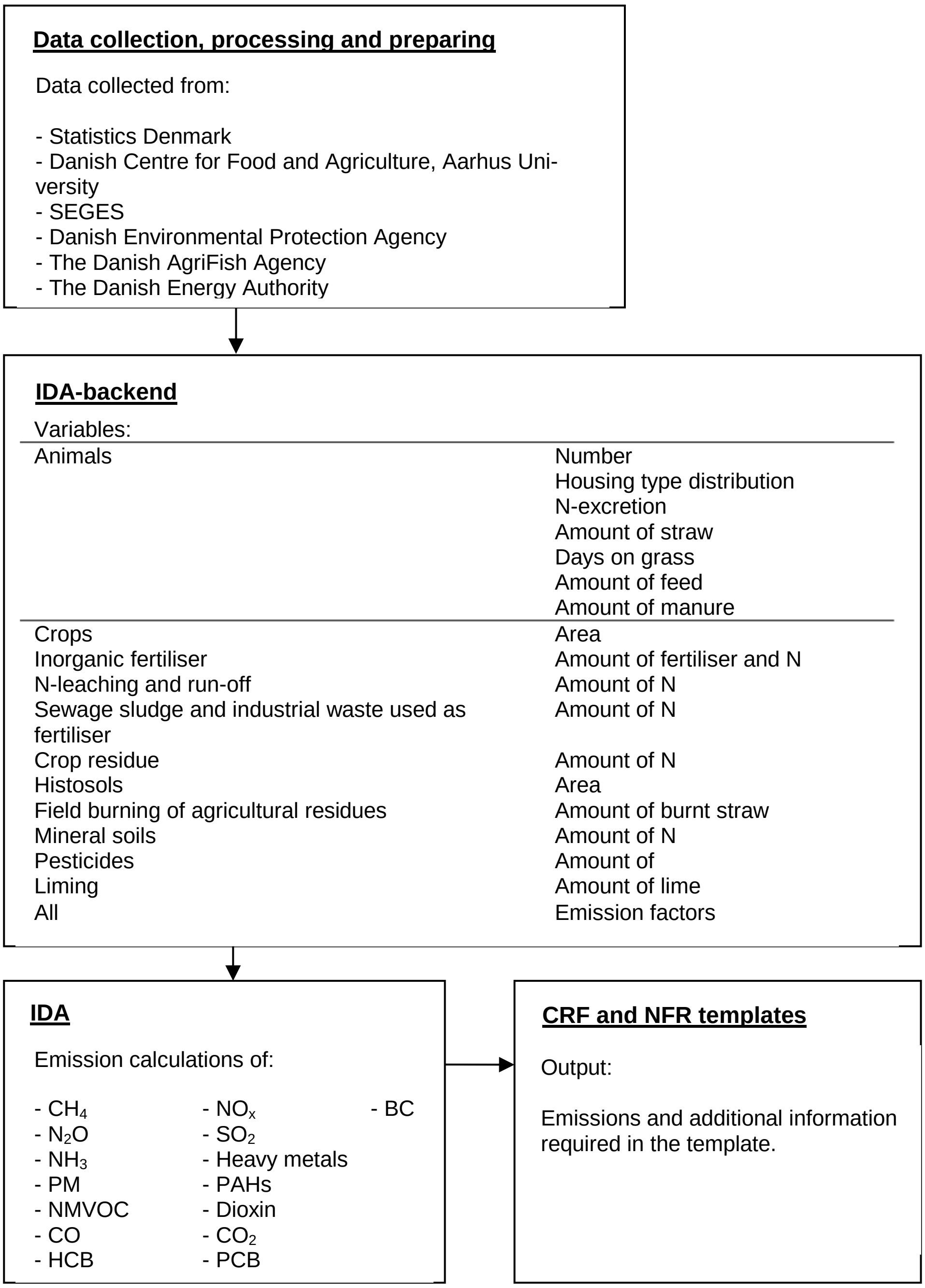

Figure 5.2 IDA - Integrated Database model for Agricultural emissions.

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 269 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	50
	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 – 2015.

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 fertiliser planning and control by the Danish farmers and authorities (Poulsen et al., 2001, Poulsen, 2016). 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-fysiologi/normtal/ (Jan. 2017).

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 2015, this source accounts for 35 % of the total GHG emission from agriculture. The emission is primarily related to ruminants and, in Denmark, particularly to cattle, which, in 2015, contributed with 87 % of the emission from enteric fermentation. The emission from swine production is the second largest source and covers 9 % of the emission from enteric fermentation, followed by horses (2 %) and sheep, goats, deer and poultry (1 %).

From 1990 to 2015, 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 12.5 million in 2015, 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 2015, mainly due to a slightly increase in emission from 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, 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) in the feed for each livestock category. Except from dairy cattle, where the EF is based on kg dry matter (DM) in the feed. For dairy cattle, 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 which have sugar beets in the feed. The parts of the equation concerning sugar beet will be left out for the remaining animal categories.

$$EF = EF_{winter} + EF_{summer}$$

Dairy cattle:

$$EF_{winter,dairy\ cattle} = F \cdot \left(\begin{array}{c} \left(\frac{GE_{F\ winter}}{55.65}\right) \cdot Y_{m\ excl\ sugar\ beet} \cdot \left(1 - \frac{grazing\ days}{365} - \frac{days\ with\ sugar\ beet}{365}\right) \\ + \\ \left(\frac{GE_{F\ winter}}{55.65}\right) \cdot Y_{m\ incl\ sugar\ beet} \cdot \frac{days\ with\ sugar\ beet}{365} \end{array} \right)$$

$$EF_{summer,dairy\ cattle} = F \cdot \left(\frac{GE_{F\ summer}}{55.65}\right) \cdot Y_{m\ grazing} \cdot \frac{grazing\ days}{365}$$

Where:

EF_{winter} = Emission factor for winter feed, kg CH_4 per head per year

EF_{summer} = Emission factor for summer feed, kg CH_4 per head per year

F = feed, kg DM

$GE_{F,winter}$ = gross energy per kg DM, MJ per kg DM in winter

$GE_{F,\ summer}$ = gross energy per kg DM, MJ per kg DM in summer

Y_m = methane conversion factor, per cent of gross energy in feed converted to methane

55.56 = energy content of CH_4, MJ per CH_4

Other animals:

$$EF_{winter} = FU \cdot \left(\left(\frac{GE_{FUwinter}}{55.65}\right) \cdot Y_m \cdot \left(1 - \frac{grazing\ days}{365}\right)\right)$$

$$EF_{summer} = FU \cdot \left(\frac{GE_{FU\ summer}}{55.65}\right) \cdot Y_{m\ grazing} \cdot \frac{grazing\ days}{365}$$

Where:
EF_{winter} = Emission factor for winter feed, kg CH_4 per head per year
EF_{summer} = Emission factor for summer feed, kg CH_4 per head per year
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
55.56 = energy content of CH_4, MJ per CH_4

Thus, to calculate the total gross energy (GE) intake, the GE per kg DM or GE per feed unit – defined as GF_F or GE_{FU}, respectively – 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

GE_F for dairy cattle are estimated by DCA (Aaes, 2016). From 2014 feed intake for dairy cattle given in the normative figures are given in kg DM per year and the energy in the feed is given in MJ per kg DM. The energy intake is a standard winter feed regardless of whether the animal grazes or not. As recommended by ERT the feed intake and energy in the feed for the years 1990-2013 is recalculated. Previous the calculation was based on FU for the years 1990-2013, which is now replaced by the calculation based on DM for all years. See Annex 3D Table 3D-10 for time series for GE for dairy cattle.

For all other livestock categories than dairy cattle, the estimation of GE (GE_{FU}). GE_{FU} 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:

$$GE_{FU} = \frac{MJ/day}{FU/day}$$

$$FU/day = \frac{kg\ dm}{day} \cdot \frac{FU}{kg\ dm}$$

$$MJ/day = \frac{kg\ dm}{day} \cdot \frac{MJ}{kg\ dm}$$

$$MJ/kg\ dm = \%_{Crudeprotein} \cdot E_{Crudeprotein} + \%_{Raw\ fat} \cdot E_{Raw\ fat} + \%_{Carbonhydrates} \cdot E_{Carbonhydrates}$$

$$\%_{Carbonhydrates} = 100 - (\%_{Crudeprotein} + \%_{Raw\ fat} + \%_{Raw\ ashes})$$

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. 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.

Estimation of $GE_{FU,\ summer}$ covers the time where animals are grazing.

Table 5.5 GE per feeding unit, MJ per FU.

	$GE_{FU,winter}$	$GE_{FU,summer}$
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-11, the annual average feed intake given in GE as MJ per day is shown, from 1990 to 2015, for each livestock category. As seen in Annex 3D Table 3D-11, GE for heifer increases 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 heifers 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, heifers are the most important subcategory and thus affect the weighed GE average for non-dairy cattle, which also increases from 2004 to 2007.

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. Development in fodder practice reflects change in the average Y_m for dairy cattle, 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 are kept at 6.00 from 2002 to 2015 (Lund, 2014).

For non-dairy cattle and sheep Y_m given in IPCC (2006) are used. For swine, horses and goats Y_m are based on Crutzen et al (1986).

Table 5.6 CH_4 conversion rate (Y_m) – national factor used for dairy cattle and heifers > ½ year 1990 – 2015, %.

Dairy cattle	1990	1991	1995	2000	2002-2015
$Y_{m\ incl.\ sugar\ beet}$	6.70	6.70	6.45	6.13	6,00
$Y_{m\ excl.\ sugar\ beet}$	6.00	6.00	6.00	6.00	6.00
$Y_{m\ grazing}$	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 127 kg CH_4 per cow per year in 1990 to 154 kg CH_4 in 2015. The IEF depends on milk yield and feed intake – see Figure 5.3. From 1990 to 2000 the IEF is almost unchanged but increases significant from 2000 to 2015. 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.

As mentioned in previous chapter, the ERT has the year recommended a recalculation of GE for dairy cattle for the years 1990-2013 due to change in calculation methodology from year 2013 to year 2014. The calculation is now for all years estimated based on the DM in feed. However, a significant increase of GE from 2013 to 2014 is still taken place, which can be explained by a markedly increase of the average milk yield. In 2011 and 2012 is seen a decrease in the average milk yield, but from 2013 is seen a significant increase of milk yield to a level of approximately 9 400 litre per cow in 2015 (Statistics Denmark). This development has to been set in context with the EU milk quota, which no longer exited from 2015. It was properly potentially possible for the Danish dairy cattle farmers to increase the milk yield from 2010/2011, but the farmers choose to holding back the feeding because of EU milk quota.

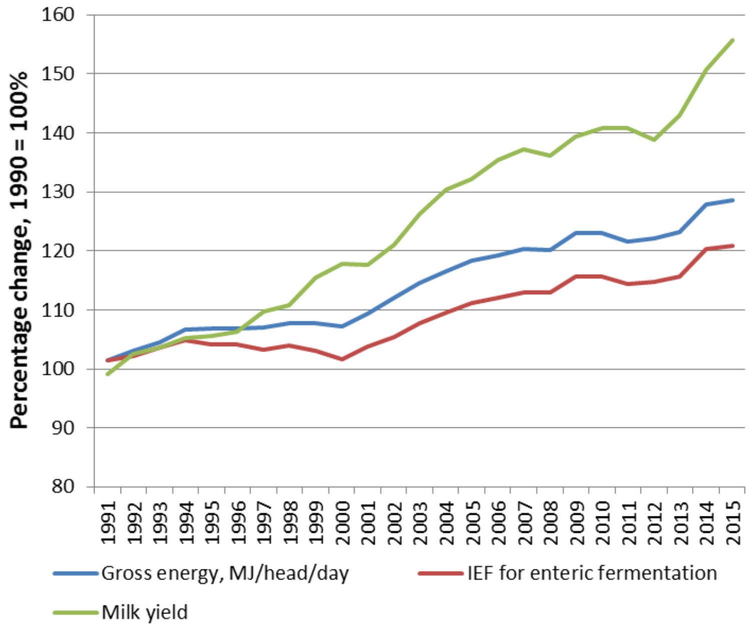

Figure 5.3 Comparison of feed intake, milk yield and IEF for dairy cattle (1990 = 100 %).

A comparison with IPCC Tier 2 calculation in Chapter 5.13.1 shows that the IEFs for the Danish inventory are higher. However, the national IEF reflects the Danish agricultural conditions and the higher level can be explained by high milk production and high feed intake.

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 – 2015 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 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 2015 – 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	122 311	66.31	3	13.05
Calves, heifer (0-6 month)	150 kg	158 774	51.10	6.5	43.57
Bulls (6 month to slaughter)	large breed: 440 kg sl. weight jersey: 330 kg sl. weight	126 653	109.05	3	21.46
Heifers (6 month to calving)	325 kg	492 084	130.24	6.5	55.52
Suckling cattle	Up to 800 kg	91 120	159.84	6.5	68.14
Average - Non-Dairy Cattle			105.7		41.59
IPCC – default value				6.5	57

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-11).

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 2015 – 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)	1 031 667	72.36	0.60	2.83
Weaners (7.4 – 32 kg)	6 196 299	10.62	0.60	0.42
Fattening pigs (32 – 110 kg)	5 307 597	41.61	0.60	1.64
Average - Swine		23.6		1.10
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, which has increased the feed per cow and thereby increased the implied emission factor. Due to fixing of the total production of milk by the EU milk quota, the number of dairy cattle has decreased. The EU milk quota ended in 2015 and the total milk production has increased, but due to higher feed efficiency the IEF and emission is almost unaltered. The emission of CH_4 from enteric fermentation from dairy cattle has decreased from 1990 to 2007 and increased from 2008 to 2012 while from 2013 to 2015 it is almost unaltered.

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.

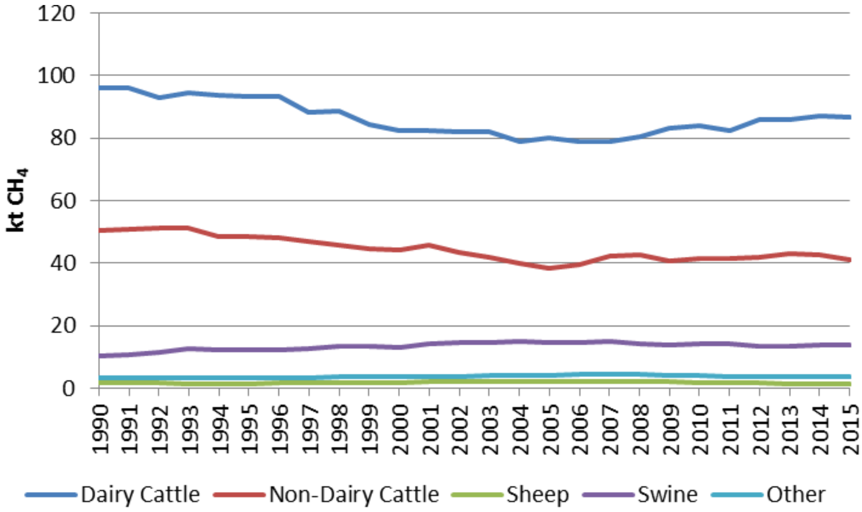

Figure 5.4: Emission of CH_4 from enteric fermentation, 1990-2015.

5.4 CH_4 emission from manure management

5.4.1 Description

This source contributes with 18 % of the total GHG from the agricultural sector in 2015. The major part of the emission originates from the production of swine (61 %) followed by cattle production (35 %). The remaining part is mainly from fur bearing animals (4 %).

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) given by the IPCC are used. For cattle and swine a national MCF factor are used while for the other animal categories MCF are based on IPCC. 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-12)	
Maximum methane producing capacity, B_0		IPCC 2006
Methane conversion factor, MCF		
- Cattle and swine, liquid manure	Based on national measures (Annex 3D Chapter 3D-1)	
- Other		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.

$$VS_{housing} = \frac{m}{365} \cdot DM_M \cdot VS_{DM} \cdot (365 - g_1) + s \cdot DM_s \cdot \left(1 - \frac{\%\,ash}{100}\right) \cdot (365 - g_2)$$

$$VS_{grazing} = \frac{m}{365} \cdot DM_M \cdot VS_{DM} \cdot g_1$$

Where:
VS = volatile solids, kg per animal per year
m = amount of manure excreted, kg per animal per year
DM = dry matter of M manure or S straw, %
VS_{DM} = volatile solids of dry matter, %
g_1 = feeding days on grass, days per year [1]
g_2 = actual days on grass, days per year
s = amount of straw, kg per animal per year
% 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, 2016).

The VS daily excretion in average for all main livestock categories and cattle subcategories is shown in Annex 3D Table 3D-12.

MCF - Methane conversion factor

During the last years several studies have been carried out to support the calculation of a MCF for Danish slurry treated in anaerobic digestion systems (see Annex 3D Chapter 3D-1). This has led to a national MCF for liquid cattle and swine manure. For other animal categories and manure types default values provided in the IPCC guidelines for MCF are used. For liquid systems for fur bearing animals 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-13 is given a survey of all national manure management systems and the MCF related to each system.

[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.

Slurry

A national MCF for both untreated and biogas treated liquid manure from cattle and swine has been estimated, see Annex 3D Chapter 3D-1. MCF for liquid cattle manure is lower compared to MCF given in IPCC 2006 while MCF for liquid swine manure is higher. See Annex 3D Table 3D-14 for time series for the national MCF.

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 days of the year and 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 2 % in fur production. This results in a MCF of 10.1 for fur slurry.

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 5.10 MCF factor for swine, deep bedding.

		DK condition, % of year		IPCC, 2006	
MCF, swine deep bedding	MCF, DK	> 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, MCF 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 almost unaltered from 1990 – 2015 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 2014 is caused by new data for use of straw to bulls, which is lower than previous estimations.

IEF for swine increases from 1990 to 2004 but decreases from 2004 to 2015. This is mainly due to change in housing systems which affect the calculation of MCF because of defences in storage time and HRT (Hydraulic Retention Time) in the barns for the different housing types, see Annex 3D Chapter 3D-1.

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 – activity data

In previous emission inventory the estimation of the amount of biogas treated slurry was estimated based on the energy production. A new data registration collected by a Danish Biogas Taskforce provides a first estimate overview of the actual amount and descriptions of different types of biomass used in biogas production 2015. This data registration is called BIB - the register of Biomass Input to Biogas production and has made it possible to improve the activity data for anaerobic digested manure.

The BIB register reflects the situation in 2015. However, data shows the actual relation between the biogas production and the amount of slurry delivered to biogas plants and it is assumed that this relation will not varies significantly from year to year. Same relation between biogas production and the amount of biogas treated slurry as in 2015 is used for the years 1990 – 2014.

In 2015, manure based biogas plants account for approximately 82 % of the total biogas production produced at 26 large-scale plants and 51 farm-level plants. The BIB register shows that manure accounts for 79 % of the total biomass input. The remaining biomass input is from sewage sludge, residues from the meat production and biomass from crops. The majority of manure sent to anaerobic digestion is slurry, 96 % (mainly from the swine- and cattle production). Deep litter to biogas treatment accounts for 2% of the total amount of manure.

In 1990, the biogas production at manure based biogas plants is by DEA estimated to 266 TJ which correspond to slurry input of 194 kt, increasing to 5 259 TJ and 3 832 kt slurry in 2015. In 2015, around 10 % of total amount of slurry is delivered to biogas production, 13 % of the total amount of cattle slurry and 8 % for pig slurry.

In Annex 3D Chapter 3D-1 is the estimation of the national MCF for biogas treated slurry described.

5.4.6 Time series consistency

The overall CH_4 emission from manure management is increased by 22% from 1990 to 2015 and this is from both the cattle and swine production. The emission from swine has increase from 1990 to 2004 and hereafter decreased until 2015. 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. But also change in housing types influence the emission. The emission increases due to change to more slurry based housing systems but decreases again due to change to housing systems with a shorter storage time and HRT (Hydraulic Retention Time) for the manure in the barns.

The emission from dairy cattle is also increased from 1990 to 2015, despite a decrease in number of dairy cattle, but is related to higher milk yield and thus higher feed intake and higher manure excretion.

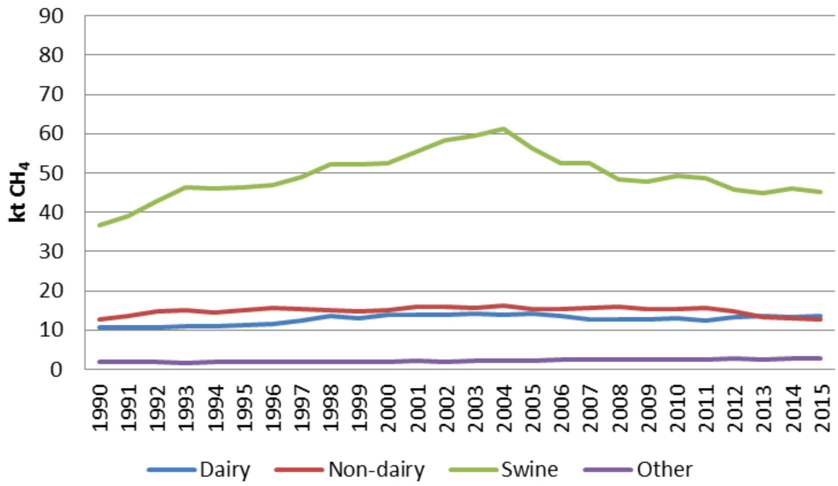

Figure 5.5 CH_4 emission from manure management, 1990 - 2015.

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 7 % of the total GHG from the agricultural sector in 2015 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 5.12 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 fertilisers plans – see Chapter 5.2.3 for further details. It is important to point out that the N-excretion rates shown in Table 5.13 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 5.13 Nitrogen excretion, annual average 1990 – 2015, kg N per head per year (AAP).

CRF Table 3.B(b)	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
Livestock category										
Dairy cattle	129.49	125.23	125.31	133.30	138.63	138.47	138.03	138.82	143.07	143.43
Non-dairy	35.57	35.93	35.70	40.66	42.90	43.63	42.77	43.19	41.74	43.09
Sheep	7.84	8.11	6.64	6.64	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	16.60	16.59
Swine	11.86	9.74	9.63	9.23	7.85	7.96	7.98	7.98	7.96	7.79
Poultry	0.63	0.62	0.55	0.73	0.60	0.56	0.54	0.50	0.52	0.55
Horses	44.15	39.56	39.56	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	5.11	5.31
Deer	16.00	16.00	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	15.60	15.60
Pheasant	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
N-excretion, total, kt N per year	293	274	269	277	261	259	257	256	257	256
N-excretion, housing, kt N per year	258	239	235	251	239	238	236	234	235	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 5.14 Volatilization of NH_3-N and NO_x-N in housing and during storage, 1990-2015.

CRF Table 3.B(b)	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
NH_3-N, housing and storage	41 986	38 535	38 494	38 890	32 732	32 613	31 696	29 346	29 462	29 426
NO_x-N, housing and storage	146	132	112	95	72	67	65	65	64	61
Sum, tons N	42 131	38 666	38 606	38 985	32 804	32 680	31 761	29 411	29 525	29 487

5.5.5 Time series consistency

The N_2O emission from manure management is estimated to 2.5 kt in 2015 of which only 0.5 is related to the indirect emission. The overall emission has decreased with 0.8 kt N_2O from 1990 – 2015 corresponding to 25 %. 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 5.13) from 1990 due to the farmers economic benefit of increased feed efficiency and due to environmental requirements.

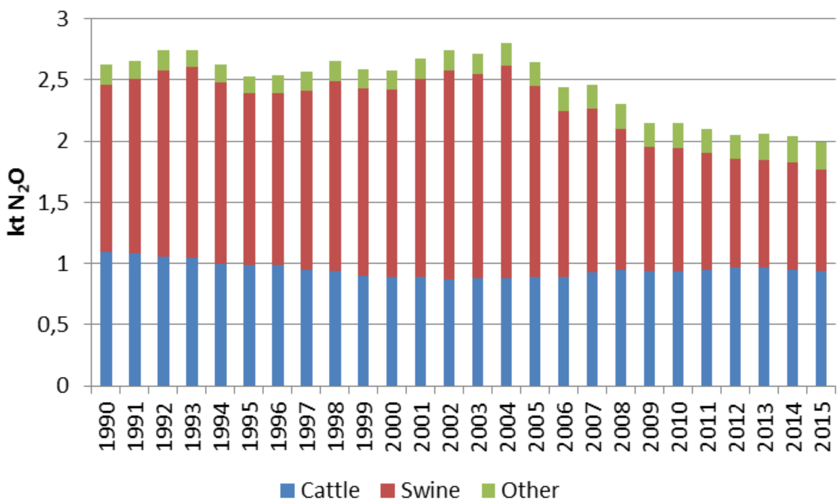

Figure 5.6 N_2O direct emission from manure management, 1990 - 2015.

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 fertiliser, 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 2015 with 72 % of the N_2O emission from the agricultural sector. The largest sources are manure and inorganic N fertiliser applied on agricultural soils. The emission has overall decreased 28 %.

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., 2016).

5.6.3 Activity data

Area of agricultural land is shown in Annex 3D Table 3D-15.

Inorganic N fertiliser applied to soils

The amount of nitrogen (N) applied to soil by use of inorganic N fertiliser is estimated from sales estimates from the Danish AgriFish Agency, the source for the FAO database. Table 5.15 shows the consumption of each fertiliser type. Furthermore, the NH_3 emission factor for each fertiliser is given, based on the values from the EMEP/EEA Guidebook, which has been updated in 2016. The NH_3 emission depends on fertiliser type and the major part of the Danish emission is related to the use of calcium ammonium nitrate and NPK fertiliser, where the emission factor is 0.008 and 0.05 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 5.15 Inorganic N fertiliser consumption 2015 and the NH_3 emission factors.

	NH_3 Emission factor[1] kg NH_3-N per kg N	Consumption[2] 1000 t N
Fertiliser type		
Calcium and boron calcium nitrate	0.05	0.2
Ammonium sulphate	0.09	7.0
Calcium ammonium nitrate and other nitrate types	0.008	98.7
Ammonium nitrate	0.015	3.7
Liquid ammonia	0.019	5.9
Urea	0.155	0.9
Other nitrogen fertiliser	0.01	24.4
Magnesium fertiliser	0.05	0.0
NPK-fertiliser	0.05	54.4
Diammonphosphate	0.05	0.3
Other NP fertiliser types	0.05	5.4
NK fertiliser	0.015	2.5
Total consumption of N in inorganic N fertiliser		203.5
National emission of NH_3-N, kt	5.02	
Average NH_3-N emission ($Frac_{GASF}$)	0.05	

[1]) EMEP/EEA (2016).

[2]) The Danish AgriFish Agency (2016).

The use of inorganic N fertiliser includes fertiliser used in parks, golf courses and private gardens. 1 % of the inorganic N fertiliser 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 fertiliser has almost halved from 1990 to 2015 (Table 5.16).

Table 5.16 Nitrogen applied as fertiliser to agricultural soils 1990 – 2015.

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
N content in inorganic N fertiliser, kt N	400	316	251	206	190	197	187	194	187	203
N_2O emission, kt N_2O	6.29	4.96	3.95	3.24	2.98	3.10	2.94	3.04	2.94	3.20

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 2015 has decreased by 9 %.

Table 5.17 Nitrogen applied as manure to agricultural soils 1990 – 2015.

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
N-excretion, housing, kt N	258	239	235	251	239	238	236	234	235	235
N in manure applied on soil, kt N	214	200	196	212	208	208	206	208	209	209
N_2O emission, kt N_2O	3.37	3.14	3.08	3.34	3.27	3.26	3.24	3.26	3.28	3.28

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 fertiliser accounts controlled by The Danish AgriFish Agency.

Table 5.18 Emission from sewage sludge applied on agricultural soils 1990 – 2015.

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
Nitrogen in sewage sludge, t N	3 115	4 635	3 625	2 173	2 692	2 592	2 470	2 457	2 554	2 768
N_2O emission, kt N_2O	0.05	0.07	0.06	0.03	0.04	0.04	0.04	0.04	0.04	0.04

Other organic fertilisers applied to soils

The category, "Other", includes emission from sludge from industries applied to agricultural soils as fertiliser. 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 fertiliser accounts controlled by The Danish AgriFish Agency. Amounts in 2002- 2004 are interpolated.

Table 5.19 Emission from sludge from industries applied on agricultural soils 1990 – 2015.

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
Nitrogen in industrial waste, t N	1 529	4 500	5 147	5 509	3 401	3 474	4 356	4 596	4 342	4 455
N_2O emission, kt N_2O	0.02	0.07	0.08	0.04	0.05	0.05	0.07	0.07	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 SEGES. N-excretion on grass has decreased due to a reduction in the number of dairy cattle and days on grass.

Table 5.20 Nitrogen excreted on grass 1990 – 2015.

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
N-excretion, grass, kt N	34	36	34	26	22	21	22	22	22	21
N_2O emission, kt	1.00	1.05	1.01	0.73	0.61	0.60	0.61	0.62	0.62	0.59

$Frac_{GASM}$

The $Frac_{GASM}$ express the fraction of N applied from all organic N fertilisers 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 2015 (Table 5.21). This is the result of an active strategy to improve the utilisation of the nitrogen in manure.

Table 5.21 $Frac_{GASM}$ 1990 – 2015.

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
N applied, kt N	253	245	239	243	236	235	235	237	237	237
NH_3-N and NO_x- N emission, kt N	35	29	25	21	21	20	20	20	20	20
$Frac_{GASM}$	0.14	0.12	0.11	0.09	0.09	0.08	0.08	0.08	0.08	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 that 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-16.

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 141 million kg N in 2015, which is mainly a result of a lower amount of N in harvest straw.

Table 5.22 N-content in crop residue, 1990-2015.

Million kg N	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
Total N in crop residue	145.8	132.5	134.1	140.2	149.9	154.1	157.4	151.0	161.6	155.0
N-content in harvest straw	24.2	20.1	17.4	14.6	14.8	14.7	16.5	14.2	13.5	13.6
CRF Table 3.D.4										
N in crop residue	121.6	112.4	116.7	125.6	135.1	139.4	140.9	136.8	148.1	141.4

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 are seen from one year to another due to the annual climate conditions e.g. in 1992 the spring and summer was extremely dry.

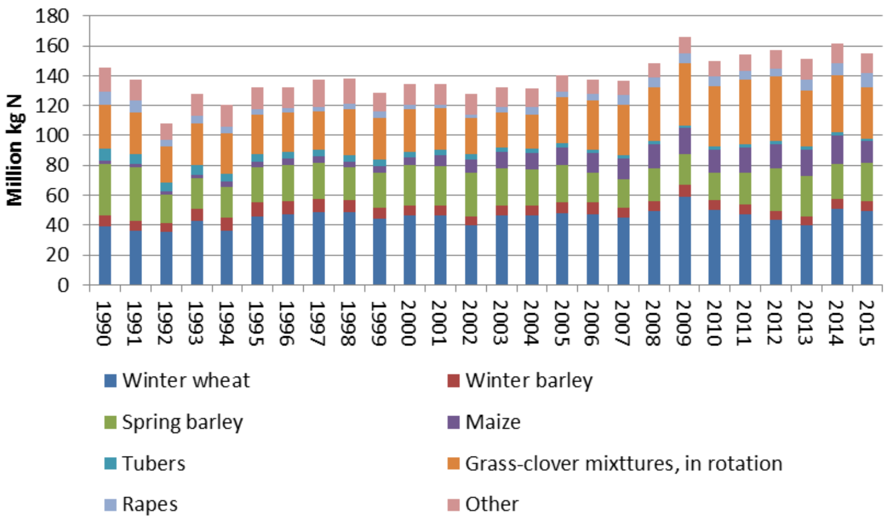

Figure 5.7 Total N in crop residue, 1990 – 2015.

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 6.3.1. 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 follows 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 organic soils of cropland, grassland and areas with no field identification, which are defined as grassland, shallow drained, nutrient-rich areas according to the 2013 Wetland Supplement (IPCC, 2014). These areas are subdivided in areas with >12 % of soil organic carbon (SOC) and 6-12 % SOC. The areas are multiplied by the default emission factor from Table 2.5 of the 2013 Wetland Supplement, IPCC (2014), which for >12 % SOC is 13 kg per ha cropland, 8.2 kg per ha grassland and 1.6 kg per ha shallow drained, nutrient-rich grassland. For areas with 6-12 % SOC the EF is halved to 6.5, 4.1 and 0.8 kg per ha, respectively. EF is constant for all years 1990-2015. The area of organic soils is shown in Table 5.23. The area of organic soils has decreased from 1990 to 2015, see more in Chapter 6.3.1.

Table 5.23 Area of organic soils in ha, 1990-2015.

Year	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
Cropland, >12 % SOC	70 992	66 816	62 640	58 464	54 288	53 538	49 650	48 232	49 248	47 763
Grassland, >12 % SOC	20 776	19 554	18 332	17 110	16 071	15 698	17 943	18 729	18 983	18 327
SN grassland*, >12 % SOC	0	0	0	0	0	940	2 384	2 817	1 348	3 289
Cropland, 6-12 % SOC	44 407	41 795	39 183	36 570	33 870	33 489	31 145	30 342	31 070	30 220
Grassland, 6-12 % SOC	12 996	12 232	11 467	10 703	10 026	9 820	11 256	11 782	11 976	11 596
SN grassland*, 6-12 % SOC	0	0	0	0	0	588	1 371	1 523	477	1 583

* SN grassland - shallow drained, nutrient-rich grassland

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 5.24.

Table 5.24 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 fertilisers	0.02	0.01
Animal manure applied to soils	0.19*	0.01
Sewage sludge applied to soils	0.02	0.01
Other organic fertilisers 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		0.8-13**

*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 2015 according to different N_2O sources. The increase from 2007 to 2008 was due to a rise in the use of inorganic N fertiliser, 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 fertiliser, due to increasing requirements for improved use of nitrogen in livestock manure and reduction of nitrogen loss to the environment.

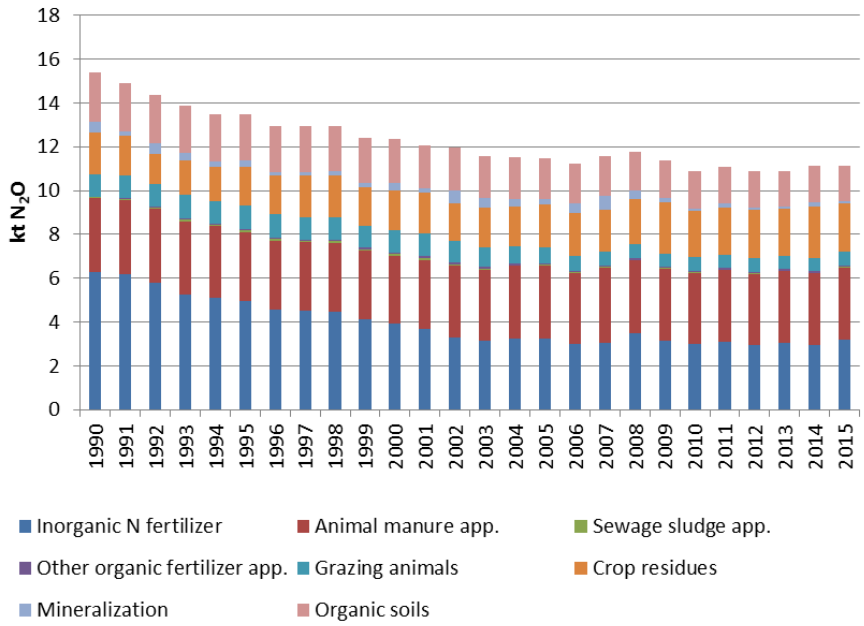

Figure 5.8 N_2O emissions from agricultural soils – direct emissions 1990 - 2015.

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 2015 with 12 % of the N_2O emission from the agricultural sector. The largest source is nitrogen leaching and run-off. The emission has overall decreased 37 % from 1990 to 2015.

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:

$$N_2O_{leaching} = \left(N_{leach\ ground} \cdot EF_{ground} + N_{leach\ rivers} \cdot EF_{rivers} + N_{leach\ estuaries} \cdot EF_{estuaries}\right) \cdot \frac{44}{28}$$

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 5.26. 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 1 500 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., 2016). 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 fertiliser, 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 – 2015 because of the reduction in the total NH_3 and NO_X emission, from 66 884 tonnes of N in 1990 to 32 475 in 2014.

Table 5.25 NH_3 and NO_x emission 2015.

	t NH_3-N	t NO_x-N
Manure	17 644	2 536
Inorganic N fertilisers	5 021	2 469
Crops	4 448	
NH_3 treated straw	130	
Burning of agricultural residues	88	
Sewage sludge and industrial sludge	52	88
Emission total	27 382	5 093
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 5.26 N leaching to groundwater, rivers and estuaries in kt, 1990-2015.

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
Groundwater	267	235	179	160	168	165	160	161	164	165
Rivers	102	104	95	67	68	73	74	65	80	94
Estuaries	100	91	81	56	55	59	59	54	63	78

Figure 5.9 shows leaching from groundwater estimated in relation to the nitrogen applied to agricultural soils as livestock manure, inorganic N fertiliser, sludge, crop residue and mineralization. The average proportion of nitrogen leaching from groundwater has decreased from around 36 % in the middle of the nineties to around 28 % in 2015. 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 fertiliser, which has been reduced by 50 % from 1990 to 2015.

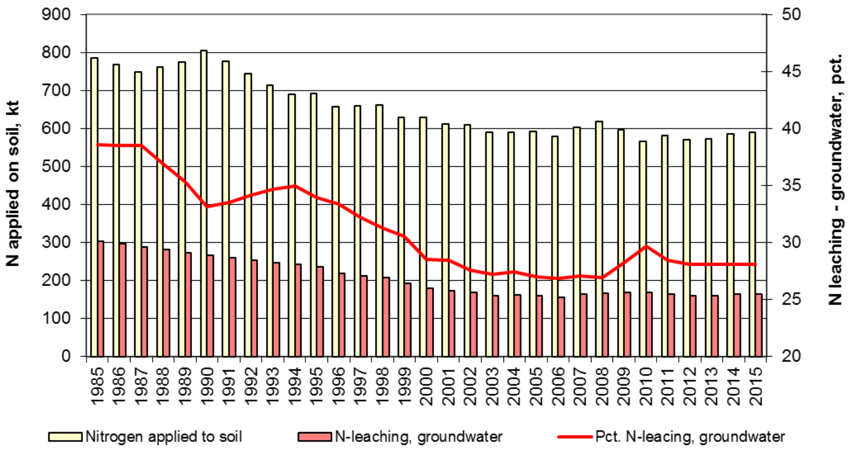

Figure 5.9 Nitrogen applied to agricultural soils and N-leaching, groundwater 1990-2015.

$Frac_{LEACH}$

The proportion of N input to soils lost through leaching and runoff ($Frac_{LEACH}$) used in the Danish emission inventory is in 2015 28 %, 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 5.27.

Table 5.27 Emission factors – N_2O from agricultural soils – indirect emissions.

	N_2O emission factor (IPCC default value)
	kg N_2O -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 2015. The dips and jumps are mainly due to change in emission from leaching and run-off.

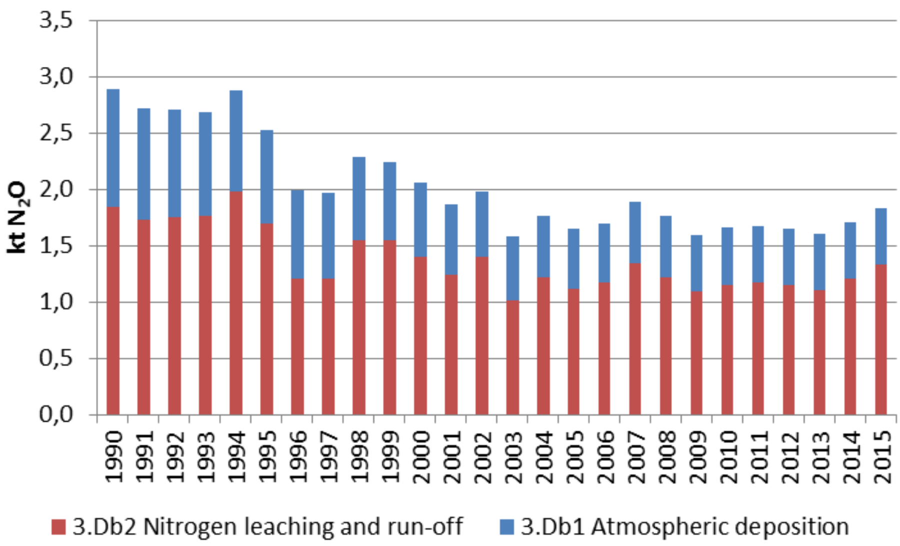

Figure 5.10 N_2O emissions from agricultural soils – indirect emissions 1990 – 2015.

5.8 Field burning of agricultural residues

5.8.1 Description

Field burning of agricultural residues has been prohibited since 1990 in Denmark 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, 2016).

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 SEGES. The total amounts are based on data from Statistics Denmark.

5.8.4 Emission factor

In Table 5.28 is shown the emission factors used to estimate emissions of CH_4 and N_2O.

Table 5.28 Factors for estimating emissions of CH_4 and N_2O, 2015.

		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	5 772 900	0.001	0.85	4 907	2.7	0.90	0.012
CH_4	Straw from seeds of grass	347 500	0.15	0.85	44 306	2.7	0.90	0.108
N_2O	Mixed cereals	5 772 900	0.001	0.85	4 907	0.07	0.90	0.0003
N_2O	Straw from seeds of grass	347 500	0.15	0.85	44 306	0.07	0.90	0.003
Total CO_2 eqv								3.47

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, 2016). 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 2014. It is based on the molecular weight for $CaCO_3$, CO_2 and C.

$$\mathrm{EF} = \mathrm{M}_{CaCO_3} \cdot \mathrm{M}_C \cdot \frac{M_{CO_2}}{\mathrm{M}_C}$$

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 71 % from 1990 to 2015. 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.

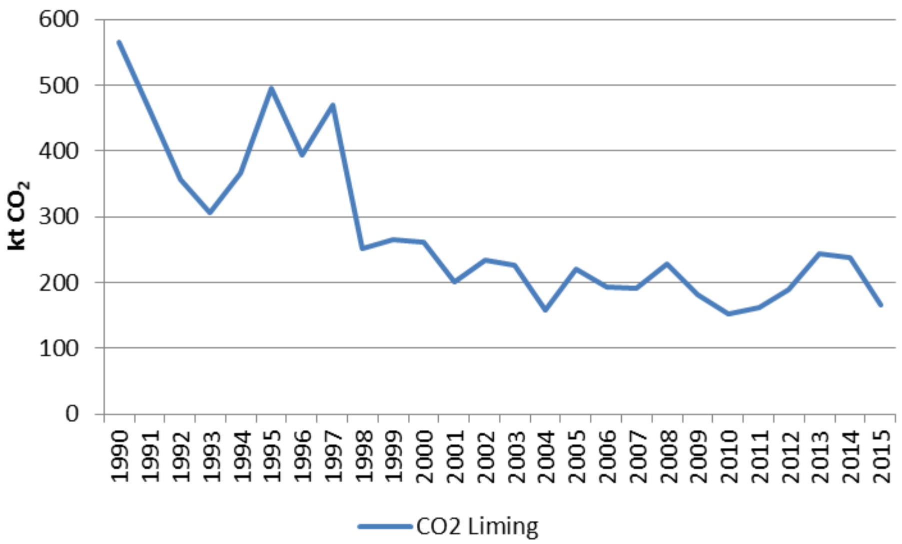

Figure 5.11 CO_2 emission from liming, 1990 to 2015.

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, 2016).

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 91 % from 1990 to 2015, but the main decrease is occurring from 1990 to 2002. From 2003 to 2015 the emission is almost unaltered. The decrease is due to decrease in the use of urea.

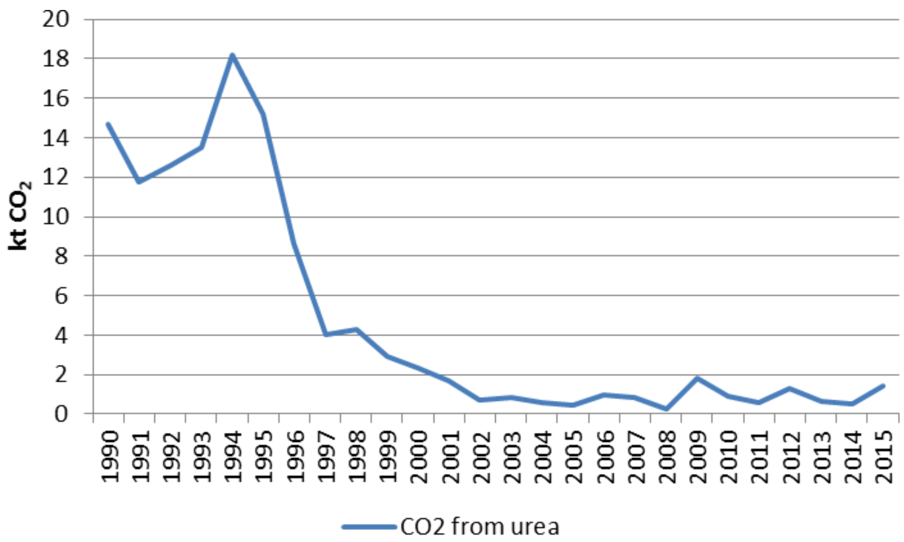

Figure 5.12 Emission of CO_2 from use of urea, 1990 to 2015.

5.11 CO_2 from other carbon-containing fertilisers

5.11.1 Description

Use of other carbon-containing fertilisers 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, 2016).

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 2015. 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 73 % from 1990 to 2015, but the main decrease is occurring from 1990 to 1999. From 2000 to 2014 the emission is almost unaltered but increases in 2015. The change is due to change in the use of CAN.

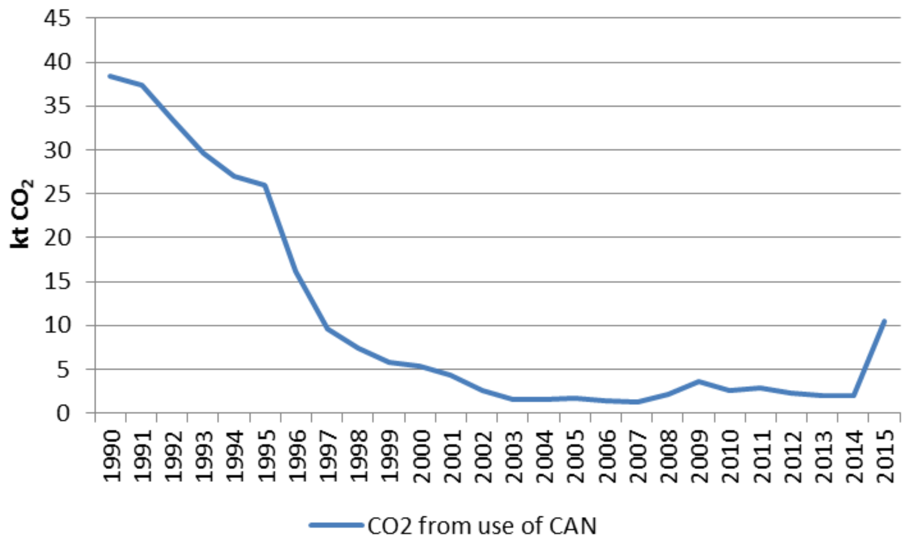

Figure 5.13 Emission of CO_2 from use of CAN, 1990 to 2015.

5.12 Uncertainties

Uncertainties are calculated using Approach 1.

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 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 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, 2016). Uncertainties related to the N_2O emission factor are based on the IPCC 2006. See Table 5.29 for uncertainty values for the agricultural sector.

Table 5.29 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 fertiliser	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 fertiliser 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 fertilisers	CO_2	3	100

5.12.2 Result of the uncertainty calculation

Table 5.30 shows the result of Approach 1 uncertainty calculation for 2015. The overall uncertainty calculation for the agricultural sector based on Approach 1 is estimated to ±19 %.

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.

Table 5.30 Uncertainty calculation, 2015.

Uncertainty		Emission, kt CO_2 eqv	Uncertainty, % Lower and upper (±)
3 Agriculture total	CH_4, N_2O and CO_2	10 299	19
3A Enteric Fermentation	CH_4	3 667	20
3B Manure Management	CH_4 and N_2O		
	CH_4	1 854	21
	N_2O	594	103
3B5 Atmospheric deposition	N_2O	138	101
3D Agricultural Soils	N_2O		
3Da Direct soil emissions	N_2O		
3Da1 Inorganic N fertiliser	N_2O	953	100
3Da2a Animal manure applied to soils	N_2O	979	103
3Da2b Sewage sludge applied to soils	N_2O	13	101
3Da2c Other organic fertiliser applied to soils	N_2O	21	102
3Da3 Urine and dung deposited by grazing animals	N_2O	177	100
3Da4 Crop Residues	N_2O	662	103
3Da5 Mineralization	N_2O	33	112
3Da6 Cultivation of organic soils	N_2O	478	102
3Db Indirect soil emissions	N_2O		
3Db1 Atmospheric deposition	N_2O	152	101
3Db2 Leaching	N_2O	395	102
3F Field Burning of Agricultural Residues	CH_4 & N_2O		
	CH_4	3	56
	N_2O	1	56
3G Liming	CO_2	166	100
3H Urea application	CO_2	1	100
3I Other carbon-containing fertilisers	CO_2	10	100

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 5.31) shows that the Danish method gives a value for dairy cattle there is 3 % higher than the IPCC Tier 2 method and for non-dairy cattle the Danish method gives a value there is 4 % higher than the IPCC Tier 2.

Table 5.31 IEFs for enteric fermentation calculated by different methods, 2015.

kg CH_4 per animal per year	Tier 2 (IPCC Y_m)	Tier 2 (DK Y_m)	Tier 2/CS
Dairy cattle	149.4	137.9	154.4
Non-dairy cattle	39.9	39.9	41.6

The three different Tier 2 calculations for non-dairy cattle all show an IEF between 39.9-41.6 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 lower animal weight/lower feed intake.

The higher value for the IEF for dairy cattle is mainly due to a higher GE in the Danish method (Table 5.32). The Danish values for feed consumption are based on the Danish normative figures, 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 5.32 GE for dairy cattle calculated by different methods, 2015.

MJ per animal per day	Tier 2 (IPCC Y_m and DK Y_m)	Tier 2/CS
Dairy cattle	350.4	392.2

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 5.33 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	143.4
Other cattle	0.33	320	38.5	Non-dairy cattle	43.1
Swine - market	0.51	107	19.9	Swine	7.8
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	16.6
Horses	0.26	438	41.6	Horses	39.6
Hens	0.96	2	0.7	Poultry	0.6
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	5.3
Fox			12.09		

MCF compared to IPCC default

See Annex 3D Table 3D-13 for the comparison of MCF given in IPCC 2006 and the MCF used in the Danish inventory. For liquid untreated and biogas treated manure for cattle and swine a national estimated MCF is used (see Annex 3D Chapter 3D-1). For other manure types and animal categories MCF is based IPCC 2006.

Distribution of animals on housing types

Table 5.34 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 5.34 Distribution of animals on housing types IPCC 2006 vs. national.

	IPCC 2006			DK 2014		
	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	77.2	31.6	89.2
Solid storage	36.8	39	13.7	1.4	0.6	0.1
Drylot	0	0	0	0	0	0
Pasture, range and paddock	20	32	-	4.9	29.5	0.0
Daily spread	7	1.8	2	0	0	0
Digester	0	0	0	10.8	0	8.9
Burned for fuel	0	0	-	0	0	0
Other	0.5	2	3	5.6	38.3	1.8
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 5.14, 5.15 and 5.16 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.

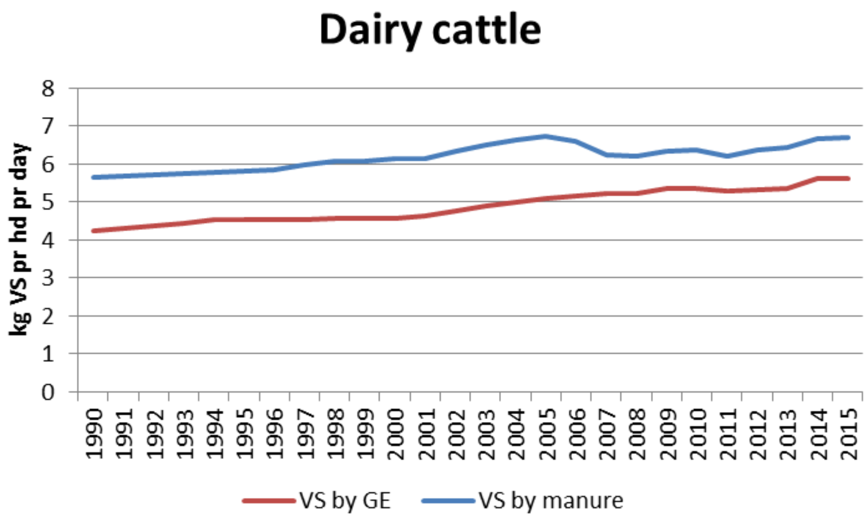

Figure 5.14 VS for dairy cattle based on GE and on manure.

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.

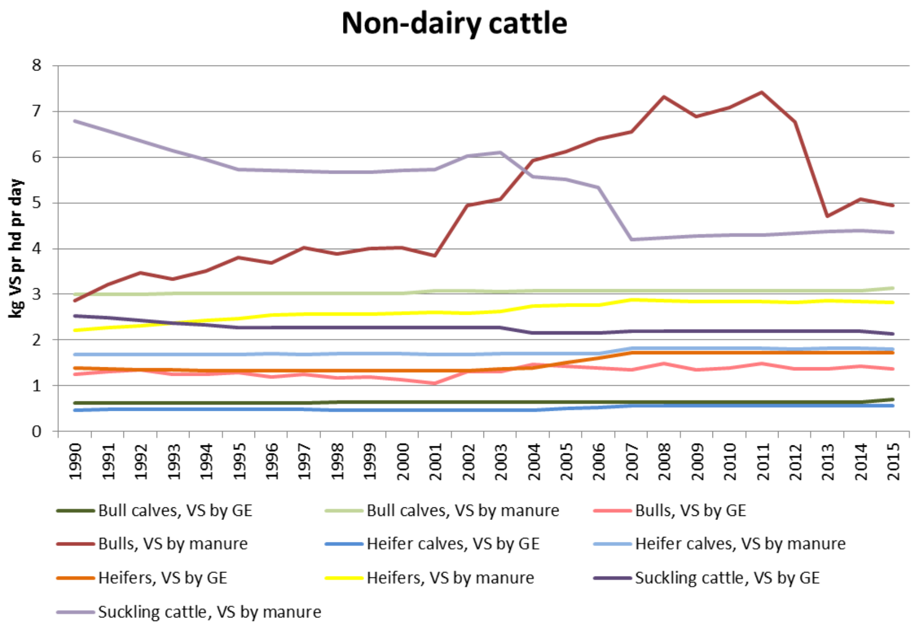

Figure 5.15 VS for non-dairy cattle based on GE and manure.

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.

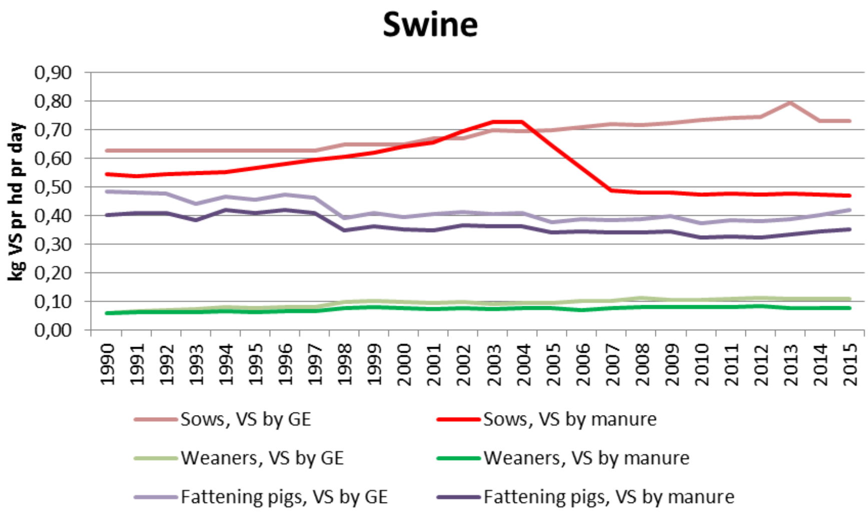

Figure 5.16 VS for swine based on GE and manure.

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-17.

The QA/QC procedure is divided in six stages as listed below:

Table 5.35 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 (2016) - 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 fertiliser.

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 2016. 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 1990-2015 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 fertiliser accounts controlled by The Danish AgriFish Agency. Farmers with more than 10 animal units is registered and have to keep accounts of the N content in manure, received manure or other organic fertiliser. 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 2015 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-17.

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 2017.

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 fertilisers bought and sold. Suppliers of inorganic N fertilisers 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 fertiliser in Denmark is, therefore, a very precise estimate for the inorganic N fertiliser 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 5.29.

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:

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Mr. Søren Tafdrup (st@ens.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.

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 2016 submission.

A range of changes in calculation of agricultural emissions 1990-2014 has taken place. The recalculation has contributed to a decrease in the total agricultural emissions for the years 1990-2014 of up to 2.5 % given in CO_2 equivalent (Table 5.36).

Table 5.36 Changes in GHG emission in the agricultural sector compared with the CRF reported last year.

	1990	1995	2000	2005	2010	2011	2012	2013	2014
Previous inventory									
3.A Enteric Fermentation, CH_4	158.2	153.9	140.9	135.6	142.0	140.4	143.9	143.9	145.4
3.B Manure Management, CH_4	72.4	86.5	96.0	101.6	93.9	93.2	89.8	87.1	88.0
3.B Manure Management, N_2O	3.3	3.1	3.2	3.3	2.7	2.6	2.6	2.5	2.5
3.D Agricultural Soils, N_2O	18.0	15.8	14.1	12.9	12.6	12.6	12.3	12.6	12.6
3.F Field Burning of Agricultural Residues, CH_4	0.1	0.1	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	0.003	0.003
3.G Liming, CO_2	565.5	496.0	260.6	219.7	152.8	161.6	188.4	243.9	237.7
3.H-I Urea and other C-containing fertilizers, CO_2	53.1	41.1	7.8	2.1	3.4	3.4	3.6	2.6	2.5
Total in CO2-eqv., Mio. t	12.73	12.20	11.34	10.97	10.59	10.56	10.46	10.54	10.57
Recalculated									
3.A Enteric Fermentation	161.6	158.7	145.2	139.3	145.2	143.7	147.0	147.9	148.4
3.B Manure Management, CH_4	61.7	74.4	83.4	87.8	80.0	79.4	76.4	74.3	75.1
3.B Manure Management, N_2O	3.3	3.1	3.2	3.3	2.7	2.6	2.6	2.5	2.5
3.D Agricultural Soils, N_2O	18.3	16.0	14.4	13.1	12.6	12.8	12.5	12.5	12.8
3.F Field Burning of Agricultural Residues, CH_4	0.1	0.1	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	0.003	0.003
3.G Liming, CO_2	565.5	496.0	260.6	219.7	152.8	161.6	188.4	243.9	237.7
3.H-I Urea and other C-containing fertilizers, CO_2	53.1	41.1	7.8	2.1	3.4	3.4	3.6	2.6	2.5
Total in CO2-eqv., Mio. t	12.63	12.08	11.23	10.79	10.33	10.33	10.27	10.28	10.40
Change									
3.A Enteric Fermentation	3.4	4.8	4.3	3.7	3.3	3.3	3.1	4.0	3.0
3.B Manure Management, CH_4	-10.7	-12.1	-12.6	-13.8	-13.9	-13.8	-13.4	-12.9	-12.9
3.B Manure Management, N_2O	0	0	0	0	0	0	0	0	-0.01
3.D Agricultural Soils, N_2O	0.29	0.22	0.33	0.25	-0.01	0.12	0.23	-0.12	0.27
3.F Field Burning of Agricultural Residues, CH_4	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
3.G Liming, CO_2	0	0	0	0	0	0	0	0	0
3.H-I Urea and other C-containing fertilizers, CO_2	0	0	0	0	0	0	0	0	0
Total in CO2-eqv., Mio. t	-0.10	-0.12	-0.11	-0.18	-0.27	-0.23	-0.19	-0.26	-0.17
Change in pct.									
3.A Enteric Fermentation	2.1	3.1	3.1	2.7	2.3	2.3	2.2	2.7	2.1
3.B Manure Management, CH_4	-14.7	-14.0	-13.1	-13.6	-14.8	-14.8	-14.9	-14.8	-14.7
3.B Manure Management, N_2O	0	0	0	0	0	0	0	0	-0.2
3.D Agricultural Soils, N_2O	1.6	1.4	2.3	1.9	-0.1	0.9	1.8	-0.9	2.1
3.F Field Burning of Agricultural Residues, CH_4	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
3.G Liming, CO_2	0	0	0	0	0	0	0	0	0
3.H-I Urea and other C-containing fertilizers, CO_2	0	0	0	0	0	0	0	0	0
Total in pct.	-0.7	-1.0	-1.0	-1.6	-2.5	-2.2	-1.8	-2.4	-1.6

The most significant inventory changes are mentioned below:

Recalculation for CH_4 from enteric fermentation has been made due to recalculated values for gross energy for dairy cattle and change in Y_m for heifers from 6.0 % to 6.5 %. This updating increases the emission of CH_4 from enteric fermentation with 2-3 % in the period 1990 to 2014.

For CH_4 from manure management recalculations is mainly due to updating of MCF for cattle and swine. Furthermore are MCF for sheep, goats and horses changed to the values given in IPCC 2006 guidelines. The emission of CH_4 from manure management has decreased 13-15 % for the period 1990 to 2014.

For N_2O is seen both decrease and increase of up till 3 % for the period 1990-2014. This is due to recalculation of the area of organic soils, which estimates a larger area of organic soils and thereby an increased emission. Emission from mineralization decrease and increase due to change of the C-TOOL, which is the model to estimate the carbon stock change in soil. Some other changes, which decrease the N_2O emission, have been made. Emission from atmospheric deposition mainly due to change in EF for NH_3 for inorganic N-fertiliser and some small changes in emission from manure management, manure on soil, indirect N_2O from manure management and leaching due to change in normative figures and NH_3 emissions.

Some changes in the number of animals have been made due to updating of the statistics and this affect both the emission of CH_4 and N_2O. Also some changes in area and yield have been made due to updating of statistics.

5.15 Planned improvements

A first estimate has been made for MCF for biogas treated slurry but the work with documentation of this will continue. Also further validation of data for amount of manure treated in biogas plants will be worked on.

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).

Studies indicate a reduction of CH_4 emission from acidified slurry. Possibilities of implementing this reduction in the inventory will be examined.

It is planned to provide a comparison of activity data for inorganic N fertiliser 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 CO_2 and CH_4 from drained ditches on organic agricultural soils have been estimated 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. According to IPCC GPG 2003, the climate is 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 2015 was warm but not the warmest year ever reported since the Danish measurements started in 1884 (www.dmi.dk) with an average mean temperature of 9.1°C, which is 1.4°C above the 1961-1990 average. .

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

2015 emissions from LULUCF were estimated to be a net source of approximately 4153.2Kt CO_2 equivalents or 8.72 % of the total reported Danish emission (excluding LULUCF).

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 IPCC Guidelines (IPCC 2006).

The distinction between tier level 2 and 3 has been based on the emission factor. The tier level definitions were 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 the respective key source analyses[1] (including LULUCF, tier 1/tier 2, level/trend).

Table 6.1 Methodology and type of emission factor.

		Tier	EF [a]	Key category
4.A.1 Forest	CO_2	Tier 3, Tier 1	CS, D	Level, Trend
4.A.2 Forest, Land converted to	CO_2	Tier 3, Tier 1	CS, D	Level, Trend
4(II) Drainage and Rewetting	N_2O, CH_4	Tier 2	D	
4.B Cropland, Living biomass	CO_2	Tier 2	CS	Level, Trend
4.B Cropland, Mineral soils	CO_2	Tier 3	CS, D	Level, Trend
4.B Cropland, Organic soils	CO_2	Tier 2	CS, D	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	Level, Trend
4.C Grassland, Mineral soils	CO_2	Tier 2	CS, D	No
4.C Grassland, Organic soils	CO_2	Tier 2	CS, D	Level, Trend
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.G. Harvested Wood Product	CO_2	Tier 2	D	Level, Trend
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

[a] CS= Country Specific value. [a] D= Default value.

6.1.3 Key categories

Key Category Analysis (KCA) approach 1 and 2 for year 1990, 2015 and trend for Denmark has been carried out in accordance with the 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 2015/ trend.

The CO_2 emissions from forests are key for forest remaining forest on both the level and the trend. For Cropland, both mineral and organic soils are key sources.

Table 6.2 Key categories, LULUCF.

		Approach 1			Approach 2		
		1990	2015	1990-2015	1990	2015	1990-2015
LULUCF 4.A.1 Forest land remaining forest land, Living biomass	CO_2	Level	Level	Trend		Level	Trend
LULUCF 4.A.1 Forest land remaining forest land, Dead organic matter	CO_2		Level	Trend		Level	Trend
LULUCF 4.A.1 Forest land remaining forest land, Organic soils	CO_2		Level		Level	Level	
LULUCF 4.A.2 Land converted to forest land	CO_2		Level	Trend		Level	Trend
LULUCF 4.B.1 Cropland remaining cropland, Living biomass	CO_2		Level	Trend		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		Level	Level	
LULUCF 4.B.2 Forest land converted to cropland	CO_2		Level			Level	Trend
LULUCF 4.B.2 Other land uses converted to cropland	CO_2		Level	Trend		Level	Trend
LULUCF 4.C.1 Grassland remaining grassland, Living biomass	CO_2		Level	Trend			
LULUCF 4.C.1 Grassland remaining grassland, Organic soils	CO_2	Level	Level	Trend	Level	Level	Trend
LULUCF 4.C.2 Forest land converted to grassland	CO_2						Trend
LULUCF 4.C.2 Other land uses converted to grassland	CO_2					Level	Trend
LULUCF 4.E.2 Other land uses converted to settlements	CO_2						Trend
LULUCF 4.G Harvested wood products	CO_2		Level	Trend		Level	Trend

6.1.4 Methods

Approximately 2/3 of the total Danish land area is cultivated and 14.5 per cent forested. Together with a 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 in 1990 within a tree generation (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. Other Land is thus 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).

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 heathland vegetation.

Savannas and rice cultivation do not occur in Denmark.

Estimation of carbon stock changes in the Danish forests is based on a combination of previous forest surveys and the present National Forest Inventory (NFI).

The Cropland and Grassland area are based on agricultural EU subsidiary systems and are 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 limited effect on the overall emission estimates as a gain one year in on sector will be counteracted by a loss in the other sector.

Table 6.3 shows the overall development in the land use classes from 1990 to 2014. Observe that the changes in Table 6.3 are from January 1st 1990 and onwards. This means that the sum of the figures is slightly different from those reported in the CRF tables as these are reported as end of year 1990. Afforestation is mainly taking place on CL and GL not previous classified as forest. Areas, which are deforested, are mainly converted to WE or GL and clearance of trees as a consequence of clearing of some areas in the State forests towards more open areas. Only a very limited area is converted to CL. Since 1990, 34 960 hectares have been changed into SE and other infrastructures. No land is converted into OL.

Christmas trees on agricultural land are reported under Forest land. This despite Christmas trees often are clear cut and may later on have an intermediate agricultural crop before it is again replanted with Christmas trees. The total area with Christmas trees was approximately 23 000 ha in 2015.

In the land use matrix, a linear approach for all land use changes has been adopted for the period 1990 to 2005 and from 2005 to 2011. From 2011 and onwards, annually updated data from the different data suppliers are used. 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.

Because there is a large area fluctuations between Cropland and Grassland in the annual LPIS information data, which not can be seen as real changes in land use, but merely in the farmers definition of their fields actually use, the LUM shows large changes. In the inventory, the effect of this has been taken into account and minimized as much as possible.

Table 6.3 Land Use Change from 1. January 1990 to 31. December 2015 based on GIS vector layers and Earth Observations[a].

1990\2015	Forest	Cropland	Grassland	Wetlands	Lakes	Settlements	Other	Sum
					Hectare			
Forest	534555	5906	2702	678	226	474	0	544541
Cropland	59242	2663975	133895	7491	3550	19814	0	2887966
Grassland	43775	142898	51595	4397	530	14670	0	257865
Wetlands	2	158	21	50574	0	2	0	50755
Lakes	0	0	0	0	52530	0	0	52530
Settlements	0	0	0	0	0	485462	0	485462
Other	0	0	0	0	0	0	26433	26433
Sum	637574	2812936	188213	63140	56836	520422	26433	4305552
Percentage	14.8	65.3	4.4	1.5	1.3	12.1	0.6	100.0

[a]Please observe that the matrix is from 1 January 1990. The figures are therefore not identical with figures given in the CRF tables.

Table 6.4 gives an overview of the emission from the LULUCF sector in Denmark. In 2015, forests have been estimated to be a net source of 228.8 kt CO_2 eqv. 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 decrease of the carbon stock is observed, as the old forests are regenerated with young trees. Cropland is ranging from being a net source from up to 4411.7 kt CO_2 eqv in 1990 to be a net source of 2605.8 kt CO_2 eqv. in 2015. Cropland and Grassland are general sources in Denmark due to large area with drained organic soils. 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 on field burning), demands on 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 (Kt CO_2) from the LULUCF sector in Denmark, 1990 - 2015.

	1990	2000	2010	2011	2012	2013	2014	2015
4. Land Use, Land-Use Change and Forestry, CO_2 (Gg CO_2-eqv)	4902.1	4207.7	-797.3	-2420.7	-252.1	1077.0	143.9	4153.2
A. Forest Land	-553.1	-563.1	-3739.2	-5778.6	-4050.8	-2423.8	-3970.4	228.8
1. Forest Land remaining Forest Land	-552.8	-586.7	-3552.2	-6963.7	-4687.2	-2961.9	-4153.6	-317.8
2. Land converted to Forest Land	-30.9	-18.6	-238.8	1133.1	584.2	485.5	130.6	493.6
B. Cropland	4411.7	3824.9	2008.2	2420.9	2548.9	2274.7	3005.0	2605.8
1. Cropland remaining Cropland	4417.2	3830.4	2028.1	2438.6	2629.3	2372.2	3031.5	2655.0
2. Land converted to Cropland	-5.6	-5.5	-19.9	-19.2	-84.1	-101.7	-28.4	-53.9
C. Grassland	931.4	819.2	855.4	872.5	1141.0	1169.9	1142.1	1363.5
1. Grassland remaining Grassland	903.3	792.2	775.6	791.1	978.3	1038.9	961.2	1141.3
2. Land converted to Grassland	14.6	15.2	69.4	71.2	151.1	118.9	168.5	210.2
D. Wetlands	101.6	75.5	90.7	98.5	79.6	52.7	61.1	55.3
1. Wetlands remaining Wetlands	99.5	67.9	52.0	58.1	48.1	40.3	48.2	40.7
2. Land converted to Wetlands	1.0	1.1	26.1	27.2	17.5	-1.8	-1.7	0.0
E. Settlements	12.9	25.2	59.5	62.2	96.6	90.4	52.6	71.3
1. Settlements remaining Settlements	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2. Land converted to Settlements	12.9	25.2	59.5	62.2	96.6	90.4	52.6	71.3
F. Other Land	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
G. Harvested Wood Products	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

6.2 Forestry

The forest definition adopted in the NFI is identical to the FAO definition (FAO, 2010 Annex 2). It includes "wooded areas larger than 0.5 ha, that *in situ* 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, firebreaks and other small open areas, that are an integrated part of the forest, are also included.

6.2.1 Forest inventory

Forest census 1881-2000

From 1881 to 2000, a National Forest Census was carried out roughly every 10 years based on questionnaires sent to forest owners (e.g. Larsen and Johannsen, 2002). Since the data were 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 using standard forestry yield tables. The two last censuses were carried out in 1990 and 2000.

National forest inventory 2002-

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 such as Sweden or Norway. The NFI has replaced the National Forest Census.

The Danish 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. In each grid cell, a cluster of four circular plots (primary sampling unit, PSU) for measuring forest factors (e.g. wood volume) are placed in the corners of a 200 x 200 m square. 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.

A detailed description of the Danish NFI is presented in Nord-Larsen and Johannsen (2016).

In the most recent five-year rotation of the NFI (2011-2015) the number of clusters (PSU) and sample plots (SSU) were 4 300 and 9 532, respectively.

Table 6.5 Number of measured clusters and sample plots in the five year rotation 2011-2015.

Year	Clusters		Sample plots			
	Total	Forest	Total	Measured	FRFL	AF
2011	2 173	850	8 520	1 896	980	388
2012	2 200	908	8 617	1 978	940	442
2013	2 197	905	8 630	1 973	1 057	399
2014	2 187	844	8 590	1 830	939	429
2015	2 204	876	8 590	1 899	957	424
Total	10 961	4 383	42 947	9 576	4 873	2 082

Note: Measured plots are plots that are selected for inventory based on aerial photographs. FRFL are plots with forest cover within forest remaining forest land and AR are plots with forest cover within forests established since 1990. A total of 7 415 plots had forest cover.

6.2.2 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 National Forest Inventory from 2002). 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 satellite 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 for the island of Bornholm, none of the scenes was cloud-free. So, to 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.

6.2.3 Estimation of forest carbon pools

In the following, procedures for estimating forest carbon pools are described in general. For a more detailed description of the calculations and the specific formulas used, readers are referred to Nord-Larsen and Johannsen (2016).

Estimation of forest area

Based on analysis of aerial photos, each NFI sample plot (SSU) is allocated to one of three forest status categories, 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. All NFI sample plots within clusters (PSU) with one or more SSU belonging to (1) and (2) are inventoried in the field.

Overall forest cover fraction is calculated as the sum of the forest covered plot area divided by the total sample plot area. In this calculation, the forest area in plots belonging to (0) is assumed to be 0. In some years, not all sample plots were inventoried. The estimated forest area in un-inventoried plots belonging to 1 or 2 was assumed to equal the average forest area in inventoried plots belonging to (1) and (2).

The overall forest area is calculated as the overall average forest cover fraction times the total land area.

The fraction of forest area with a specific characteristic, such as forest established before or after 1990, is estimated as the forested plot area with the particular characteristic divided by the total forested plot area. The total forest area with a particular characteristic is subsequently found as the fraction of forest area with the particular characteristic times the total forest area.

Estimation of volume, biomass and carbon pools

Growing stock is calculated using species specific, individual tree volume functions developed for the most common Danish forest tree species (e.g. 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. For trees lacking volume functions, volumes are calculated using functions for trees with a similar phenology.

Biomass and carbon stocks are calculated using species specific, individual tree biomass models developed for the most common forest tree species in Denmark (Skovsgaard et al. 2011, Skovsgaard and Nord-Larsen 2012, Nord-Larsen and Nielsen 2015). For species where no biomass function is available, above ground biomass is calculated as the volume times the basic density (e.g. Moltesen 1988, Skovsgaard et al. 2011, 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. Biomass is converted to carbon using a factor of 0.47 g C/g.

Total growing stock, biomass and carbon stocks are estimated by obtaining an estimate of average stocks per hectare on inventoried NFI plots times the overall forest area. The total growing stock, biomass or carbon stocks with a given characteristic are estimated as the sum of the stocks with the particular characteristic divided by the inventoried plot area, times the total forest area.

Dead wood volume, biomass and carbon content

The volume of standing dead trees and lying dead trees with their base inside the sample plots are calculated using individual tree volume functions, similarly to the calculations for live trees. The volume of lying dead tree parts (e.g. broken off branches, but excluding lying dead trees with their base outside the sample plot) 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 multiplied with species specific basic densities and a reduction factor according to the structural decay of the wood. Biomass is converted to carbon using a factor of 0.47 g C/g.

Similar to live biomass, total dead wood, biomass and carbon stocks are estimated by obtaining an estimate of average stocks per hectare on inventoried NFI plots times the overall forest area.

Forest floor

Forest floor carbon stocks are measured as part of the NFI. Changes in this C pool are based on depth measurements performed on all NFI plots in the annual census by the method described in the NFI protocol (Knudsen et al. 2016) and species specific standard forest floor basic densities.

Forest mineral soil and organic soil

The NFI monitoring was supplemented by an additional forest soil inventory in order to document that forest soils are not an overlooked source for CO_2 emissions and to be able to distinguish mineral soils from organic soils (by a topsoil carbon concentration of 12% in the 0-25 cm soil layer below the O-horizon) for calculations of carbon stocks and area of mineral soils and organic soils respectively. Based on this criterion, organic forest soils represent 5% of the forest area. This fraction is consistent with the map classification of organic soils using the Digital Geological Map of Denmark (1:25.000 and 1:200.000). For organic soils, the default carbon source emission factor of 2.6 t C/ha/yr was used (Wetland supplement, 2013, Table 2.1).

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 source for emissions of CO_2, 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.

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 data from the re-measured sites in the so-called "Kvadratnet" (Agricultural Network) suggested that mineral forest soil C pools are not sources for CO_2 and thus supported that more accurate estimates of litter and soil C pool removals/emissions do not need to be included in the reporting (Callesen et al. 2015). The methodology of the survey is described in Callesen et al. (2015) and NIR with data for the year 2013 (Nielsen et al. 2015).

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 area of forests remaining forest of approximately 500 000 ha. Based on power analyses, we thus evaluated 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 in six depth sections: forest floor, 0-10, 10-25, 25-50, 50-75 and 75-100 cm and processed the samples as described in the KN study reported in Nielsen et al. (2015).

Soil carbon stock changes in forest remaining forest

Mineral soil C stocks in forest remaining forest are estimated at 155 t C/ha to 1 m depth for soils with <12%C in 0-25 cm. No overall changes in SOC stock to 1 m depth were detectable in mineral soils in a depth of 0-100 cm between 1990 and 2007-9 (Callesen et al., 2015).

6.2.4 Carbon pools in forest remaining forest

The carbon pool in live and dead biomass estimated for the most recent rotation of the NFI (2011-2015) is 41 million tonnes C (Figure 6.1). The live above ground biomass carbon makes up 81 % of the total carbon in biomass and dead wood makes up only 1.5 % of the total. Carbon in biomass in forests established after 1990 make up 3.2 % of the total. 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, due to improved detection of forest caused by improvements of aerial photos used for this.

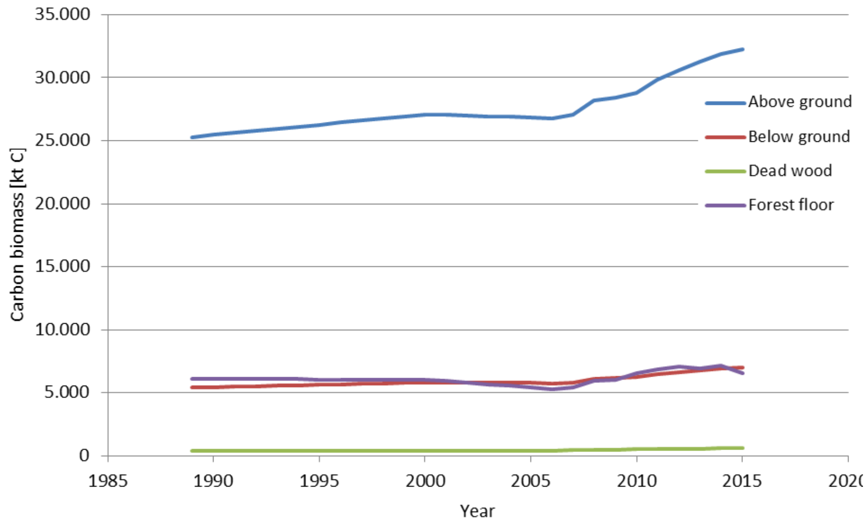

Figure 6.1 Forest carbon in forests established before 1990 estimated from NFI data from 2002-2015. Note that estimates for 2002-2005 are based on only 1-4 years of measurements. Only from 2006 are the estimates based on a full five-year rotation of the NFI.

6.2.5 Uncertainties and time series consistency

Danish national forest resource assessment has developed over the years from the earliest forest census more than a century ago to the current national inventory. 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 substituted 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 improvements.

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 6.6).

Table 6.6 Tier 1 and 2 estimates of the uncertainty in the forest.

		1990	2015					
		Emission/ sink, kt CO_2 eqv.	Emission/ sink, kt CO_2 eqv.	Activity data, %	Emission factor, %	Combined uncertainty	Total, uncertainty, %	Uncertainty, 95 %, kt CO_2 eqv.
4.A Forests		-553.1	228.8				3.8	8.8
4.A.1 Forest land remaining forest land, Living biomass	CO_2	-737.9	-2470.7	5	2	5.4	5.4	133.0
4.A.1 Forest land remaining forest land, Dead organic matter	CO_2	-5.8	2016.6	5	2	5.4	5.4	108.6
4.A.1 Forest land remaining forest land, Organic soils	CO_2	189.9	136.3	10	50	51.0	51.0	69.5
4.A.2 Land converted to forest land	CO_2	-30.9	493.6	10	9	13.3	13.3	65.5
4(II) A. Forest land, organic soils	CH_4	4.0	29.1	10	90	90.6	90.6	26.4
4(V) Biomass Burning	CH_4	0.7	0.0	10	30	31.6	0.0	0.0
4(V) Biomass burning	N_2O	0.4	0.0	10	30	31.6	0.0	0.0

6.2.6 QA/QC and verification

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. Further, improvements to this end are expected, as new biomass models for six common broadleaved species are under development. Further, projects aimed at improving consistency of forest carbon pool estimation across Europe (Diabolo), is expected to yield a new set of biomass equations from a very large dataset collected across Europe.

Integration with multi-phase and multi scale inventory, e.g. through other in-situ data like LiDAR scanning or satellite imagery will contribute to the continued QA/QC process of the NFI and the carbon stock estimates for forests.

6.2.7 Recalculation

Recalculations were made compared to the ordinary submission in 2016. Christmas trees on agricultural land have been moved back to forestland in both the Convention and the KP reporting.

6.2.8 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, which is already implemented partly in the new estimations.
- A new project, Sinks2, 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.

6.3 Land converted to forest

See section 6.2.1 Information on approaches used for representing land areas and on land-use databases used for the inventory preparation.

6.3.1 Forest definition

The definition of land converted to forest corresponds to the definition used for forest remaining forest (see section 6.2) and the LULUCF categories used elsewhere (e.g. land use and land-use change matrix).

6.3.2 Methodological issues for land converted to forest

Living biomass

As with forest remaining forest, Denmark applies the stock change method, hereby including both growth and harvesting in the overall estimation.

When converting land to forestland, the standing living above- and below ground biomass are assumed to be removed from the land. For land converted e.g. 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. In Table 6.7 the default values for the amount of living biomass removed is shown.

For deforestation direct estimation of the removed biomass above and below ground are based on biomass maps based on Lidar data. For the Forest floor and dead wood average forest estimates are used for the share of the deforestation which involves removal of wooded areas (defined as having canopy heights above 2 m and crown cover more than 10 pct.). For open areas previously assigned to the forestland use classification as open areas within the forest matrix, carbon pools are assumed similar to the grassland estimates.

Table 6.7 Default values for the amount of DM (dry matter, kg per hectare) used for estimating carbon stock changes where land use conversions take place. The default C stocks in mineral soil (<6%C in 0-25 cm) are used for estimation of C stock changes following land-use change.

		Dry matter, kg DM pr hectare		
		Above ground biomass	Below ground biomass	Default C stock in mineral soil, tonneC/ha
Forest land				142[c] (excl. ff)
Christmas trees		21 277	4 255	142
Cropland		9 577	2 298	120.8
Grassland	Improved Grassland	2 400	6 720	142a
	Unmanaged Grassland	2 200	6 160	142
Wetlands	Peat extraction	0	0	NE
	Other Wetland	3 600	10 080	NE
Settlements		2 200	2 200	96.6[b]
Other land		0	0	NA

[a] Same as for forest land.
[b]80 % of the carbon stock in Cropland (IPCC chapter 8.3.3.2).
[c] Average of all forest mineral soils (<6 % SOC, 262 plots in NFI and Kvadratnettet).

Forest floor

The included soil carbon pool changes concerned carbon sequestration due to development of forest floors, i.e. the organic layer on top of the mineral soil as well as C sequestration in the mineral soil.

Forest floor C stocks after afforestation were estimated based on depth measurements performed as an integrated part of the NFI. Depth measurements were converted to C stocks based on bulk densities and concentrations similar to the method described for forests remaining forest, as described in Nord-Larsen & Johannsen (2016).

Mineral soil

In the calculation of SOC changes after afforestation, a linear model assuming an increase of 21 t C in mineral soil per 100 years was used. This is based on measured SOC stocks (mineral soil) in cropland, grassland and forest (Table 6.7).

Several previous national field studies mentioned above (Vesterdal et al. 2002a, 2002b, 2007) did not suggest statistically significant 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 for mineral soils (<6%C in 0-25 cm) reported from a parallel project for cropland soils (Table 6.7). These data indicate that mineral soils are small sinks for CO_2 following afforestation of former cropland. Using a transition time of 100 years, these soil carbon contents were used to calculate the modest rates of soil carbon stock change for cropland to forest conversion (0.21 tC/ha/yr over 100 years).
Uncertainties and time series consistency

See Section 6.2.1 and 6.2.2 for recalculation since 1990.

6.3.3 Carbon pools in land converted to forest

The amount of carbon in biomass in forests established after 1990 has been increasing rapidly during the time of NFI measurements (Figure 6.2). 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. In addition, in the early measurements, aerial photographs were of a poorer quality and recent afforestation may have been difficult to detect.

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.

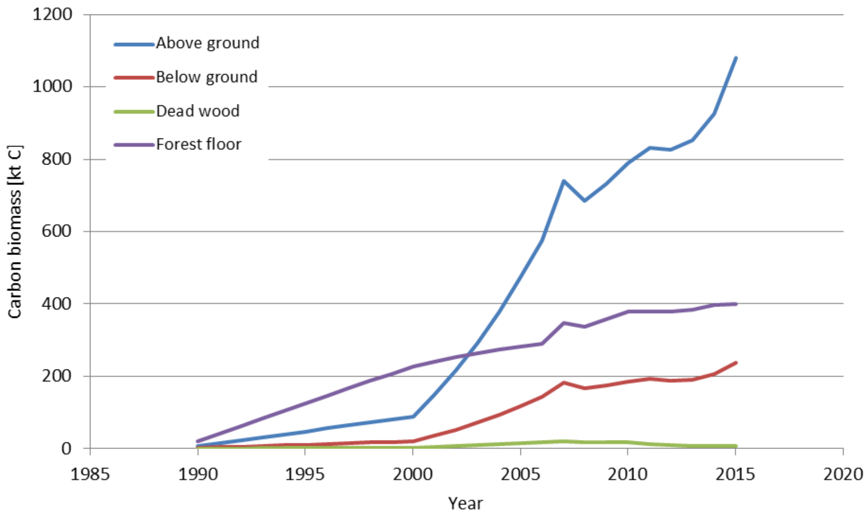

Figure 6.2 Forest carbon in forests established after 1990 estimated from NFI data from 2002-2014. Note that estimates for 2002-2005 are based on only 1-4 years of measurements. Only from 2006 the estimates are based on a full five-year rotation of the NFI.

6.3.4 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

6.3.5 Recalculation

Recalculations were made compared to the ordinary submission in 2016. Christmas trees on agricultural land have been moved back to forestland in both the Convention and the KP reporting. An error was found in the data for living biomass on afforested land in the Convention reporting. This has slightly changed the amount of living biomass in the most recent years. The soil carbon stock in mineral forest soils has been re-evaluated so it matches the condition for the Danish soil classification. In this the definition of an organic soil is >6% OC. The new average value for SOC in forest soils of 142 tonnesC/ha (0-100 cm) is based on more than 300 soil samples.

6.4 Implemented and planned improvements

A QA/QC of the Land Use matrix is a continuous process.

The basic information utilised to provide 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 afforested 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 for the next reporting be possible to provide some indications of the frequency of harvesting/thinning occurring on the afforested areas. Given the fact that the afforested area is still a relatively small part of the full forest area, there will be more uncertainty on the estimate related to afforested areas compared to the area of forest remaining forest. New data sources based on e.g. ALS / LiDAR data will potentially improve the estimates and the mapping process, bur requires more development to be implemented on an annual reporting basis.

Documentation for carbon pools in soil and litter is expected to be further improved following the next resampling of forest soils.

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 as well as 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. The area of Christmas trees is now handled as a specific part of the forestland use, and the dynamics therein are handled directly in the estimation of the carbon pools.

6.5 Emissions from wet and drained soils

Improvements of soil categories

The Wetland supplement (WS 2013, Figure 1.2, p 1.6) has introduced new soil categories including 'mineral wet soils' and 'mineral drained soils' (inland or coastal) as soil categories in addition to the formerly used 'dry mineral soils' (GPG 2006). These categories have not yet been implemented in the reporting, but we are aware of the issues raised concerning SOC levels and effects of rewetting on non-CO_2 greenhouse gases.

The temporal change in shares of drained and rewetted soils has been assessed based on current trends in forest management. A change in these soil categories was made in 2008 based on expert assessment of observed trends in the past 20 years of active maintenance of pre-existing ditches in forests.

Table 6.8 Outline of assumptions on drainage changes over time for mineral and organic soils in forest.

Share, %	Mineral soil		Organic soil	
	Drained (ditched)	Undrained (not ditched)	Drained (ditched)	Undrained (not ditched)
1990 - 2008	65% - > 55% (0.5% points per year)	35%->45% (0.5 % points per year)	75%	25%
After 2008	55%	45%	50%	50%

The area of rewetted mineral and organic soil following the previously reported area shares of ditched/unditched is:

Rewetted mineral soil: 65% - 55% = 10 % of total forest area on mineral soils.

Rewetted organic soil: 75%-50%= 25% of total forest area on organic soils.

Reporting of nitrous oxide emissions

The only soil category for which nitrous oxide emissions apply is 'organic soils, drained', and default emission values have been used. Measurements of nitrous oxide emissions from conditions applying for organic drained soils in Denmark are scarce or lacking. Danish measurements that apply to a hydromorphic, loamy soil were 0.4 – 0.6 kg N_2O-N ha^{-1} yr^{-1} (Christiansen et al., 2012b), which is somewhat lower than the WS 2013 default value.

Organic soils, drained: 2.8 (range 0.57 – 6.1) kg N_2O-N ha^{-1} yr^{-1} (Table 2.5 in Wetland supplement, p. 2.33). Remaining soil categories do not apply, since they are either too dry or too wet to produce nitrous oxide.

Reporting of methane emissions

The following emission factors for methane were identified; we note that units vary between chapters in WS 2013. A default area of 2.5% ditches was assumed. Table numbers refer to the 2013 Wetland Supplement.

Table 6.9 Identified emission factors for methane in WS 2013 used in methane emission calculations.

CH_4 EF for organic drained soils	Table 2.3	kg CH_4/ha/yr	2.5
CH_4 EF for ditches on organic drained soils	Table 2.4	kg CH_4/ha/yr	217.0
CH_4 EF for organic rewetted poor soils	Table 3.3	**kg CH_4-C/ha/yr**	92.0
CH_4 EF for organic rewetted rich soils	Table 3.3	**kg CH_4-C/ha/yr**	216.0
CH_4 EF rewetted Inland Mineral Wetland Soils	Table 5.4	kg CH_4/ha/yr	235.0

In a Danish study of three forests in eastern Denmark on hydromorphic soils the reported methane emissions were -0.08 - 3.2 kg CH_4 ha^{-1} yr^{-1} (Christiansen et al., 2012a; Christiansen et al., 2012b). The default value for drained organic soils seems to be reasonable until national estimates are better founded by representative measurements. Since no water level measurements in ditches and rewetted soils are available, it is not possible to judge whether the 2013 Wetland Supplement default values for methane emissions apply to Danish conditions.

6.6 Cropland

6.6.1 Cropland and cropland management (4B1)

The total Danish cropped agricultural area of approximately 2.7 million hectare can relate to approximately 600 000 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 2.65 million hectare (Table 6.9). 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 6.3

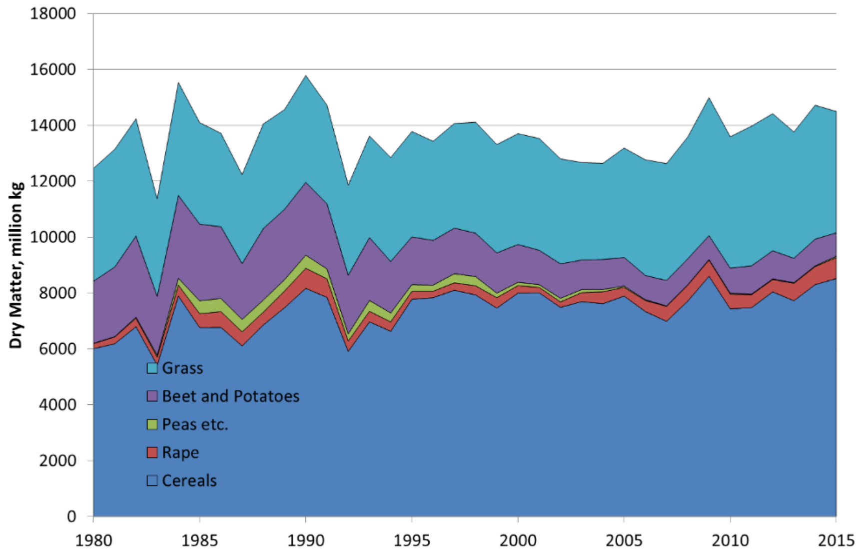

Figure 6.3 Total crop yield given as kernel, root fruits and grass as measured in dry matter (Million kg dry matter per year, Source: Statistic Denmark).

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 (>25 kg N per ha per year) is reported under Grassland. All fertilisation with nitrogen is reported under Agriculture 3D2.

Table 6.9 shows the development in the agricultural area from 1990 to 2014 (Statistics Denmark). A general trend is a continuous decrease of 6 000 - 7 000 ha per year in the agricultural area. However, from 2013 to 2014 is reported an increase in the area with annual crops of 37.000 hectares. The reason is partly a decrease in the area with grass in rotation, but this cannot explain the large increase.

Table 6.9 Cropland area in Denmark 1990-2014 according to Statistics Denmark and the Land Use Matrix, hectares.

	1990	2000	2010	2013	2014	2015
Annual crops (CL) [1]	2236535	1938633	2049304	2044704	2081830	2064949
Grass in rotation (CL)	306325	330834	327319	323846	316350	258202
Permanent grass (CL and GL)	217235	166261	199859	195484	192617	254770
Horticulture – vegetables (CL)	16428	10803	10812	9930	11745	11119
Perennial fruit trees – perennial wooden crops (CL)	10267	9892	8181	7684	7217	7391
Set-a-side and other land (CL)	3861	192441	51309	46249	41873	37559
Total agricultural land area reported by Statistics Denmark	2788276	2646982	2646400	2627817	2652026	2632947
Willow and other crops for energy purposes (CL)	588	695	4049	5690	5776	5478
Hedgerows (CL)	61326	60554	59791	59589	59509	59485

[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 the land use matrix 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, Christmas trees on agricultural land, Hedgerows and Willows.

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 2015
- Area and harvest surveys from Statistics Denmark, 1980 to 2015
- 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 2015.

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 6.7.

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. Previous was all Christmas trees reported under Forest land although Denmark has a high production of Christmas trees on agricultural land which is managed, fertilized and has pesticide application like agricultural crops and thus in many cases are taking place inside the crop rotation. Analysis of the rotations showed that up to 80 per cent of Christmas trees was followed by an annual crop or grass. The far major part of this crop growing could therefore not be seen as afforestation followed by deforestation. As a consequence has all Christmas trees grown on Cropland been mowed into the Cropland reporting. Christmas trees inside established forest are still reported under Forestland. The area with Christmas trees on Cropland are annual reported by Statistics Denmark. The total area for different main classes and the used carbon stock in above-ground and below-ground biomass are given in Table 6.10. 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 6.12 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.

The carbon fraction of dry matter (DM) is assumed 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 6.10 Mg living biomass per hectare and area, ha, with perennial wooden trees and – bushes, 1990-2015.

	Living bio-mass, Mg DM per ha	1990	2000	2010	2014	2015
Black currant	5.20	1269	1492	1935	1719	1121
Other berries	5.20	663	611	533	914	690
Rosehip	13.99	0	0	197	139	133
Cherries	25.45	1787	2804	1743	1317	1059
Plumes	25.45	0	0	68	63	67
Hazelnut and Walnuts	25.45	0	0	14	28	27
Aples	33.76	2726	1678	1684	1484	1501
Pears	13.99	351	441	357	308	317
Elderberry	25.45	0	0	9	12	12
Grapes	5.20	0	0	45	62	79
Other fruit trees	13.99	0	0	60	88	90
Rowan-berries	33.76	0	0	16	23	26
Willow	17.43	588	695	4049	5776	5478
Miscanthus	17.43	1	6	156	70	69
Total		7385	7727	10865	12001	10668

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 was previously given to approximately 400-800 km of hedgerow in the latter years only financial support has been given to app. 100 ha. From 2017, this subsidiary is ceased. There are no figures on how many hedgerows have been removed in the same period as these to a large extend are not protected.

In Table 6.11 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 6.13. 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. No new planting data has been reported for 2014 and thus is the planting rate set to 0.

Table 6.11 Hedges planted and removed under the governmental subsidiary system 1990 to 2015.

	1990	2000	2010	2013	2014	2015
Planted 3-rowed, km	928	852	109	109	0	0
Planted 6-rowed, km	0	250	29	30	0	0
Planted small biotopes, ha	0	0	64	36.3	0	0
Percentage removed, %	75%	27%	20%	20%	20%	0%
Percentage new, %	25%	74%	80%	80%	80%	0%
Hedges remowed, ha	522	219	21	21	0	0

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 (See Annex3E_LULUCF).

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 (Taghizadeh-Toosi et al., 2014b) 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, hedge-rows 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 (Taghizadeh-Toosi et al., 2014b) 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 6.5.

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". 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.

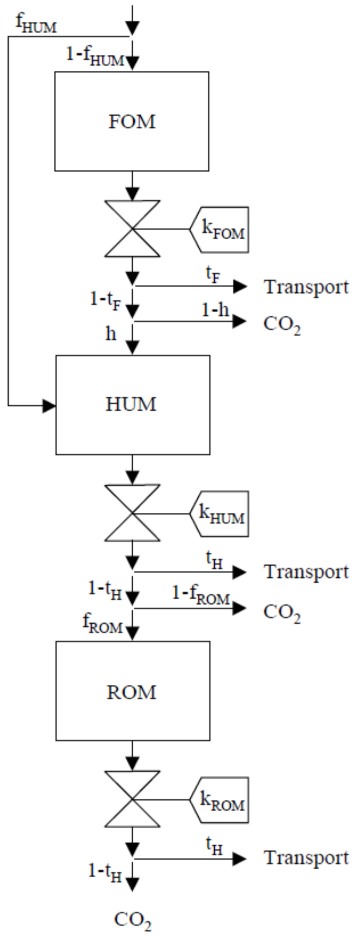

Figure 6.4 A simple diagram of C-TOOL.

Input data to C-TOOL and out put

A major revision of the soil parameters was made in 2016. The new version (Version 2.3) was implemented in the 2017 submission for all years. Version 2.3 include ALL agricultural mineral soils in Cropland and Grassland. In the reporting are mineral soils in Grassland therefore reported as IE. This also to facilitate the trivial annual conversions from CL to GL and from GL to CL as mentioned in the land use matrix (table 6.2).

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 %. 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. The manure data is used as input to C-TOOL.

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 240 000 hectares of the agricultural area has this additional crop every year. The demand for catch crops has altered the way of farming in two 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 0.27 tonnes carbon per hectare per year (Eriksen et al. 2014). 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.naturerhvervsstyrelsen.dk).

More detailed figures on the distribution as an example of the crop yield and areas are given in Annex 3F, Table 3.F10-12.

The overall input to C-TOOL varies between years (Figure 6.4) due to the actual growing conditions in that particular year. The year 2015 was a good year for growing cereals. The total harvest yield was the second highest ever recorded whereas the yield of maize for silage was less than normal. The variation in the input to C-TOOL gives an 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.

C-TOOL is initiated with data from 1980. 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.

The FOM-pool (Fresh Organic Matter) which in fact is undecomposed crop residues has a very fast turnover rate (N_2O emissions from crop residues returned to soil 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 6.6 shows the development in the two pools. Since 1980, there has been an almost steady state in the total carbon stock in the agricultural soils despite a slightly increased yield, which has been counteracted by an increased temperature.

Due to the large C stock in the soils it is difficult to see the small annual changes in Figure 6.5, but it is obvious that the total carbon stock fluctuates more than the two more steady pools, HUM and ROM. Figure 6.6 shows the annual changes.

Two examples

Both year 2006 and 2007 were bad cropping years with a cereal crop yields of 7-9 % below the average of the 2001-2010. The average Danish temperature was however 1.9 °C higher than the reference for 1961-1990 in 2007. Therefore, both due to the low C input and a high degradation rate, the agricultural soils was estimated to have a high loss of carbon in these years, Figure 6.5.

Year 2010 was very cold and temperatures below the average from 1961 to 1990. Year 2010 had an average of 7.0 °C against the normal of 7.7 °C. The means that the degradation goes down. The average cereal yield was 3.5 % lower than the average of 2001-2010. The result was an increased carbon stock in the soil.

In recent years (1999 - 2015), 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 2015 had an average temperature of 9.1 °C or 1.4 °C above the average from 1961 to 1990.

Year 2015 had the second highest recorded cereal yield. Combined with the 9th warmest recorded temperature since 1874 this resulted in a fairly steady carbon stock in the soil, but not as high as in 2014.

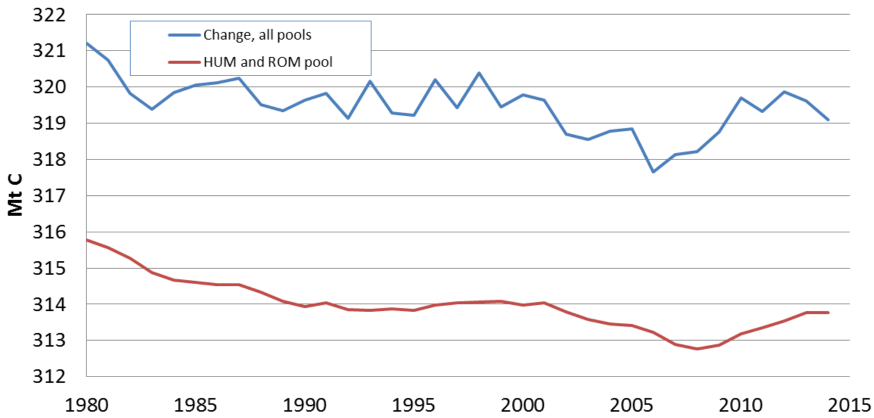

Figure 6.5 The development in the C-stock in agricultural soils (fixed area for 1990), Mt C (million tonne C).

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 2010. Since 1990 C-TOOL has estimated a loss of 1.8 % 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.

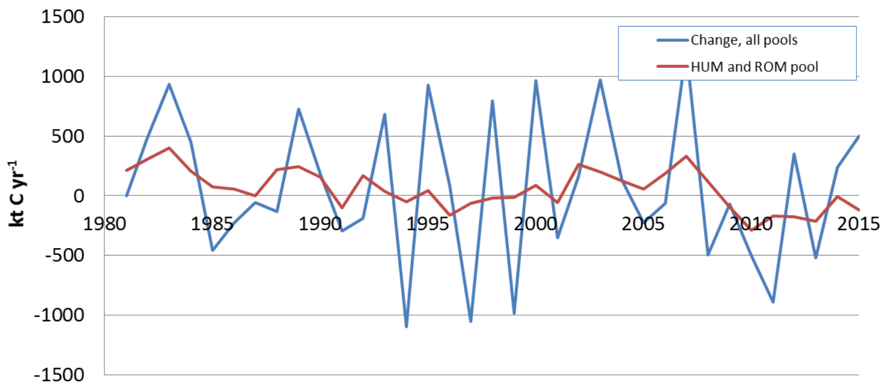

Figure 6.6   Estimated annual emissions from mineral soils 1981 to 2015 (kilo tonnes CO_2 yr^{-1}).

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 6.7 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 increased crop yields that increase the amount of organic matter returned to soil and 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. The uncertainty in the measurements is very high so overall it is concluded that the modelled results are in line what is found in plot sampling.

C-TOOL (Ver 2.3) has estimated an overall average loss from 1987 to 2009 of 0.66 tonnes C per ha. In the soil sampling grid is found an average loss of approx. 4 tonnes C per ha. 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. A new sampling in grid is planned in 2018/2019. This will further verify the development.

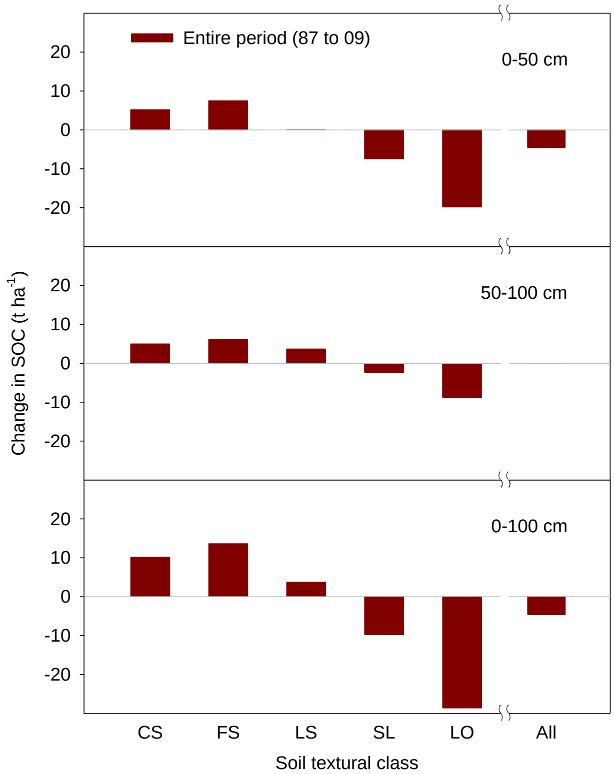

Figure 6.7 The change in carbon stock in soil (0 - 100 cm) in >460 paired agricultural plots from 1987 to 2009 (Taghizadeh-Toosi et al. 2014).

Organic soils - 4B1

A complete new soil map of the organic soils was made in 2010 for the inventory (Figure 6.8). 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.

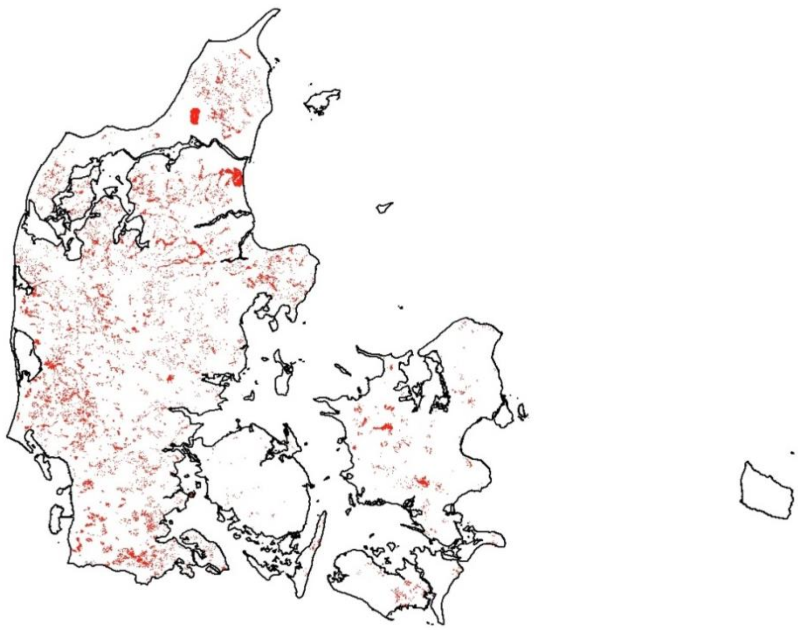

Figure 6.8 The new organic soil map for Denmark for year 2010, > 12 % OC (Greve et al. 2014).

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 2015 24 708 hectares with annual crops and 23 055 with grass in rotation were located to be grown on the organic soil area in the defined Cropland area. Every year we can see that some areas are falling out of the land where the farmers are not applying for subsidies. Some of these are found in the map for Wetlands (4.D) but not all. In 2015 3 289 hectares could not be recognized. Further drainage of the organic soils in Denmark has not been allowed for many years. The most likely situation is that these areas have become wet and not suitable for cropping purposes. These areas has been assigned an emission of 3.6 tonnes C per ha as for shallow-drained nutrient-rich grassland from the 2013 Wetland Supplement (IPCC 2014).

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 47 763 hectare in 2015 is farmed in the Cropland area and 18 327 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 trend over the years is a slightly increasing organic area, which is reported as permanent Grassland. One reason could be that a larger area becomes wet and not suitable for annual crops any more.

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 6.11 compared with the IPCC default values. For areas not reported in the land field system is used default Tier 1 emission factors from the 2013 Wetland Supplement (IPCC, 2014). 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 estimate also covers the boreal zone, the measured Danish values 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 6.11 Emission factors from organic soils, tonnes C per ha per year.

	Cropland Annual crops and grass in rotation	Grassland Permanent grass	Abandoned land Abandoned land
Soils > 12 % OC	11.5 (SE = ±2.0)	8.4 (SE = ±1.0)	3.5
Soils 6-12 % OC	5.75	4.2	1.75
IPCC 2014, Boreal and Temperate	7.9 (CI = 6.5-9.4)	3.8-6.1 (CI = 5.0-7.3)	Grassland shallow drained 3.6 (CI = 1.8-5.4)

As emission factor for N_2O from the 2013 Wetland Supplement the 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, 3Da6. No CH_4 emission is reported from drained CL, which is in accordance with the 2013 Wetland Supplement, although for the shallow-drained abandoned organic soils are reported a CH_4 emission factor of 39 kg CH_4 ha^{-1} yr^{-1}.

In Table 4B is included the organic area with 6-12 % OC but by a mistake includes the area in Table 4B the sum of the organic area in Cropland and in Grassland. The emission estimates are correct. The sum of the area in 4B and 4C is therefore not equal to the area in 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 6.12.

Table 6.12 Emissions from cropland organic soils 1990 to 2015.

	1990	2000	2005	2010	2011	2012	2013	2014	2015
Cropland, 6-12 % OC, ha	44407	39183	36570	33844	34077	32516	31865	31547	31803
Cropland, > 12 % OC, ha	70992	62640	58464	54105	54478	52034	51049	50596	51052
Cropland, total, ha	115398	101822	95034	87949	88555	84550	82914	82143	82855
Emission, total, kt C	-1072	-946	-883	-819	-813	-761	-742	-751	-737
Emission, total, kt CO_2	-3930	-3467	-3236	-3002	-2980	-2791	-2721	-2753	-2705

Uncertainties and time series consistency

A Tier 1 uncertainty analysis has been made for part of the LULUCF sector cf. Table 6.13. 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 6.13 Tier 1 uncertainty analysis for Cropland for 2015.

		1990	2015					
		Emission/ sink, kt CO_2 eqv.	Emission/ sink, kt CO_2 eqv.	Activity data, %	Emission factor, %	Combined uncertainty	Total, uncertainty, %	Uncertainty, 95 %, kt CO_2 eqv.
4.B Cropland		4411.7	2605.8				36.1	941.8
4.B.1 Cropland remaining cropland, Living biomass	CO_2	-84.9	387.9	3	15	15.2	15.2	59.0
4.B.1 Cropland remaining cropland, Mineral soils	CO_2	572.4	-438.0	3	75	75.0	75.0	328.7
4.B.1 Cropland remaining cropland, Organic soils	CO_2	3929.7	2705.0	3	50	50.1	50.1	1355.4
4.B.2 Forest land converted to cropland	CO_2	3.1	143.0	10	50	51.0	51.0	72.9
4.B.2 Other land uses converted to cropland	CO_2	-8.7	-200.5	10	50	51.0	51.0	102.2
Other cropland issues	N_2O, CH_4	0.0	3.6	10	50	51.0	51.0	1.8

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 since 2010 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 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 very low due to the subsidised system.

As shown in Figure 6.5 and 6.6 the increase in carbon stock as estimated by C-TOOL seems 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 new version of C-TOOL and inclusion of abandoned organic soils which previous were omitted. The new version of C-TOOL covers all mineral soils in Cropland and Grassland. Therefore are carbon losses due to land use changes between CL and GL now reported as IE.

All changes have been implemented for all years.

Planned improvements

The relatively high land use conversion from CL to GL and vice versa is due to the farmers reporting on the actual crop on that specific land parcel. As a consequence, a given land may one year be reported as in annual rotation, the next year as permanent grass and then again back into annual rotation. This creates high land use conversions between CL and GL, as seen in 2012 and in 2015, which are most likely artefacts. It will be investigated how the reporting can be improved so these artefacts can be avoided. The result is that a higher share of land is removed from "Land remaining Land" to "Land converted to". This has no effect on the overall emission estimate but is an allocation issue.

Verification and investigation of the hedgerows will take place in 2017. A new soil sampling in the agricultural network is planned in 2018/2019.

6.6.2 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 17 696 hectares were converted from CL to GL from 2014 to 2015 and that 31 236 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 farmer's registration of the land use.

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, 2013, 2014 and 2015 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 (Table 6.7).

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 deforested areas, the average carbon stock per hectare for all deforested areas is used.

Change in carbon stock in dead organic matter

When forestland 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. Due to current harvest practises (chipping), no significant amount of dead organic matter is left on site. Based on the NFI measurements of O-horizon thickness, default bulk density values, and a C:N ratio of 22 (Vejre et al., 2003) an average emission factor of 5.1 kg N_2O-N per ha is used.

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 6.7). To reach the new equilibrium state is used a default transition period of 100 years. The default IPCC-value of 20 years seems according to Danish investigations not to be applicable for Danish conditions.

N_2O emissions for forest land converted to Cropland is based on the Tier 2 methodology with the default C stock of 142 t C/ha as given in Table 6.7 and using a C:N value of 22 (Callesen et al., 2007) 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.

6.7 Grassland

6.7.1 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 2015 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 total area were 255 791 hectares and in 2015 this has been reduced to 188 212. This quite a small area, but here it should be remembered the uncertainty to accurately report GL and CL.

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 <25 kg N per ha per year is reported under Grassland. If the farmers are reporting permanent grassland but are using >25 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". However, the sector GL remaining GL is showing a loss in carbon stock due to a high inter-annual land use conversion. This has some effect on the inventory, but limited as a whole, as the estimated loss can be founding the land, which GL is converted to.

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 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). The grassland estimate only included soils with at least 12 % OC and not soils with 6-12 % OC as in cropland, due to uncertain emission factors. All emissions from organic soils, except for deforested areas, are reported in GL remaining GL. As there has been a fairly high conversion of cultivated organic soils to permanent grass, the emission from organic soils on GL has increased over the latest years.

Table 6.13 CO_2 emissions from drained Grassland organic soils 1990 to 2015.

	1990	2000	2005	2010	2011	2012	2013	2014	2015
Grassland, 6-12 % OC, ha	12908	11390	10630	9985	9820	11256	11782	11976	11596
Grassland, > 12 % OC, ha	20776	18332	17110	16071	15698	17943	18729	18983	18327
Grassland, total, ha	33685	29722	27740	26055	25518	29199	30512	30959	29923
Emission, total, Gg C	228.7	201.8	188.4	176.9	173.1	198.0	206.8	209.8	202.7
Emission, total, Gg CO_2	838.7	740.0	690.7	648.7	634.7	726.0	758.3	769.1	743.1

In agriculture CRF Table 3D, N_2O emissions from both Cropland and Grassland are reported.

Uncertainties and time series consistency

Table 6.14 Tier 1 uncertainty analysis for Grassland for 2015.

		1990	2015					
		Emission/ sink, kt CO_2 eqv.	Emission/ sink, kt CO_2 eqv.	Activity data, %	Emission factor, %	Combined uncertainty	Total, uncertainty, %	Uncertainty, 95 %, kt CO_2 eqv.
4.C Grassland		931.4	1363.5				27.7	377.2
4.C.1 Grassland remaining grassland, Living biomass	CO_2	64.7	406.5	3	7	7.4	7.4	30.2
4.C.1 Grassland remaining grassland, Organic soils	CO_2	838.6	734.7	3	50	50.1	50.1	368.2
4.C.2 Forest land converted to grassland	CO_2	2.0	94.0	10	50	51.0	51.0	47.9
4.C.2 Other land uses converted to grassland	CO_2	12.6	114.3	10	50	51.0	51.0	58.3
4(II) Grassland on organic soils	CH_4	13.5	12.0	10	90	90.6	90.6	10.8
4(V) Biomass Burning	CH_4	0.0	0.0	10	30	31.6	31.6	0.0
4(V) Biomass burning	N_2O	0.0	0.0	10	30	31.6	31.6	0.0
4(III) Mineralization/-immobilization, Grassland	N_2O	0.0	1.9	10	90	90.6	90.6	1.7

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

The relatively high land use conversion from GL to GC and vice versa is due to the farmers reporting on the actual crop on that specific land parcel. As a consequence may a given land one year be reported as in annual rotation, the next year as permanent grass and then again back into annual rotation. This creates high land use conversions between GL and CL, as seen in 2012 and in 2014, which is most likely artefacts. It will be investigated how the reporting can be improved so these artefacts can be avoided. The result is that a higher share of land is removed from “Land remaining Land” to “Land converted to”. This has no effect on the overall emission estimate but is an allocation issue.

6.7.2 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, 2013, 2014 and 2015. 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 6.7).

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 4E2).

Change in carbon stock in dead organic matter

When forestland 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 6.7). To reach the new equilibrium state a default transition period of 100 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.

6.8 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 103 888 hectares. By end of 2015 this area has increased to 119 976 hectares. Of this was 52 663 ha lakes and rivers in 1990 increasing to 56 836 ha by end of 2015 inside the > 7000 km long coastline.

6.8.1 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. Approximately 400 hectares are utilized for peat extraction. It is assumed that 800 hectares are drained and affected by the excavation. The amount of excavated peat is decreasing. In 2015 were 156 000 m^3 excavated.

Wetland area

In the beginning of 1990, the total area with partly covered WE remaining WE was estimated to be 51 225 hectares. By end of 2015, the area with partly water covered WE remaining WE has increased to 63 140 hectares. The total area with peat extraction is about 300 hectares open surface (Lykke Larsen, Pindstrup Mosebrug, personal comm.). Based on aerial photos, it is assumed that 800 hectares area affected by drainage.

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 6.9). 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.

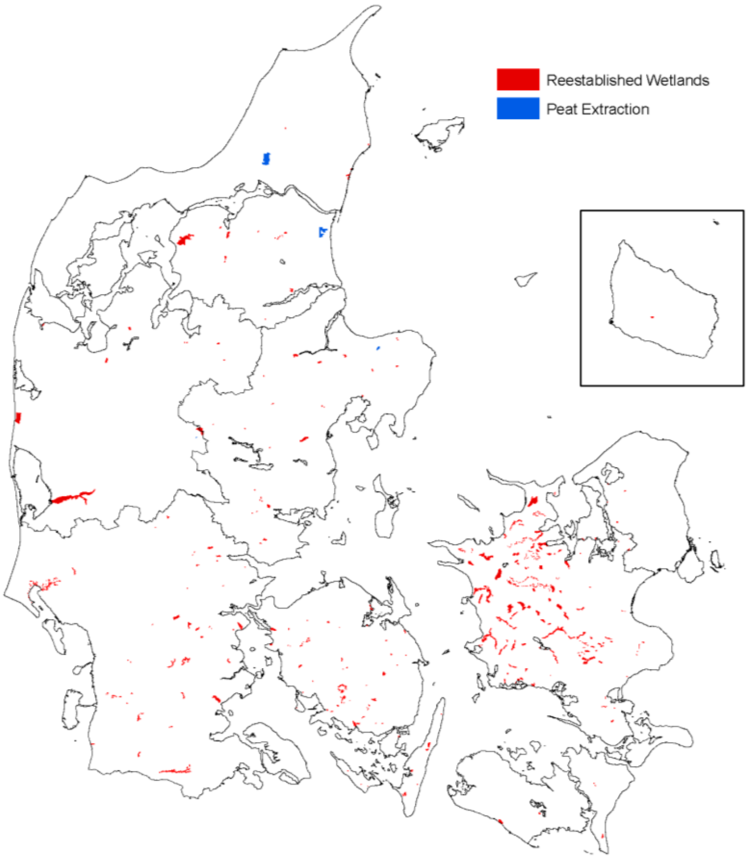

Figure 6.9 Areas with established wetlands, increased water tables and peat extraction in 2008.

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 156 000 m^3 in 2015. 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, no changes are 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 6.15 Tier 1 uncertainty analysis for WE remaining WEs and re-established WE for 2015.

		1990	2015					
		Emission/ sink, kt CO_2 eqv.	Emission/ sink, kt CO_2 eqv.	Activity data, %	Emission factor, %	Combined uncertainty	Total, uncertainty, %	Uncertainty, 95 %, kt CO_2 eqv.
4.D Wetlands		101.6	55.3				60.4	33.4
4.D.1.1 Peat extraction remaining peat extraction	CO_2	99.5	40.7	**10.0**	**75.0**	75.7	75.7	30.8
4.D.1.2 Flooded land remaining flooded land	CO_2	NO	0.0	10	75	75.7	0.0	0.0
4.D.2. Land converted to wetlands	CO_2	1.0	0.0	10	75	75.7	75.7	0.0
4(II) Land converted to wetlands	CH_4	0.6	14.3	10	90	90.6	90.6	13.0
4(II) Peatland	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	90	90.6	90.6	0.1

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.

6.8.2 Land converted to wetland (4D2)

In order to restore nature and reduce the environmental impact Denmark has actively re-established WE (Figure 6.9). The size of each restoration project range from less than 1 ha and 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 16 872 ha have been established. These are primarily on CL and GL. Of this is 4 306 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 870 hectares of forest has been converted to 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 forestland 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, the N_2O emission is negligible from restored wetlands (Chapter 3). Therefore, no N_2O emission has been estimated for land converted to WE.

Methane emission

According to the 2013 Wetlands Supplement the CH_4 emission is 216 kg CH_4-C per ha for temperate areas, equivalent to 288 kg CH_4 per ha from restored rich wetlands (Chapter 3, Table 3.3). This has been included in the inventory. The area with organic soil reported as WL is the converted area multiplied with 16.7%. This is based on our detailed maps from 2010-2015 with a GIS overlay of the organic soil map from 2010. This showed that only 16.7% of the area was located on soils having > 12% OC.

Uncertainties and time series consistency

The time series are complete.

QA/QC and verification

No verification has been made yet.

Recalculation

A recalculation of the organic area has been made according to the GIS analysis of the organic soils.

Planned improvements

None.

6.9 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 485 462 hectares in 1990 increasing to 520 422 hectares by end of 2015 or to approx. 12 % of the total Danish area.

6.9.1 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 6.16 Tier 1 uncertainty analysis for Settlements for 2015.

		1990	2015					
		Emission/ sink, kt CO_2 eqv.	Emission/ sink, kt CO_2 eqv.	Activity data, %	Emission factor, %	Combined uncertainty	Total, uncertainty, %	Uncertainty, 95 %, kt CO_2 eqv.
4.E Settlements		12.9	71.3				62.9	44.9
4.E.2 Forest land converted to settlements	CO_2	2.9	8.4	10	75	75.7	75.7	6.3
4.E.2 Other land uses converted to settlements	CO_2	9.9	58.4	10	75	75.7	75.7	44.2
Other Settlement issues	N_2O	0.1	4.5	10.0	90.0	90.6	90.6	4.1

The time series are complete.

QA/QC and verification

No QA/QC has been performed.

Recalculations

None.

Planned improvements

No improvements are planned.

6.9.2 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, and for the years 1990 to 2011, only three occasions are used (1990, 2005 and 2011) with a linear increase in the area in the years between. Annual recorded changes in cadastral maps are used to estimate the annual changes from 2011 and onwards. Regarding the increase from 2012 to 2013, all new houses and roads are included in the cadastral map from 31.12.2012 to 31.12.2013. In 2015, it is estimated that 1455 hectares has been converted. Mainly from Cropland.

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 forestland 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 96.7 tonnes carbon per ha is assumed to be areas Settlements (Table 6.7) or 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. The degradation rates of soil organic carbon according to C-TOOL shows that 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

A recalculation has been made because of the changes in the default carbon stock in agricultural soils.

Planned improvements

No improvements are planned.

6.10 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.

6.11 Direct N_2O emissions from N fertilization of Forest Land and Other land use

Only a very small amount of nitrogen fertilisers is used in the Danish forests and only to Christmas trees. All emissions are reported under Agriculture CRF Table 3. Ds1 since there is only one common national statistics for N fertilization in agriculture and forestry.

6.12 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. So far, no CH_4, 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 habitats 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.

6.12.1 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 (Table 2.5).

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.

CH_4 emission from organic forest soils is based on the emission factors in table 6.10, a default area of ditches of 2.5 %, and the areas described in 6.9.2. No methane emissions were calculated for Inland mineral wet soils, as we are not able to assess the area of such soils.

6.12.2 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 (see table 6.9, section 6.2.15 this report). Organic soils constituted 5 % of the forest area based on information on presence of peat from the NFI. The area of rewetted organic forest soils are remains under the forest land category, since the actual changes in water kevel are unknown However, we assume that the CO_2 emissions have ceased and have been replaced by CH_4 emissions.

6.12.3 Emissions of N_2O from drained forest soils

The total N_2O emission from forest soils has been estimated to 0.074 kt N_2O in 1990 and 0.08 kt N_2O in 2015.

6.12.4 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.

6.13 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.

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. This is estimated by C-TOOL based on 20 subdivisions (counties and soil types)

6.13.1 Methodological issues

According to IPCC (2006, Chapter 11.2.1.2, p. 11.11), a default fraction of 1 % is assumed emitted as N2O-N during mineralization of the total N content following conversion.

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 (13 t C/ha) with a default C:N value of 22 was used to estimate the N mineralized. A proportion of 1 % of the N stock mineralized equalling 5.13 kg N2O-N/ha is assumed to be emitted as N2O-N (IPCC (2006, Chapter 11.2.1.2, p. 11.11)).

For estimation of the N_2O emission from CL and GL to SE, the average carbon stock in the respective land use classes, combined with a C:N value of 10 for CL and 15 for GL, is used. A proportion of 1 % of the N stock mineralized is assumed to be emitted as N_2O-N.

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 6.7. 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 have lower value than cropland soils, the default methodology will only estimate a low N_2O emission for occasions where CL is converted to GL.

6.13.2 Emissions of N_2O from deforestation and land-use conversion

In 2015, emissions of N_2O from deforestation were estimated at 0.004 kt N_2O and for land use conversion to SE, 0.0133 kt N_2O.

6.14 Biomass burning

Burning of forest is prohibited as well as burning of wooden debris from hedgerows are very seldom. In 2014, there were forest fires on two hectares, and 724 hectares with controlled burning of heathland and five hectares with Mountain Pine (*Pinus mugo*). In 2015, no forest fires were reported. Due to the humid climate, wildfires in the forest are very seldom and normally affect 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, the default standing wood volume is 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 for the controlled burning.

Table 6.17 Burned areas 1990 –2015, ha per year.

	1990	2000	2005	2010	2011	2012	2013	2014	2015
Forest area burned, ha	150.0	0.0	0.0	0.0	0.0	0.0	2.0	2.0	0.0
Heathland area burned, ha	47.0	121.6	638.4	359.0	377.0	709.0	729.0	705.0	714.0
Total burned area, ha	197.0	121.6	638.4	359.0	377.0	709.0	731.0	707.0	714.0
Emission, CH_4, kt	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Emission, N_2O, kt	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total, kt CO_2 eqv.	1.09	0.01	0.06	0.03	0.03	0.06	0.08	0.08	0.06

Table 6.23 Tier 1 uncertainty analysis for Biomass burning for 2015.

		1990	2015					
		Emission/ sink, kt CO_2 eqv.	Emission/ sink, kt CO_2 eqv.	Activity data, %	Emission factor, %	Combined uncertainty	Total, uncertainty , %	Uncertainty, 95 %, kt CO_2 eqv.
4.(V) Biomass Burning		1.1	0.1				22.4	0.014
4(V) Biomass Burning	CH_4	0.7	0.0	10	30	31.6	31.6	0.009
4(V) Biomass burning	N_2O	0.4	0.0	10	30	31.6	31.6	0.010

6.15 Harvested Wood Products (HWP)

Carbon emissions from harvested wood products (HWP) have been reported since 2013. 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: sawn wood, wood-based panels and paper, and paper products with default half-lives of 35, 25 and two years, respectively, stipulated by the 2013 Supplementary GPG. HWP originating from imported wood is excluded. HWP originating from deforestation activities (estimated directly as biomass in deforested areas able to produce HWP products) is excluded from the calculations.

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).

According to a questionnaire on the production of the Danish wood industry, the production of sawnwood in 2015 was about 428.000 m^3, while the production of wood-based panels was about 387.000 m^3. 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 2 relevant companies). 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 2015 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 2015 is reported to about 158.000 tonnes carbon - 69.000 tonnes from sawnwood and 89.000 tonnes from wood-based panels. The outflow from the pool is reported to about 112.000 tonnes carbon in 2014 - 66.000 tonnes from sawnwood and 47.000 tonnes carbon from wood-based panels. Thus, there has been a net carbon sequestration in HWP of about 46.000 tonnes carbon in 2015. The projected net sequestration in 2015 is about 19.000 tonnes carbon.

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 Danish case, 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 to both 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 6.18 HWP in use from domestic harvest (CRF table 4.Gs1).

HWP produced and consumed domestically (ΔC HWPdom IU DH)	HWP in use from domestic harvest				
	Gains	Losses	Half-life	Annual Change in stock (ΔC HWP IU DH)	Net emissions/ removals from HWP in use
	(t C)		(yr)	(kt C)	(kt CO2)
Total	158210.79	-112231.04		45.98	-168.48
1. Solid wood	158210.79	-112167.51		46.04	-168.72
Sawnwood	68797.41	-65503.12	35.00	3.29	-12.07
Wood panels	89413.38	-46664.40	25.00	42.75	-156.64
2. Paper and paperboard	NO	-63.53	2.00	-0.06	0.23

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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. Wastewater 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 updated activity data obtained from the Danish EPA (Kristensen, 2016a, b). Furthermore, default IPCC values for the methane content in the landfill gas (LFP) and the content of DOC in sludge was adopted according to recommendation of the 2016 in-country review.

The *CRF category 5.B. Biological treatment of solid waste*, is comprised by sub-category *5.B.1 Composting* and sub-category *5.B.2 Anaerobic digestion at biogas facilities.* Sub-category *5.B.1* 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. Changes in the time trend for this year´s submission are due to an updated value for the emission factor for N_2O and updated activity data obtained from the Danish EPA (Kristensen, 2016b). For the sub-category *5.B.2 Anaerobic digestion at biogas facilities* changes in the time trend CH_4 emissions are due to recalculations recommendation of the 2016 in-country review.

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. Wastewater treatment and discharge*, the emissions reported in this chapter are a result of calculations in continuation of previously used and reported methodology. Updated activity data for nitrogen in the effluent wastewater in 2013 and 2014 and for nitrogen in the influent wastewater for 2014 have resulted in minor changes in the time series (cf. chapter 7.9 on source specific recalculations.

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 QA/QC procedures and recalculations reflecting the recommended improvements of the 2016 in-country review. Especially, efforts were put into reporting numbers in the NIR that re 100% similar to the DRF reporting numbers.

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 3F, Table 3F-1.1.

Table 7.1.1 Emissions for the waste sector, Gg CO_2 equivalents.

		1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
5.A. Solid waste disposal	CH_4	1,536	1,331	1,073	909	772	773	742	702	691	655
5.B. Biological treatment of solid waste	CH_4	38	57	101	118	140	135	138	143	176	188
5.B. Biological treatment of solid waste	N_2O	12	21	153	59	94	90	91	93	113	113
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	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	0.26	0.26
5.D. Waste water treatment and discharge	CH_4	96	99	103	105	106	107	108	108	109	109
5.D. Waste water treatment and discharge	N_2O	61	69	63	64	57	61	55	59	61	63
5.E. Other	CO_2	18	20	18	18	18	18	16	16	21	21
5.E. Other	CH_4	1.92	2.17	1.98	1.95	1.99	2.03	1.83	1.80	2.44	2.44
5. Waste	total	1,763	1,598	1,513	1,276	1,190	1,187	1,152	1,123	1,175	1,153

5.A. Solid Waste Disposal is the dominant source in the waste sector with contributions in the time series varying from 87 % (1990) to 57 % (2015) 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 2014 with 1990, the emissions from Solid Waste Disposal Sites have decreased with 57.3%.

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 1990-2015 between 2.9 % (1990) and 26.1 % (2015). CH_4 contributes the most to the sectorial total, varying between contributions of 2.2% (1990) and 16.3 % (2015). N_2O contributes with between 1 % (1990) and 9.8 % (2015) of the sectorial total. The emissions increase steadily over the time series for both components. Comparing 2015 with 1990, the sum of CH_4 and N_2O emissions (in units CO_2 equivalent) from composting and biogas facilities have increased with 498 %. The increase in the emission from category *5.B.1.* is dominated by an increase in methane emission from biogas production. The methane emission from biogas production increases from 3.6 Gg in 1990 to 72 Gg CO_2 eqv.in 2015, while the emission from composting increased from 47 Gg to 200 Gg CO2 eqv. in 2016. The level is highest for composting but still the increase is a factor 6 higher for biogas facilities compared to composting plants.

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 1990-2015 between 0.01 % (1990) and 0.02 % (2015). The trend for the total emissions 1990 - 2015 from this source is increasing; compared to 1990 the 2014 emissions have increased with 39.6 %.

5.D. Waste water treatment and discharge. This source contributes with CH_4 and N_2O emissions. The contribution to CO_2 equivalent emissions from the sum of CH_4 and N_2O is for the time series 1990-2015 between 7.8 % (1990) and 12.8 % (2014). CH_4 contributes the most to the sectorial total, varying between contributions of 8.9 % (1990) and 14.9 % (2015). N_2O contributes with between 3.5 % (1990) and 5.4 % (2014) of the sectorial total. The CH_4 emissions increase steadily over the time series, while for the N_2O a decreasing trend in the indirect N_2O emission levels out the fluctuations but slightly increasing trend in the direct N_2O emission. The net N_2O emission in 2015 compared to 1990 shows a net increase of 2%, while for CH_4 an steadily increase from 1990 to 2015 of 21.3 % is observed. The trend for the total CO_2 equivalent emissions 1990 - 2015 from this source is increasing. Compared to 1990, the 2015 emissions have increased with 9.5 %.

5.D. Other. This source contributes with CO_2 and CH_4 emissions from accidental fires. The contribution to the total emissions from the waste sector varies from 1-1 % (1990) to 2.1 % (2015).

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 2015 has decreased with 34.6 % 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.B.2. Anaerobic digestion at biogas facilities	CH_4	Tier 1	CS
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 KCA only one of the eleven categories is identified as a key source category. At Tier 2 KCA, three of the eleven source categories are identified as key sources categories in 2015 (Table 7.1.3). The Tier 1 key source identification is based on ranking of absolute quantitative emissions 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*, *5.B.1. Composting and 5.E Accidental fires* are 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 2015, while only the Tier 2 KCA assessment identified category *5.B.1. Composting* and *5.E Accidental fires* as key source for level in 2015 only.

Both category *5.A. Solid Waste Disposal* and *5.B.1. Composting* are key source category for trend calculated in CO_2 equivalents, from 1990 to 2015; 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 source 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	2015	1990-2015	1990	2015	1990-2015
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.B.2. Anaerobic digestion at biogas facilities	CH_4	-	-	-	-	-	-
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	-	-	-	-	Level	-
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. The new waste reporting system (2010-2015) provides statistics of waste amounts according to the waste producer and the amount of waste according to treatment type, e.g. landfill. Both statistics refers to the receiver, i.e. receivers of produced waste (waste collection companies, and receivers of waste for treatment, e.g. landfill operators. Statistics on treatment types are assumed to be final treatment; i.e. meaning that none of the waste is temporary landfilled (Kristensen 2016b). 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, 2014). 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 2010-2015 in the reporting year 2017.

The general development for solid waste at disposal sites is influenced by government instruments such as 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 at landfills. 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 at landfills. Data on final disposal of waste in Denmark is presented in Annex 3F, Table 3F-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 and in Annex 3F.

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). There are 56 active disposal sites (SWDS) existing today, reporting to the new waste data system (Kristensen, 2016). Methane collections from 29 of these SWDS are reported to be used at energy-producing installations in the Energy statistics in 2016 (DEA, 2016a, 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 from the Danish landfills has decreased 57.3 % from 1990 to 2015.

A full time series (1990-2015) of these data are shown in Annex 3F, Table 3F-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/9492.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	3190	68.8	0.5	6.8	61.5	1536
1995	1969	66.8	7.6	5.9	53.2	1331
2000	1489	58.9	11.3	4.8	42.9	1073
2005	983	50.4	9.9	4.0	36.4	909
2010	2463	40.0	5.7	3.4	30.9	772
2011	2587	38.3	3.9	3.4	30.9	773
2012	2475	36.7	3.7	3.3	29.7	742
2013	1417	35.2	4.0	3.1	28.1	702
2014	1278	33.7	3.0	3.1	27.7	691
2015	1084	32.3	3.2	2.9	26.2	655

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 3F, Table 3F-2.2 and Table 3F-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, 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:

$$t_{1/2} = \frac{ln2}{k} \Rightarrow k = \frac{ln2}{t_{1/2}}$$ 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).

$$DDOCm(t) = W_i \cdot DOC_i \cdot DOC_f \cdot MCF + DDOCm(t-1) \cdot e^{-k}$$ 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 0.5 (IPCC, 2006) 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. The Danish Energy Agency registers the biogas amounts recovered at disposal sites in energy units (TJ) (DEA, 2016). 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:

$$R_T = \frac{B \cdot 0.41 \cdot 0.678 \text{kg/m}^3}{15.19 \text{MJ/m}^3}$$ 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 3F-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	2014	2015
Food	111.7	52.0	26.5	4.6	2.0	1.1	1.2	0.9	0.3	0.3
Paper and cardboard	180.2	84.1	43.0	7.5	5.9	5.4	4.0	4.9	5.7	3.6
Wood	201.5	260.9	254.8	2.6	19.7	18.7	13.5	9.5	7.7	9.6
Plastic	27.0	14.2	8.8	4.6	8.9	8.5	11.2	5.8	6.6	5.5
Textile, fur and leather	5.0	3.1	2.3	0.8	5.8	6.1	4.6	4.8	5.6	3.8
Biodegradable garden waste	136.0	65.2	35.2	7.0	0.4	10.6	3.8	7.2	4.1	5.2
Chemicals, inert	7.7	4.7	3.6	1.4	1.4	0.5	0.1	0.2	0.4	0.2
Electric & Hazardous*	0.5	0.3	0.7	83.7	3.4	1.8	2.6	1.4	0.3	0.2
Glass*	37.3	18.5	10.6	4.8	7.5	7.2	4.4	5.4	5.5	4.8
Metal*	184.3	127.8	107.4	77.9	182.3	157.6	134.2	125.2	163.0	93.1
Scrap vehicles	104.5	64.5	48.8	48.7	21.4	17.3	1.6	0.0	0.0	0.0
Demolition, inert*	282.8	174.5	132.0	87.1	151.0	186.2	201.3	193.2	199.2	200.9
Soil & Stone*	466.1	308.6	271.3	174.0	1744.6	1860.8	1854.4	2060.9	1982.1	687.2
Particulate matter and dust*	32.1	0.0	0.3	0.1	6.8	8.1	25.2	8.6	6.3	2.6
Sludge, inert	90.7	44.5	25.0	10.7	3.9	11.2	12.5	9.6	6.7	6.7
Sludge, degradable	210.7	135.7	107.1	37.7	28.3	41.8	19.4	9.2	5.8	5.4
Ash & Slag	465.8	145.0	8.5	33.8	52.4	37.8	13.6	29.3	21.0	15.9
Other not combustible waste	645.9	464.8	402.9	395.9	88.7	102.1	70.9	53.8	44.7	39.2
Total degradable	1,128	776	601	147	213	270	248	230	228	228
Total inert	2,062	1,193	888	836	2,121	2,213	2,131	2,300	2,237	856
Total	3,190	1,969	1,489	983	2,334	2,483	2,379	2,530	2,465	1,084

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, 2014, 2015) and the new waste data system provides data for 2011-2014 (DEPA, 2013, 2014, 2015). Data for 2010 to 2015 have been received from the Danish EPA.

For the years 2010-2015 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 3F, Table 3F-2.4 and 3F-2.5).

For the old ISAG database, 1994-2009 (DEPA, 1996a, 1998a, 1999a, 2001a, 2001b, 2002a, 2004a, 2004b, 2005a, 2006a, 2006b, 2008, 2010a, 2011a, 2014, 2015), 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 3F, Table 3F-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. 1940-1969 data are assumed constant at the 1970 level.

Waste amounts for the whole time series, i.e. 1940- 2015, categorised, allocated and divided into 18 waste types as described above, are provided in Annex 3F, Table 3F-2.4 and Table 3F-2.5, Corresponding annual fractional distributions of the total amount of deposited waste according to type, respectting 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 3F, Table 3F-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	2010	2011	2012	2013	2014	2015
Food	3.5	2.6	1.8	0.06	0.04	0.05	0.04	0.01	0.03
Paper and cardboard	5.7	4.3	2.9	0.1	0.1	0.1	0.2	0.2	0.3
Wood	6.3	13.3	17.1	0.5	0.8	0.5	0.4	0.4	0.9
Plastic*	0.8	0.7	0.6	0.3	0.3	0.5	0.2	0.3	0.5
Textile. fur and leather	0.2	0.2	0.2	0.2	0.2	0.1	0.2	0.2	0.4
Biodegradable garden waste	4.3	3.3	2.4	0.002	1.3	0.3	0.3	0.2	0.5
Chemicals. inert*	0.2	0.2	0.2	0.04	0.02	0.003	0.007	0.02	0.0
Electric & Hazardous*	0.02	0.02	0.05	0.0003	0.004	0.07	0.008	0.01	0.0
Glass*	1.2	0.9	0.7	0.3	0.2	0.1	0.2	0.2	0.4
Metal*	5.8	6.5	7.2	8.2	6.4	5.8	5.4	6.6	8.6
Scrap vehicles*	3.3	3.3	3.3	1.0	0.7	0.07	0.0008	0.00	0.00
Demolition	8.9	8.9	8.9	7.4	9.9	9.4	8.4	8.1	18.5
Soil & Stone*	14.6	15.7	18.2	76.1	73.1	77.4	80.2	80.4	63.4
Particulate matter and dust*	1.01	0.0004	0.02	0.2	0.2	1.1	0.4	0.3	0.2
Sludge. inert*	2.8	2.3	1.7	0.1	0.4	0.5	0.4	0.3	0.6
Sludge. degradable	6.6	6.9	7.2	1.1	1.0	0.8	0.4	0.2	0.5
Ash & Slag*	14.6	7.4	0.6	2.4	1.8	0.8	1.6	0.9	1.5
Other waste. inert*	20.3	23.6	27.1	2.1	3.5	2.4	1.8	1.8	3.6

*inert waste fractions

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, 2016.

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.

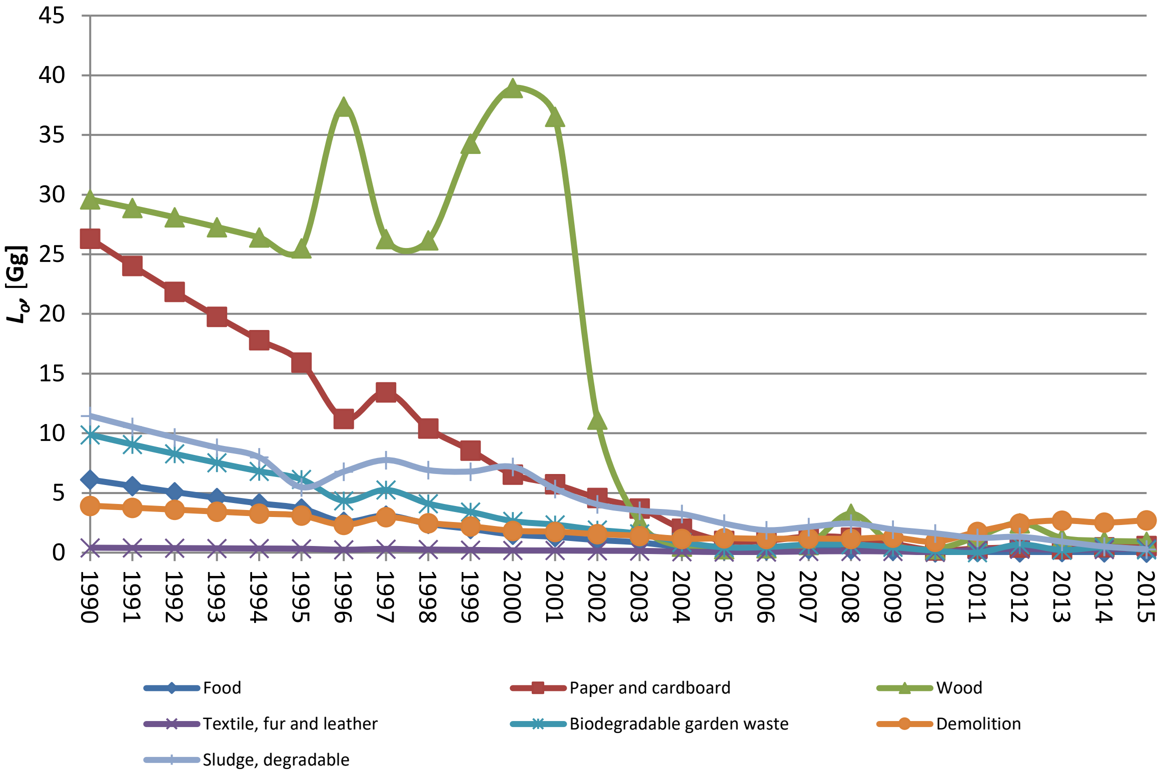

Figure 7.2.1 Annual amounts of deposited methane generation potential per waste type.

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 become 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.

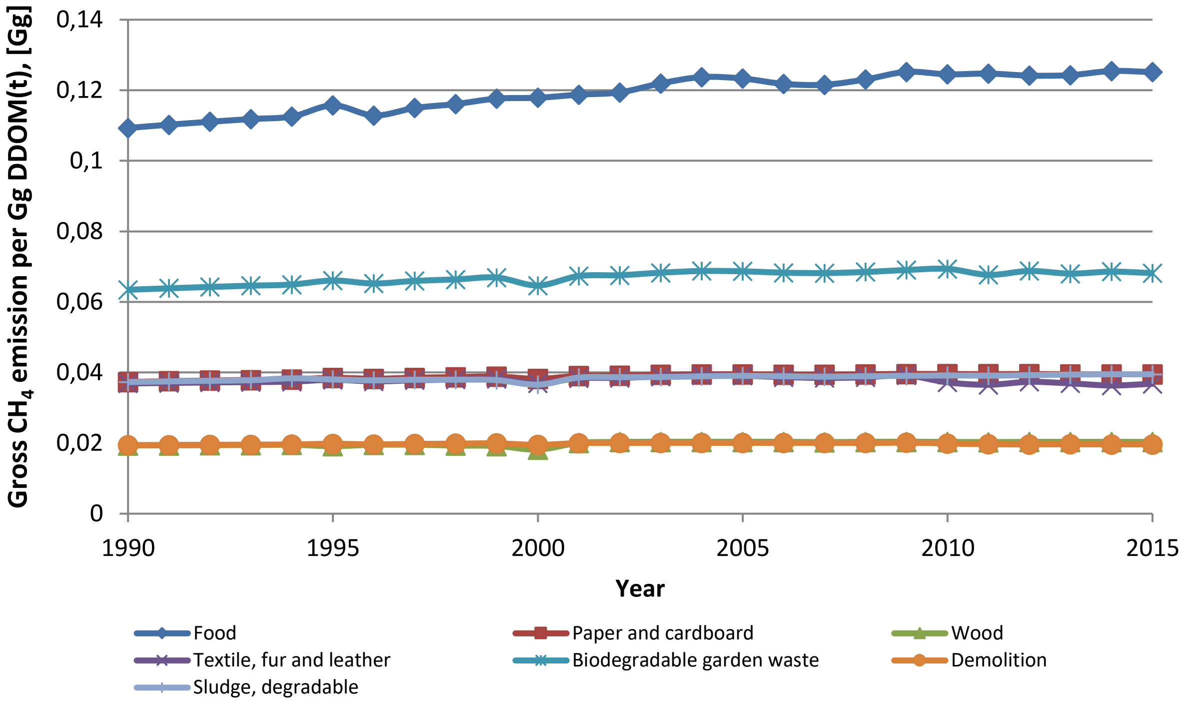

Figure 7.2.2 Annual gross implied emission factors for each waste type.

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 1990-2015.

Year	Total Deposited Waste	Accumulated amount of decomposable D*DOCm* Eq. 7.2.4	Annual amount of degraded D*DOCm.* 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 D*DOCm*
1990	3190	2063	93	88	68.8	0.5	68.3	61.5	0.019	0.030
1995	1969	2063	92	60	66.8	7.6	59.2	53.2	0.027	0.026
2000	1489	2009	86	59	58.9	11.3	47.7	42.9	0.029	0.021
2005	983	1681	73	6	50.4	9.9	40.4	36.4	0.037	0.022
2010	2463	1395	59	3	40.0	5.7	34.3	30.9	0.013	0.022
2011	2587	1349	56	5	38.3	3.9	34.4	30.9	0.012	0.023
2012	2475	1303	54	8	36.7	3.7	33.0	29.7	0.012	0.023
2013	1417	1258	52	6	35.2	4.0	31.2	28.1	0.020	0.022
2014	1278	1215	50	5	33.7	3.0	30.7	27.7	0.022	0.023
2015	1084	1175	48	5	32.3	3.2	29.1	26.2	0.024	0.022

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, D*DOCm*, 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.

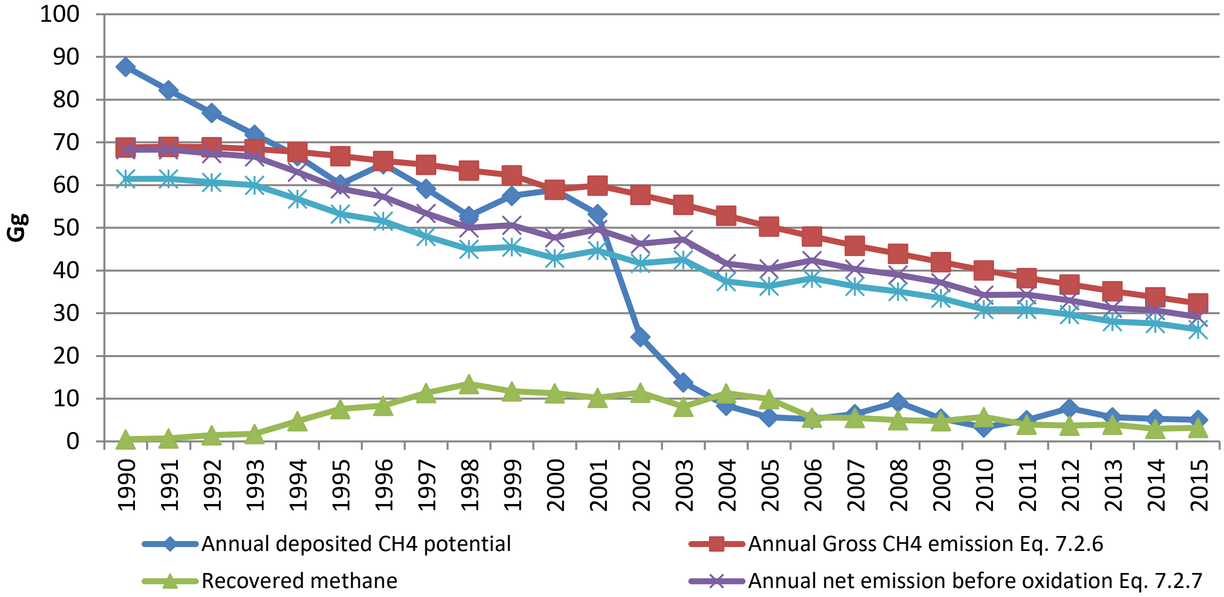

Figure 7.2.3 Time trend in the annual deposited methane potential, gross methane emission, collected methane, annual net methane emission before and after oxidation.

In total a reduction in the net methane emission from 1990 to 2015 of 57.3 % is observed. This reduction in the methane emission is accompanied by a decrease in the accumulated amount of decomposable degradable organic matter. *DDOCm* of 43.1 % and a 94.2 % decrease in the amount of deposited methane potential from 1990 to 2015. 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 3F, Table 3F-3.1.

Table 7.3.1 National emissions from composting - 1990 to 2015, Mg.

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
CH_4	1,386	1,859	3,242	3,420	3,876	3,736	3,744	3,828	4,661	4,652
N_2O	40.5	70.3	512.9	197.5	314.7	303.3	303.9	311.0	380.4	379.6

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 2010-2014 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.

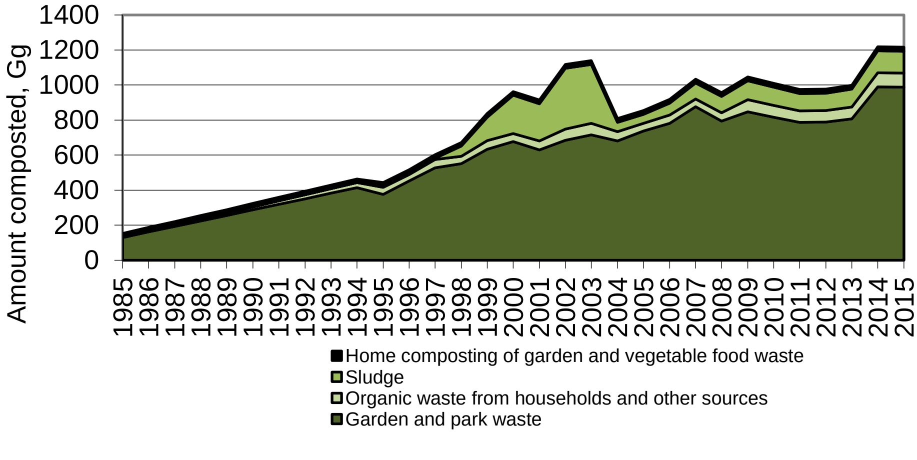

Figure 7.3.1 Trends in the national amount of composted waste.

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 2010-2015 have been received from the Danish EPA and have been grouped according to the distributional amounts four types reported in ISAG in 2009 (Kristensen, 2016a).

The Danish legislation on sludge (DEPA, 2006c) was implemented in the summer of 2003. This stated that composted sludge must 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	2015
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	110*

Type 1 waste treatment sites normally includes biogas producing facilities, but these have been excluded in Table 7.3.1.
*The number of composting plants in the dataset received by the Danish EPA for the period 2010-2015.

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 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 1990-2015.

- 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 3F, Table 3F-3.2.

Table 7.3.3 Activity data composting, Gg.

	1990	1995	2000	2010	2011	2012	2013	2014	2015
Composting of garden and park waste	288	376	677	817	787	789	808	808	808
Composting of organic waste from households and other sources	16	40	47	68	65	65	67	67	67
Composting of sludge	NO*	7	218	103	99	100	102	102	102
Home composting of garden and vegetable food waste	20	21	21	23	23	23	23	23	23
Total	324	444	963	1011	975	977	976	976	976

*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	0.24	1.92	0.11
Source	Boldrin et al., 2009	IPPC, 2006 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 Anaerobic 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).

Emissions from anaerobic digestion at wastewater treatment plants are 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 (2016).

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, 2014); [2]Spildevandscenter Avedøre (2012, 2013, 2014); [3]DEA (2014); [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.

Fugitive emissions from anaerobic digestion of organic waste

Emissions of CH_4 from biogas plants occur from stacks and ventilation during several stages of the process, e.g. ventilation in the receiving hall of the plant, from the emergency flare and from upgrading units.

Emissions that are more significant occur from leakages in the production equipment and pipelines. These leakages are by nature very variable from plant to plant and as such difficult to quantify at a national level.

The 2006 IPCC Guidelines consider emissions from biogas plants (anaerobic digestion) as part of the waste sector, and as such, the detailed documentation of the emission inventory for Denmark is included in Chapter 7. According to the IPCC Guidelines, emissions of CH_4 from such facilities due to unintentional leakages during process disturbances or other unexpected events will generally be between 0 and 10 % of the amount of CH_4 generated. In the absence of further information, use 5 percent as a default value for the CH_4 emissions (IPCC, 2006).

A Danish project measured leakages from nine biogas plants in Denmark. The results are reported in DEA (2015). Five of the plants were small farm-based plants while the other four were larger plants. The results were that the CH_4 leakage varied from nil to 10 % of the production. The largest leakage rates were detected for the larger plants. The weighted average for the nine plants was 4.2 %.

The emission is estimated using the biogas production data included in the annual energy statistics combined with a CH_4 content of the biogas of 65 % and the net calorific value of CH_4 of 50 GJ per tonnes. The activity data and resulting emissions are shown in Table 7.3.6 below.

Table 7.3.6 Activity data and emissions from anaerobic digestion of organic waste

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
Biogas production, TJ	266.4	745.8	1441.7	2375.2	3184.1	3072.4	3274.0	3434.0	4336.9	5259.4
CH_4 production, TJ	173.2	484.8	937.1	1543.9	2069.7	1997.1	2128.1	2232.1	2819.0	3418.6
CH_4 production, tonnes	3463.0	9695.9	18741.9	30877.8	41393.1	39941.4	42562.1	44641.6	56379.8	68371.8
CH_4 emission, tonnes	145.4	407.2	787.2	1296.9	1738.5	1677.5	1787.6	1874.9	2368.0	2871.6

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	2014	2015
CH_4 emission from										
Human cremation	0.48	0.52	0.49	0.48	0.49	0.49	0.48	0.50	0.49	0.51
Animal cremation	0.03	0.04	0.08	0.14	0.26	0.22	0.22	0.21	0.21	0.20
Total	0.51	0.55	0.57	0.62	0.76	0.71	0.70	0.71	0.70	0.71
N_2O emission from										
Human cremation	0.60	0.64	0.61	0.60	0.62	0.60	0.60	0.62	0.61	0.64
Animal cremation	0.03	0.05	0.10	0.17	0.33	0.03	0.28	0.26	0.26	0.25
Total	0.64	0.69	0.71	0.77	0.95	0.64	0.88	0.88	0.87	0.89
Total human cremation CO_2 eqv.	192	205	195	191	197	192	191	198	194	202
Total animal cremation CO_2 eqv.	11	14	32	55	104	16	89	82	83	80

While emissions from human cremations have been steady over the last two decades, emissions from animal cremations have increased. In 1990, animal cremations represented 5.6% of the total emission of CO_2 eqv. from cremations. In 2015, this number has increased to 39.8%. Emissions for the whole time series are provided in Annex 3F. Table 3F-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 1990s, 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, 2017).

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, 2017). 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, 2016), number of cremations and the fraction of cremated corpses in relation to the total number of deceased (DKL, 2017). Annex 3F, Table 3F-4.2 presents data for the entire time series 1990-2015.

Table 7.4.3 Data human cremations, DKL (2017), Statistics Denmark (2016).

Year	1990	1995	2000	2010	2011	2012	2013	2014	2015
Nationally deceased	60,926	63,127	57,998	54,368	52,516	52,325	52,471	51,340	52,555
Cremations	40,991	43,847	41,651	42,050	41,248	40,909	42,349	41,532	43,238
Cremation fraction, %	67.3	69.5	71.8	77.3	78.6	79.6	80.7	80.9	82.3

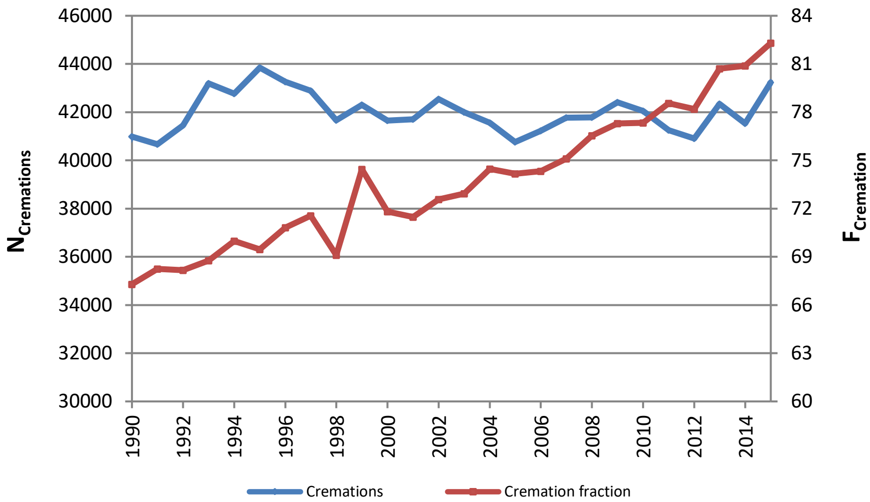

Figure 7.4.1 Visualisation of the development in cremations (DKL, 2017) where the number of cremation, $N_{cremations}$, is shown at the left Y-axis. The cremation percentage, $F_{cremations}$, shows the percentage of cremated deceased of the total number of deceased for the years 1990-2015.

Even though the total number of annual cremations is fluctuating, the cremation percentage has been steadily increasing since 1990. 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.

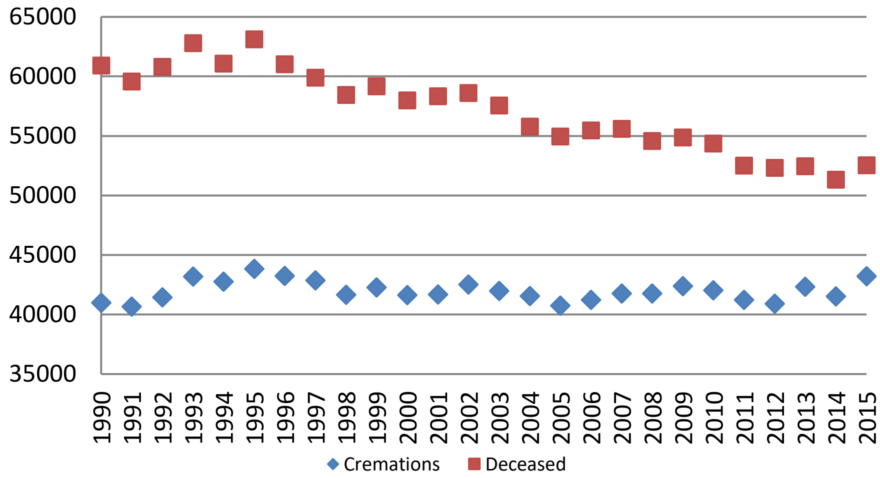

Figure 7.4.2 Trends of the activity data for cremation of human corpses and the national number of deceased persons.

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 1990-2014 is available in Annex 3F, Table 3F-4.3.

Table 7.4.6 Activity data. Source: direct contact with all Danish crematoria.

	1990	1995	2000	2010	2011	2012	2013	2014	2015
Total. Mg	150	200	443	1,449	1,219	1,238	1,146	1,161	1,119

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, 2013 and 2014 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.

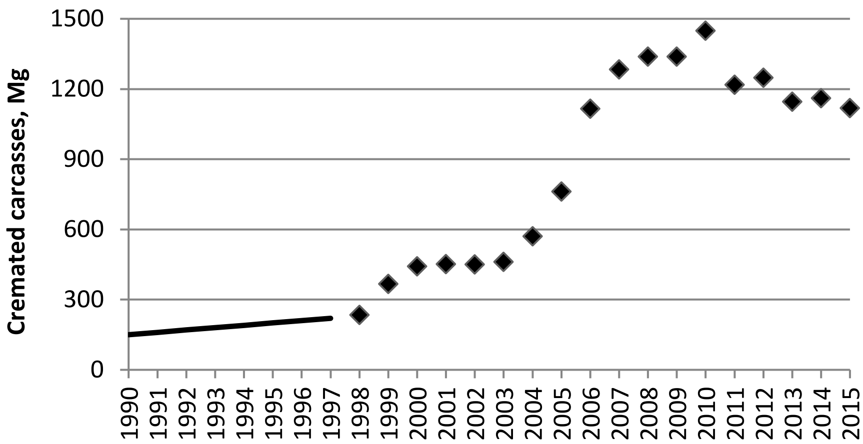

Figure 7.4.3 The amount of animal carcasses cremated (Mg). Data from 1998-2014 are delivered by the crematoria and is considered to be exact; these data are marked as points. Data from 1990-1997 are estimated and are shown as the thick line in the figure.

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 2014, 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 3F, Table 3F-3.3) with the highest influent contribution occurring at the biggest and most advanced technological WWTPs in Denmark (Thomsen & Lyck, 2005; DNA, 2010; Thomsen, 2016).

Documentation for the 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% (DEPA, 2015; Thomsen, 2016).

Regarding diffuse emissions from the sewer system, very little data are available (e.g. Lyngby-Taarbæk Kommune, 2014). 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. However. the sewer system is 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; DANVA, 2011; 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 (2016). However, the indirect N_2O emissions from separate industries are included, as effluent N data are available from the National Monitoring and Assessment Programme for the Aquatic and Terrestrial Environments (NOVANA) (DEPA, 1994, 1996b, 1997, 1998b, 1999b, 2000, 2001c, 2002b, 2003b, 2004c, 2005b, 2005c and DNA, 2007, 2010, 2011, 2012, 2013, 2014, 2015, 2016).

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 3F, Table 3F-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	2014	2015
$CH_{4,AD,gross}$	12.69	18.43	21.20	20.87	21.28	19.10	19.21	17.91	17.96	21.73
$CH_{4,recovery}$	12.57	18.27	20.97	20.63	21.06	18.89	18.97	17.67	17.69	21.49
$CH_{4,AD,net}$	0.12	0.16	0.23	0.24	0.22	0.22	0.24	0.25	0.27	0.24
$CH_{4,sewer+MB}$	0.22	0.25	0.27	0.27	0.28	0.28	0.27	0.29	0.29	0.29
$CH_{4,st}$	3.49	3.54	3.62	3.67	3.76	3.78	3.79	3.80	3.82	3.84
$CH_{4,total}$	3.83	3.94	4.12	4.19	4.26	4.28	4.31	4.34	4.38	4.37

Regarding the time trend, the net CH_4 emission from anaerobic treatment has increased 50 % from 1990 to 2015, while a less significant increase is observed in the CH_4 emission from the sewer system, mechanical and biological treatment is observed (23.5%). Lastly, the CH_4 emission from scattered houses not connected to the collective sewer system has increase with 9.3 % reflecting the increase in the number of people not connected to the collective sewer system. In total CH_4 emissions quantified as a sum of CH_4 emissions from anaerobic treatment processes, i.e. $CH_{4,AD,net}$, the sewer system, mechanical and biological treatment, i.e. $CH_{4,sewer+MB}$ and scattered houses, i.e. $CH_{4,st}$, has increase 12.5 % from 1990 to 2015.

Nitrous oxide emission

N_2O formation and releases, both during the treatment processes at the WWTPs and 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 1990-2015 is shown in Annex 3F, Table F-5.2.

Table 7.5.2 N_2O emissions from wastewater, Mg.

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
$N_2O_{, indirect}$	133	119	79	55	55	53	52	52	55	58
$N_2O_{, direct}$	73	111	134	161	136	150	131	147	150	152
$N_2O_{, total}$	205.9	230.5	213.1	216.4	191.2	203.4	183.1	199.0	204.8	210.0

Regarding the time trend, the indirect N_2O emission has decreased 56.4% N_2O from 1990 to 2015, while the direct N_2O emission has increased 108 %, resulting total N_2O emission has decreased 2 % from 1990 to 2015.

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 (IPPC, 2006) and the IPCC Good Practice Guidance (IPCC, 2000).

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 in Denmark reported by the Danish Nature Agency, the National Focal Point for point sources. The Danish Nature Agency collects all point source data the National Monitoring and Assessment Programme for the Aquatic and Terrestrial Environments, NOVANA. Since the late eighties annually reports documenting results from the monitoring of point sources; wastewater treatment plants, industry, rainwater conditioned effluent (storm water), scattered houses, freshwater aquaculture and mariculture. The results of point source monitoring are reported in the national water quality parameter database system (www.miljoportalen.dk) and in reports (DEPA, 1994, 1996b, 1997, 1998b, 1999b, 2000, 2001c, 2002b, 2003b, 2004c, 2005b, 2005c and DNA, 2007, 2010, 2011, 2012, 2013, 2014, 2015, 2016).

Data on energy production from Danish wastewater treatment plant with anaerobic sludge digestion is reported in the energy statistics; data received from the Danish Energy Agency. These data do not include any information on venting or flaring, which are however included in the reported gross energy production data (Søren Tafdrup, 2014).

Data on flaring and venting have been obtained from Environmental reports (or green accounts) publish by the individual WWTPs, in some cases on a yearly basis. 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 (Table 7.5.3; Thomsen, 2016).

Country-specific data on the emission factor for direct emission of N_2O are documented by monitoring data as presented in Thomsen et al., 2015 and Thomsen, 2016.

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, $CH_{4.AD}$.

$$CH_{4,WWTP} = CH_{4,sewer+MB} + CH_{4,AD} \quad \text{Eq. 7.5.1}$$

The fugitive emissions from the sewer system, primary settling tank and biological N and P removal processes, $CH_{sewer+MB}$, are estimated as:

$$CH_{4,sewer+MB} = EF_{sewer+MB} \cdot TOW_{inlet}$$

$$\Downarrow$$

$$CH_{4,sewer+MB} = B_o \cdot MCF_{sewer+MB} \cdot TOW_{inlet} \quad \text{Eq. 7.5.2}$$

where

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).

$MCF_{sewer+MB}$ is the fraction of DOC that is anaerobically converted in sewers and WWTPs. $MCF_{sewer+MB}$ equals 0.003 based on an expert judgement (Vollertsen, 2012) 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; DANVA, 2011).

The emission factor, $EF_{sewer+MB}$, 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 emission potential from anaerobic processes, $CH_{4.AD.gross}$, is calculated as:

$$CH_{4,AD,gross} = f_{AD} \cdot MCF_{AD} \cdot B_o \cdot TOW_{inlet} \qquad \text{Eq. 7.5.3}$$

where

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).

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).

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.

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 t STP (Standard Temperature and Pressure), 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 (DEA, 2015).

The net methane emission from anaerobic digestion in biogas tanks are at present estimated according to equation 5 for the whole time series:

$$CH_{4,AD,net} = EF_{AD} \cdot CH_{4,AD,recovered} \qquad \text{Eq. 7.5.4}$$

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. 2016).

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, 2016).

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 at 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 **54.31 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 2.4 (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 1997, no BOD or COD data for Danish WWTPs exists. For the years 1998-2014 data on COD and BOD are available.

Table 7.5.3 shows the increase in the contribution from industries to the influent wastewater, the development in the population number of Denmark, compared to the In the second approach, an average of BOD/COD ratios throughout the time series equal to 2.7 was applied to in place of the default value of Danish monitoring data for BOD and COD. The Danish COD/BOD ratio is on average 2.7 throughout the time series. Based on plant level data on TOW and energy production, the fraction of TOW in units of Gg COD at anaerobic WWTPs has been derived. Data for the whole time series are reported in in Annex 3F, Table 3G-5.3. Details on the activity data reported in Thomsen, 2016.

The time series for activity data on TOW are presented in Table 7.5.3. The full time series is presented in Annex 3F, Table 3F-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	2014	2015
Contribution from industrial inlet [%]	2.5	22.2	38	40.5	40.5	40.5	40.5	40.5	40.5	40.5
Population-Estimates (1000)	5135	5216	5330	5411	5535	5561	5581	5603	5627	5660
TOW (Gg COD/year)	295	327	365	364	372	378	364	383	384	385
TOW (Gg BOD/year)	97	116	149	141	145	151	135	136	138	168
COD/BOD ratio	3.1	2.8	2.5	2.6	2.6	2.5	2.7	2.8	2.8	2.3
$COD_{influent.anaerobic}$ [Gg]*	106	154	177	174	177	159	160	149	150	181

* The amount of the influent TOW at Danish WWTP using anaerobic digestion as sludge management strategy (Thomsen, 2016).

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 methane lost by venting; i.e. EF_{AD} value of 0.013 (Equation 7.5.4). A detailed verification of the activity data used for justifying the national EF_{AD} value is provided in Table 7.3.5 and in Thomsen, 2016.

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 54.31 kg COD per person per year using the default IPCC conversion factor of 2.4 (IPPC, 2006). For scattered houses, the default IPPC BOD/COD conversion factor of 2.4 was considered most representative for scattered houses as the average Danish BOD/COD ratio of 2.7 reflects the presence of industrial COD in the influent wastewater at Danish WWTPs. The default IPCC value of 54.31 kg COD per person per are considered conservative and the most appropriate to use in the estimation of 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.

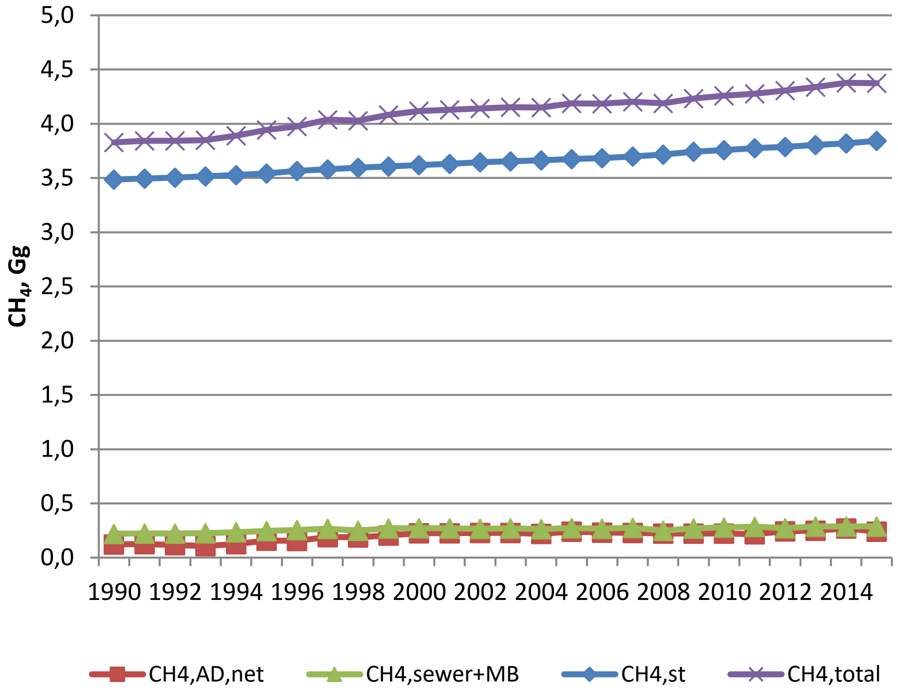

Figure 7.5.1 Time trends for net methane emission, methane emission from sewer systems, mechanical and biological treatment, from septic tanks and from anaerobic treatment processes.

The methane emission due to venting, i.e. $CH_{4.AD.net}$, has increased by 99.7% from 1990 to 2015. The methane emission from the sewer system, mechanical and biological treatment, i.e. $CH_{4.sewer+MB}$, has increase by 30.7% from 1990 to 2015. The methane emission from scattered houses, i.e. $CH_{4.st}$, has increased by 10.2%.

The total methane emissions, i.e. $CH_{4.total}$, has increased from 3.83 Gg in 1990 to 4.37 Gg methane in 2015 corresponding to an increase in net methane emissions from wastewater handling of 14.2 %.

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:

$$E_{N_2O} = EF_{N_2O,direct} \cdot m_{N,\inf luent} \cdot \frac{M_{N_2O}}{2 \cdot M_N}$$ 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:

$$E_{N_2O} = EF_{N_2O,direct} \cdot m_{N,\inf luent}$$ 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.

The indirect N_2O emission from WWTPs is calculated according to Equation 7.5.8:

$$E_{N_2O,WWTP,effluent} = D_{N,WWTP} \cdot EF_{N_2O,WWTP,effluent} \cdot \frac{M_{N_2O}}{2 \cdot M_N}$$ 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 0.005 kg N_2O-N per kg sewage-N produced (IPPC, 2006).

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 1990-2015 cf. Annex 3F, Table 3F-5.4.

Table 7.5.4 Nitrogen content in the influent and effluent wastewater, Mg.

	1990	1995	2000	2010	2011	2012	2013	2014	2015
Influent wastewater to WWTPs[1]	14,679[3]	22,340	26,952	27,357	30,049	26,316	29,557	30,033	30,509
Effluent wastewater from WWTP[2]	10,268	8,938	4,653	4,025	3,916	3,849	3,652	3,467	3,705
Effluent wastewater, Total[2]	16,884	15,152	10,005	6,960	6,770	6,597	6,399	6,986	7, 359

[1]Data on the influent wastewater N load from municipal WWTPs are available from the Danish Water Quality Parameter Database held by the Danish Nature Agency.

[2]Effluent wastewater, total includes discharges from the separate industry, 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 DNA 2007, 2010, 2011, 2012, 2013, 2014, 2015, 2016).

[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 3F, Table 3F-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 81% in 2015 (DEPA, . 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; Thomsen et al., 2015).

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.

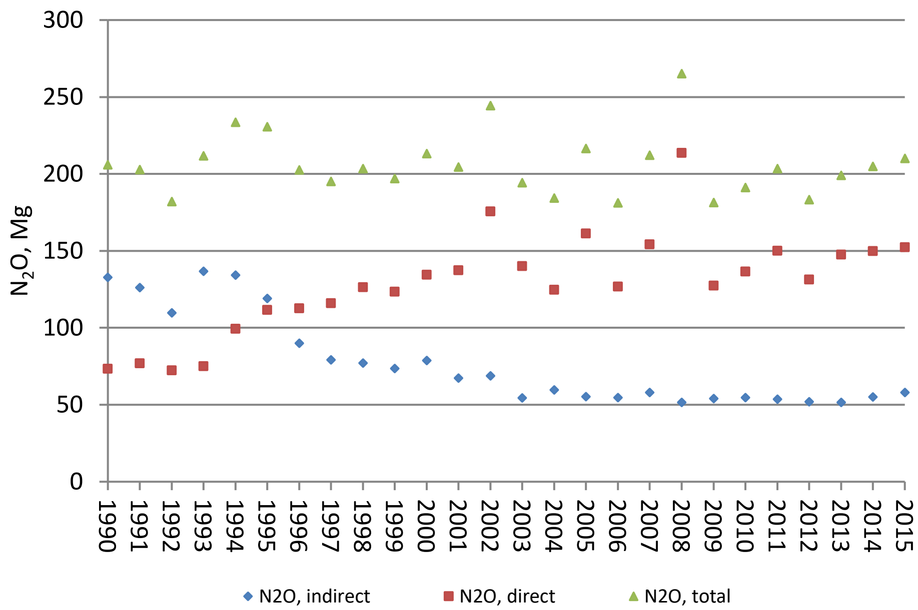

Figure 7.5.2 Time trends for the direct and indirect emission of N_2O (from wastewater effluents) and total N_2O emission.

The annual fluctuations may be caused by several factors, 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, DNA 2007, 2010, 2011, 2012, 2013, 2014, 2015, 2016, Vollertsen et al., 2002), may contribute to the "noise" or fluctuation in the trend of the calculated N_2O emission.

The direct emission shows an increasing trend from 73.2 ton in 1900 to 152.2 ton in 2015. Comparing 2015 with the base year 1990 an increase of 107.8 % 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 73.2 tonnes N_2O in 1990 to 57.8 tonnes N_2O in 2015 corresponding to a reduction of 56.4 %.

The indirect emission is the major contributor to the emission of nitrous oxide in the period 1990-1995. From 1996 and forward, the direct N_2O emission is the major contributor to the total N_2O emission. Overall, a net reduction of 2% is observed for the total N_2O emission from wastewater handling.

7.6 Other 5.E.1 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 3F-6, Table 3F-6.1.

Table 7.6.1 Overall emission of greenhouse gasses from accidental fires,1990-2015.

		1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
CO_2 emission from											
Accidental building fires	Gg	63.1	72.2	63.8	62.4	61.7	67.6	60.5	58.9	96.4	96.4
- of which non-biogenic	Gg	11.4	13.1	11.5	11.3	11.1	12.2	10.8	10.6	15.6	15.6
Accidental vehicle fires	Gg	6.1	6.5	6.9	6.9	7.3	6.3	5.6	5.4	5.7	5.7
Total. non-biogenic	Gg	17.5	19.6	18.4	18.1	18.3	18.4	16.4	16.0	21.3	21.3
CH_4 emission from											
Accidental building fires	Mg	64.1	73.4	64.9	63.8	64.6	68.5	61.7	60.6	86.0	86.0
Accidental vehicle fires	Mg	12.8	13.6	14.3	14.3	15.1	13.1	11.6	11.3	11.8	11.8
Total	Mg	76.9	87.0	79.2	78.1	79.7	81.6	73.3	71.9	97.8	97.8
5.E. Other											
CO_2-eqvivalents	Gg	19.5	21.8	20.4	20.1	20.3	20.5	18.2	17.8	23.7	23.7

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 (www.odin.dk). ODIN is developed and run by the Danish Emergency Management Agency (DEMA, 2007).

Activity data for accidental building fires are given by ODIN (DEMA. 2014). 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. 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 1990-2014. 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 1990-2015) and the occurrence of building fires (2007-2014) 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 3F-6, Table 3F-6.2.

Table 7.6.2 Occurrence of all fires and building fires.

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
All fires	17025	19543	17174	16,551	16728	16157	14084	14546	13180	13180
Building fires	10187	11694	10276	9,903	9325	11447	9932	9893	9473	9473

The building fires that occurred in the years 2007-2014 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, 2007, 2008, 2009, 2010, 2011, 2012, 2013, 2014, 2015, 2016).

	Size	Detached	Undetached	Apartment	Industry	Additional	Container	All building fires
Average. %	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
	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 of 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 3F, Table 3F-6.3.

Table 7.6.4 Accidental building fires full-scale equivalent activity data.

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
Container fires	750	861	756	729	594	729	584	584	584	584
Detached house fires	777	892	784	755	833	818	742	660	660	660
Undetached house fires	231	265	233	224	194	206	181	318	318	318
Apartment building fires	367	421	370	357	348	362	327	299	299	299
Industry building fire	320	368	323	311	281	334	298	751	751	751
Additional building fires	437	501	440	424	429	740	610	577	577	577

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 2014 as the best reliable and their respective references.

Table 7.6.5 Emission factors building fires, per FSE fire,. 2014.

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 1990-2014 are shown in Annex 3F, Table 3F-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 3F, Table 3F-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 The average floor space in Danish buildings (square metre).

	1990	1995	2000	2010	2011	2012	2013	2014	2015
Detached houses	156	155	156	163	164	165	165	165	165
Undetached houses	129	129	131	134	132	134	133	133	133
Apartment buildings	75	75	75	77	78	78	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, 1998, 1999, 2000, 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010, 2011, 2012, 2013, 2014, 2015, 2016). DEMA provides very detailed data for 2007-2014. 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 3F, Table 3F-6.5a-c.

Table 7.6.8 Occurrence of all fires and vehicle fires*.

	1990	1995	2000	2010	2011	2012	2013	2014
All fires	17.025	19.543	17.174	16.728	16.157	14.084	14.546	13.180
Vehicle fires	3.354	3.850	3.383	3.459	3.255	2.889	2.841	2.981

*(DEMA, 1998, 1999, 2000, 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010, 2011, 2012, 2013, 2014, 2015, 2016).

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 2007-2014 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 2007-2014.

The total number of registered vehicles is known from Jensen et al. (2013) and Statistics Denmark (2016). 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 1990-2014 is shown in Annex 3F. Table 3F-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
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
2014	2,390,554	514	12,846	11	310,417	32	43,568	53
2015	2,390,554	514	12,846	11	310,417	32	43,568	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
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
2014	295,948	82	141,418	33	3,085	2	1,722	14
2015	295,948	82	141,418	33	3,085	2	1,722	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			
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			
2014	1,053	0	79,045	68	12,998	18			
2015	1,053	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. 2016). 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
2014	1,162	11,463	4,046	10,861	134
2015	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 2007-2015 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 3F. Table 3F-6.8a-c.

Table 7.6.11 Burnt mass of different vehicle categories, Mg.

Vehicle category	1990	1995	2000	2010	2011	2012	2013	2014	2015
Passenger cars	407	466	557	739	674	592	555	524	524
Buses	116	223	242	266	160	130	121	217	217
Light duty vehicles	37	55	82	171	185	133	118	105	105
Heavy duty vehicles	869	902	969	715	606	579	455	422	422
Motorcycle. moped	5	6	8	11	12	11	11	12	12
Other transport	-	-	-	33	29	29	26	27	27
Caravan	30	36	44	63	59	57	59	55	55
Train	128	121	89	24	28	23	18	18	18
Ship	257	228	218	189	249	160	100	111	111
Airplane	12	11	12	7	3	5	5	4	4
Bicycle	-	-	-	0	0	0	0	0	0
Tractor	164	202	216	347	254	283	330	346	346
Combine harvester	530	476	425	398	271	236	402	469	469
Machine	-	-	-	43	51	53	53	53	53
Total	2,555	2,727	2,863	3,025	2,624	2,319	2,253	2,364	2,364

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 are 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 2010-2014 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 1990-2015.

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 (1998-2015). 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 3F, Table 3F-5.5).

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 (2007-2015) (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 1990-2014.

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 ±69.4 % and the trend in GHG emission, calculated as the per cent change in GHG emissions in 2015 compared to 1990, is 25.8%..

Table 7.7.6 National Tier 1 uncertainty estimates for the waste sector.

Pollutant	National emission, 2015. $GgCO_2$ eqv.	Total emission uncertainty, %	Trend* 1990-2015, %	Trend uncertainty, %
GHG	1,153	±69	-35	±26
CO_2	21	±300	-21	±17
CH_4	995	±82	-43	±18
N_2O	230	±55	198	±153

*Per cent change in emission in 2015 with respect to the base year 1990.

**GHG emissions are calculated in units of CO_2 equivalents.

7.7.3 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 (2006) and IPCC (2000).

As regards completeness, waste amounts for the whole time series, i.e. 1940-2015. 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 3F, Table 3F-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). Plant level data and modelling is in progress. Improved transparency and completeness of the activity data is expected to be documented and published this year (Thomsen & Hjelgaard, 2017).

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 2010-2014 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. For 2010-2015 we assume the same distribution across composting types as for 2009. Improved quality of the composting data has been achieved (Kristensen, 2016a).

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 1998-2015 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, 2016).

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, 2016).

Waste Other

For accidental fires, DEMA provides detailed data for 2007-2014 and the total number of nationally registered fires for 1990-2015 (DEMA, 1998, 1999, 2000, 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010, 2011, 2012, 2013, 2014, 2015, 2016). 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 agreement/ Comment
DCE data-exchange folder: O:\ST_ENVS-Luft-Emi\Inventory\2015\6_Waste\Level_1b_ProcessingLevel_1b_Processing	Inventory data storage system	AD and EF	DCE		
Report series published by the Danish Nature Agency (DNA) and available from the Danish Nature Agency (DNA): www.nst.dk			Report series: "*Point sources*" (2006-2015)	Naturstyrelsen Vestjylland Anna Gade Holm (angho@nst.dk) Marianne Thomsen (mth@envs.au.dk)	Public available reports
Danish Water Quality parameter Database	Annually reported wastewater characteristics at plant level which includes all years 1990-2015	AD	www.miljoeportalen.dk	Naturstyrelsen Vestjylland Anna Gade Holm (angho@nst.dk) Marianne Thomsen (mth@envs.au.dk)	Authorised access
DCE data-exchange folder: O:\ST_ENVS-Luft-Emi\Inventory\2015\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 registered due to statutory requirements
DCE data-exchange folder: U:\ST_ENVS-Luft-Emi\Energy\2015	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: O:\ST_ENVS-Luft-Emi\Inventory\2015\6_Waste\Level_1b_Processing\5A Solid Waste Disposal	Excel file with the FOD model: "swds_fod_model_1940-2015.xls"	AD. EF. Model	IPCC 2000. 2006 Thomsen & Hjelgaard. 2017	Marianne Thomsen (mth@envs.au.dk)	-
http://www.dkl.dk	Number for cremations	AD	Association of Danish Crematories	Hanne Ring hr@dkl.dk	Public access
http://www.statistikbanken.dk	Statistics for population. buildings and vehicles	AD	Statistics Denmark		Public access
DCE data-exchange folder: O:\ST_ENVS-Luft-Emi\Inventory\2015\6_Waste\Level_1a_Storage	Cremated animal carcasses	AD	Dansk Dyrekremering ApS	Knud Ribergaard info@danskdyrekremering.dk	Personal contact
DCE data-exchange folder: O:\ST_ENVS-Luft-Emi\Inventory\2015\6_Waste\Level_1a_Storage	Cremated animal carcasses	AD	Ada's Kæledyrskrematorium ApS	Anders Oxholm anders@adakrem.dk	Personal contact
DCE data-exchange folder: O:\ST_ENVS-Luft-Emi\Inventory\2025\6_Waste\Level_1a_Storage	Cremated animal carcasses	AD	Kæledyrskrematoriet	Annette Laursen 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: O:\ST_ENVS-Luft-Emi\Inventory\2053\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. 2014) 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 3F. Table 3F-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. 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 and 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, 2016. 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, 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. Thus, it is thus 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, 2011 and 2013.

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 (DEPA, 1996a, 1998a, 1999a, 2001a, 2001b, 2002a, 2004a, 2004b, 2005a, 2006a, 2006b, 2008, 2010a, 2011a, 2014, 2015): 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 (DEPA, 2013,2014, 2015) into 18 well-defined waste types as described in Chapter 7.2 and in Nielsen et al. (2016) and Thomsen and Hjelgaard (2017).
- 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 3F, Table F3-2.3 and F3-2.6.

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 (2000 and 2006) (cf. Chapter 7.10 on planned improvements for the waste sector).

Composting

- ISAG Waste Statistics (DEPA, 1996a, 1998a, 1999a, 2001a, 2001b, 2002a, 2004a, 2004b, 2005a, 2006a, 2006b, 2008, 2010a, 2011a, 2014, 2015)
- The New Danish Waste Reporting System (www.mst.dk) (DEPA, 2013, 2014, 2015, 2016)

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 2010-2015 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 has 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. 2016).
Knowledge of the amount of sludge treated at WWTPs with anaerobic sludge digestion has been used as input parameter for calculation of the gross methane emission from anaerobic treatment. It 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, 2014, 2015, 2016)
- Danish Emergency Management Agency (DEMA) database (DEMA 1998-2016)
- 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 (2007-2016) 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 are 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 data-sets 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 3F-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 (2000 and 2006). For WWTP the calculations follow the IPCC (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 1940-1984 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 regarding both 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 1990-2015 are shown in Annex 3F-7.

The joint effect of these recalculations is a decrease in the GHG emissions between 14 % (1990) and 13 % (2015).

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	2014
5.A. Solid Waste Disposal										
CH_4. previous inventory	Gg	71.0	62.2	51.0	44.0	37.2	37.1	35.3	33.9	33.0
CH_4. recalculated	Gg	61.5	53.2	42.9	36.4	30.9	30.9	29.7	28.1	27.7
Change. CO_2 equivalents	Gg	-237.9	-224.8	-203.4	-190.1	-6.4	-6.2	-5.6	-5.8	-5.4
Change	%	-15.5	-16.9	-19.0	-20.9	-20.6	-20.0	-18.8	-20.7	-19.4
5.B. Biological treatment of Solid Waste										
CH_4. previous inventory	Mg	1,532	2,267	4,027	4,717	4,811	5,539	5,342	6,910	7,181
CH_4. recalculated	Mg	1,532	2,266	4,029	4,717	5,611	5,414	5,531	5,703	7,029
N_2O. previous inventory	Mg	41.5	72.8	515.7	200.2	253.1	317.9	293.0	413.8	413.8
N_2O. recalculated	Mg	40.5	70.3	512.9	197.5	314.7	303.3	303.9	311.0	380.4
Change. CO_2 equivalents	Mg	-268.2	-765.1	-792.2	-797.7	38.3	-7.5	8.0	-60.8	-13.7
Change	%	-0.5	-1.0	-0.3	-0.5	16.4	-3.3	3.5	-25.9	-4.8
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	0.71	0.70
CH_4. recalculated	Mg	0.51	0.55	0.57	0.62	0.76	0.71	0.70	0.71	0.70
N_2O. previous inventory	Mg	0.64	0.69	0.71	0.77	0.95	0.88	0.88	0.88	0.87
N_2O. recalculated	Mg	0.64	0.69	0.71	0.77	0.95	0.88	0.88	0.88	0.89
Change. CO_2 equivalents	Mg	0	0	0	0	0	0	0	0	4.64
Change	%	0	0	0	0	0	0	0	0	1.64
5.D. Wastewater treatment and discharge										
CH_4. previous inventory	Gg	3.83	3.94	4.12	4.19	4.26	4.28	4.31	4.34	4.38
CH_4. recalculated	Gg	3.83	3.94	4.12	4.19	4.26	4.28	4.31	4.34	4.37
N_2O. previous inventory	Gg	0.21	0.23	0.21	0.22	0.19	0.20	0.18	0.20	0.20
N_2O. recalculated	Gg	0.21	0.23	0.21	0.22	0.19	0.20	0.18	0.20	0.20
Change. CO_2 equivalents	Gg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.44	0.62
Change	%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.26	0.37
5.E. Other										
CO_2. previous inventory	Gg	17.54	19.60	18.40	18.13	18.30	18.34	16.29	15.97	21.27
CO_2. recalculated	Gg	17.54	19.60	18.40	18.13	18.30	18.34	16.29	15.97	21.27
CH_4. previous inventory	Gg	0.08	0.09	0.08	0.08	0.08	0.08	0.07	0.07	0.10
CH_4. recalculated	Gg	0.08	0.09	0.08	0.08	0.08	0.08	0.07	0.07	0.08
Change. CO_2 equivalents	Gg	0	0	0	0	0	0	0	0	-7
Change	%	0	0	0	0	0	0	0	0	-1

7.9.1 Solid waste disposal on land recalculations

The recalculation of emissions from Solid Waste Disposal on Land is caused by an update in the activity data in the new waste reporting system 2010-2015. Furthermore, during the in-country review, the country specific DOC_i value for sludge was changed from 0.57 to 0.15 (IPCC, 2006) and the methane content of the LFG was changed from 0.41 to the default IPCC value of 0.5 (IPCC, 2006). On total, these changes result in a reduction in the methane emission in 1990 of 15% and in 2014 of 19%.

7.9.2 Biological treatment of Solid Waste

The N_2O emission factor for composting of organic waste was updated from 0.30 to 0.24 kg N_2O / Mg wet weight organic waste (IPCC, 2006). Furthermore, minor technical errors in the calculation methodology was corrected. In total the emissions from biological treatment of solid waste has decrease throughout the time series ranging between -0-3 to -1% in the years 1990-2009. In the period 2010-2014, the changes are more significant due to improved data on composting received by the DEPA. In the latter time period the emission increases 38& in 2010 and decreases -26% in 2013.

7.9.3 Waste Incineration and open burning

No recalculations were made for Waste Incineration, except for 2014 where a minor increase of 1% is observed due to updated activity data.

7.9.4 Wastewater treatment and discharge

For Wastewater treatment and discharge recalculations occur only in 2013 and 2014 due to updated activity data causing a minor decrease of -0.3% in 2013 and a minor increase in 2014 of 0.4%.

7.9.5 Other

No recalculations were made for sector 5.E on accidental fires except for 2014 where a minor decrease results from an update of activity data.

7.10 Source specific planned improvements

For the category 5.A. Solid Waste Disposal, the first set of plant level modelled emissions have been compared to monitoring data performed by the Danish Technological Institute. In the next NIR, the whole tie series for the 56 active SWDS will be presented. The reason for the described improvements is the Government financed implementation of biocovers on Danish landfills as instrument for reducing methane emissions from category 5.A. The plant level emission model is expected to be documented in a sector report in 2018.

Regarding 5.B Biological treatment of Solid Waste, data on composting were received. However, there are still challenges in differentiating between collected and treated amounts of organic waste. For this reason, a review of composting plants will be performed in 2017.

Regarding 5.D. Wastewater treatment and discharge, the directed N2O and CH4 emissions from separate industries will be included in the next NIR.

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. A more detailed overview is provided in Tables 9.2 – 9.5.

Information on recalculations for the aggregated submission of Denmark and Greenland 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, 2016 for Denmark (resubmitted in November 2016), 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 2015 submission are:

9.1.1 Energy

Stationary Combustion

For stationary combustion plants, the emission estimates for the years 1990-2014 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 2012, 2013 and 2014.

The disaggregation of fuel consumption between industrial subsectors has been updated according to updated data from the Danish Energy Agency.

The CO_2 emission factors for residual fuel oil have been recalculated. This was initiated due to on a review recommendation. The revised emission factor is based on plant specific EU ETS data and is discussed in NIR Chapter 3.2.

The consumption of gas oil has been recalculated as a consequence of the recalculations for diesel oil applied for transport.

Mobile sources

The following recalculations and improvements of the emission inventories have been made since the emission reporting in 2016.

Civil aviation

Small changes in the list of aircraft types – representative aircraft types has been made in the model used for calculating civil aviation emissions.

The following largest percentage differences (in brackets) for civil aviation are noted for: CO_2 (-0.4 %), CH_4 (3.4 %) and N_2O (14.7 %).

Road transport

The fuel consumption and emission factors for road transport have been updated with data from the updated COPERT model – COPERT V. In addition CNG vehicles and gasoline hybrid cars and vans have been explicitly included in the model.

The percentage emission change interval and year of largest percentage differences (low %; high %, year) for the different emission components are: CO_2 (0 %), CH_4 (-1.1 %; 0.6 %, 2013) and N_2O (-0.5 %; 1.5 %, 2012).

Navigation

A few changes have been made in relation to engine load factors for two specific ferries in 2013 and 2014.

The following largest percentage differences (in brackets) for domestic navigation are noted for: CO_2 (-0.2 %), CH_4 (-0.2 % and N_2O (-0.2 %).

Industry

A complete revision of the non-road model containing building and construction machinery has been made. From engine manufacturers new input data for engine load factors have been provided based on electronic engine power registrations. Further, equipment size - engine size relations, equipment scrapping curves and annual working hours as a function of engine age has been included in the model. From Stage IIIA engine emission levels onwards, specific fuel consumption factors have been updated also based on engine manufacturers advice.

The following largest percentage differences (in brackets) for mobile industry are noted for: CO_2 (-28 %), CH_4 (-27 % and N_2O (-14 %).

Agriculture/forestry

Changes have been made to the non-road model in relation to diesel fuelled agricultural machinery. From Stage IIIA engine emission levels onwards, specific fuel consumption factors have been updated also based on engine manufacturers advice.

The following largest percentage differences (in brackets) for mobile industry are noted for: CO_2 (-9 %), CH_4 (-0.5 % and N_2O (-2.1 %).

Fishing

Fuel transferal made between fisheries and national sea transport has resulted in minor changes in fuel consumption for fisheries, due to changes in national sea transport as described above.

The following largest percentage differences (in brackets) for fisheries are noted for: CO_2 (0.2 %), CH_4 (0.2 % and N_2O (0.2 %).

Other (Military and recreational craft)

Updated emission factors derived from the road transport model have caused a few emission changes from 1985-2014. The following largest percentage differences (in brackets) for military are noted for: CO_2 (0 %), CH_4 (-0.5 %) and N_2O (0.5 %).

Fugitive emissions

The following recalculations regarding fugitive emissions from fuels have been applied for the time series.

Oil production (1B2a2)

Activity data for the oil terminal are updated for 2011-2014 according to the annual environmental report. The recalculation is of minor importance (<0.001 % of the total CH_4 emission from 1B2b2).

Venting and flaring (1B2c)

Flaring in gas transmission has been updated for 2014 according to information from the Danish gas transmission company Energinet.dk.

Activity data and emissions are updated for one of the gas storage plants; for 2014 as the 2014 environmental report has become available, and for 2012 due to updated values in the 2015 environmental report.

Emission factors for N2O have been updated for flaring in oil/gas production and exploration for the entire time series.

The recalculations have only minor influence on the emissions from 1B2c. The largest change is in 2014 where the CH_4 and N_2O emissions have changed by -0.9 tonnes and +0.7 tonnes respectively, corresponding -0.1 % and +0.5 % of the total CH4 and N2O emissions from 1B2c.

9.1.2 Industrial Processes

Other process uses of carbonates

A calculation error was corrected for the source category of "Other uses of soda ash". The recalculations in the activity data occur for the entire time series. The recalculations result in changes of 0.2 % in average (1990-2014) and falls between -0.0 % (2012) and 2.8 % (1990). Minor changes also occur for the activity data for 1994-1998 and 2000-2013 due to recalculations done by Statistics Denmark.

Product uses as substitutes for ozone depleting substances

There are recalculations for 2009-2014 for the major subcategory "2F1 Refrigeration and air conditioning" for both HFCs and PFCs. The overall recalculations for this category are between -0.01 % (2011) and 0.86 % (2009), the average recalculation for 2009-2014 is a decrease of 0.14 %.

Other product manufacture and use

Recalculations are made for N_2O from product uses; medical applications and N_2O used as propellant. Changes occur for 1990-2004 and 2013-2014 for medical use and for 2009-2014 for propellants. The overall recalculations are – 3% for 1990-2004 and between -1.5 % (2013) and 1.0 % (2012) for the later years.

9.1.3 Agriculture

Recalculation of the CH4 emission has been provided, which has lowered the CH_4 emission for all years 1990-2014 corresponding to a lower emission of 3-5 %. The recalculation is mainly caused by an adjustment of the national methane conversion factor (MCF) for cattle and swine. The national MCF was introduced first time in submission 2016 in relation to a study concerning the reduced emission from slurry used for biogas production. In line of this work, the MCF also for untreated cattle and swine slurry was estimated. Further work with this study during 2016 has led to adjustment of MCF.

The N_2O emission has been recalculated for multiple subcategories and the consequence is a lower N_2O emission all years 1990-2014. The most important change is seen for emission from mineralization and is due to change of the C-TOOL, which is the model to estimate the carbon stock change in soil.

9.1.4 LULUCF

Christmas trees on agricultural land has been moved back to Forest Land and reported as Forest Land.

The emission from Cropland and Grassland has been recalculated for several reasons:

An updated version (Ver. 2.3) of our dynamic modelling tool for organic matter turn over in mineral agricultural soils has been implemented. The major outcome from the update is different development in the total carbon stock over time where (in general) the previous version showed a carbon stock decrease over time and the new parameterization shows a more steady state. This has only very little influence on the net-net ac-counting for Cropland Management.

Due to recommendation from the UN review team, we have included emissions from organic soils, which have fallen out of the EU Land Parcel Information System. These small land areas are difficult to track, as there is no information on their actual agricultural use.

The distribution between the total area of Cropland and Grassland has been changed due to better information in the LPIS from the Danish authorities.

9.1.5 Waste

For Solid Waste Disposal, recalculation have been made for the years 2011-2014 due to updates data in the Danish waste reporting system. This has led to smaller changes in the methane emissions from solid waste disposal sites in the range of +/-1% from 2011-2014.

For Composting, recalculations have been made though the times series due to an update of the N_2O emission factor from 0.30 to 0.24 according to the 2006 IPCC guidelines.

For wastewater treatment and discharge, updated activity data for nitrogen in the effluent wastewater in 2013 and 2014 and for nitrogen in the influent wastewater for 2014 have resulted in recalculations and associated changes in the total N_2O emission from wastewater treatment and discharge corresponding to reduction of 0.73% in 2013 and an increase of 1.22 in 2014.

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 small and the changes for the whole time-series are between -0.45 % (2013) and 0.01 % (1996). The implications of the recalculations on the level and on the trend, 1990-2014, of the national total are very 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 -0.78 % (1996) and -6.07 % (2014), see Table 9.1.

Table 9.1 Recalculation performed in the 2017 submission for 1990-2014. Differences in pct. of CO_2 equivalents between this submission and the November 2016 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	-4.54	-2.08	-6.33	-1.07	-3.15	-3.13	-0.78	-3.25	-2.22	-3.89	-2.81
Total CO_2 eqv. Emissions without Land-Use Change and Forestry	-0.07	-0.08	-0.37	0.01	-0.18	-0.11	0.01	-0.12	-0.06	-0.22	-0.10
	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Total CO_2 eqv. Emissions with Land-Use Change and Forestry	-1.98	-4.85	-1.63	-1.89	-2.35	-3.88	-3.40	-2.01	-1.59	-4.27	-5.50
Total CO_2 eqv. Emissions without Land-Use Change and Forestry	-0.12	-0.31	-0.15	-0.18	-0.20	-0.30	-0.22	-0.23	-0.16	-0.25	-0.28
	2012	2013	2014								
Total CO_2 eqv. Emissions with Land-Use Change and Forestry	-5.58	-3.98	-6.07								
Total CO_2 eqv. Emissions without Land-Use Change and Forestry	-0.16	-0.45	-0.35								

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.

The implication of the recalculations is further shown in Tables 9.2-9.5.

Table 9.2 Recalculation for CO_2 performed in the 2017 submission for 1990-2014. Differences in kt CO_2 eqv. between this and the November 2016 submission for DK. Excluding Greenland and Faroe Islands.

CO_2 kt	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Total National Emissions and Removals	-3400	-1682	-4863	-837	-2528	-2467	-722	-2678	-1736	-2944	-2012	-1427	-3578
1. Energy	28	33	35	29	32	27	27	22	22	19	17	16	18
1.A. Fuel Combustion Activities	28	33	35	29	32	27	27	22	22	19	17	16	18
1.A.1. Energy Industries	4	5	7	6	8	4	6	4	2	3	3	4	4
1.A.2. Manufacturing Industries and Construction	-55	-53	-60	-67	-71	-71	-80	-89	-89	-93	-93	-82	-82
1.A.3. Transport	0	0	0	0	0	0	0	0	0	0	0	-1	-1
1.A.4. Other Sectors	80	81	88	90	94	94	101	108	109	109	107	95	96
1.A.5. Other	-	-	-	-	-	-	-	-	-	-	-	-	-
1.B. Fugitive Emissions from Fuels	-	-	-	-	-	-	-	-	-	-	-	-	-
2. Industrial Processes and product use	2	1	1	0	0	0	0	0	0	0	0	0	0
2.A. Mineral industry	2	1	1	0	0	0	0	0	0	0	0	0	0
2.B. Chemical industry	-	-	-	-	-	-	-	-	-	-	-	-	-
2.C. Metal industry	-	-	-	-	-	-	-	-	-	-	-	-	-
2.D. Non-energy products from fuels and solvent use	-	-	-	-	-	-	-	-	-	-	-	0	0
2.G. Other product manufacture and use	-	-	-	-	-	-	-	-	-	-	-	-	-
3. Agriculture	-	-	-	-	-	-	-	-	-	-	-	-	-
3. G. Liming	-	-	-	-	-	-	-	-	-	-	-	-	-
3.H. Urea application	-	-	-	-	-	-	-	-	-	-	-	-	-
3.I. Other carbon-containing fertilizers	-	-	-	-	-	-	-	-	-	-	-	-	-
4. Land Use, Land-Use Change and Forestry (net)	-3431	-1716	-4898	-867	-2560	-2494	-749	-2700	-1758	-2964	-2030	-1443	-3596
4.A. Forest Land	-1601	-20	-19	-19	-19	-19	-19	-19	-19	-19	-19	-19	-19
4.B. Cropland	-1994	-1858	-5038	-1005	-2696	-2628	-881	-2829	-1886	-3089	-2153	-1564	-3714
4.C. Grassland	164	162	159	157	155	152	150	148	145	143	141	138	136
4.D. Wetlands	0	0	0	0	0	0	0	0	0	0	0	0	0
4.E. Settlements	0	0	0	1	1	1	1	1	1	1	2	2	2
4.F. Other Land													
4.G. Harvested wood products	-	-	-	-	-	-	-	-	-	-	-	-	-
5. Waste	-	-	-	-	-	-	-	-	-	-	-	-	-
5.E. Other	-	-	-	-	-	-	-	-	-	-	-	-	-

	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Total National Emissions and Removals	-1207	-1289	-1538	-2890	-2298	-1133	-934	-2572	-2953	-2942	-2021	-3021
1. Energy	16	15	13	14	8	3	2	4	2	1	2	-56
1.A. Fuel Combustion Activities	16	15	13	14	8	3	2	4	2	1	2	-56
1.A.1. Energy Industries	5	4	3	2	13	0	0	0	2	-6	0	-61
1.A.2. Manufacturing Industries and Construction	-78	-71	-79	-89	-203	-200	-77	-178	-215	-255	-273	-276
1.A.3. Transport	0	-1	-1	-1	-1	-1	-1	0	0	0	0	3
1.A.4. Other Sectors	90	83	89	102	199	203	79	182	215	262	276	279
1.A.5. Other	-	-	-	-	-	-	-	-	-	-	-	-
1.B. Fugitive Emissions from Fuels	-	-	-	-	-	-	-	-	0	0	-	0
2. Industrial Processes and product use	0	0	0	0	0	0	0	0	0	0	0	0
2.A. Mineral industry	0	0	0	0	0	0	0	0	0	0	0	0
2.B. Chemical industry	-	-	-	-	-	-	-	-	-	-	-	-
2.C. Metal industry	-	-	-	-	-	-	-	-	-	-	-	-
2.D. Non-energy products from fuels and solvent use	0	0	0	0	0	0	0	0	0	0	0	0
2.G. Other product manufacture and use	-	-	-	-	-	-	-	-	-	-	-	-
3. Agriculture	-	-	-	-	-	-	-	-	-	-	-	-
3. G. Liming	-	-	-	-	-	-	-	-	-	-	-	-
3.H. Urea application	-	-	-	-	-	-	-	-	-	-	-	-
3.I. Other carbon-containing fertilizers	-	-	-	-	-	-	-	-	-	-	-	-
4. Land Use, Land-Use Change and Forestry (net)	-1223	-1304	-1551	-2904	-2307	-1136	-936	-2576	-2955	-2943	-2023	-2965
4.A. Forest Land	-19	-19	4	3	-1	8	3	3	11	-46	22	16
4.B. Cropland	-1339	-1419	-1667	-3017	-2413	-1248	-1041	-2686	-3059	-2783	-2593	-2837
4.C. Grassland	133	131	109	106	102	99	96	100	85	-125	539	-153
4.D. Wetlands	0	0	1	1	2	3	3	4	5	8	6	6

Continued												
4.E. Settlements	2	2	2	2	2	2	3	3	3	3	3	4
4.F. Other Land												
4.G. Harvested wood products	-	-	-	-	-	-	-	-	-	-	-	-
5. Waste	-	-	-	-	-	-	-	-	-	-	-	-
5.E. Other	-	-	-	-	-	-	-	-	-	-	-	-

Table 9.3 Recalculation for CH_4 performed in the 2017 submission for 1990-2014. Differences in kt CO_2 eqv. between this and the November 2016 submission for DK. Excluding Greenland and Faroe Islands.

CH_4, kt CO_2 eqv	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Total National Emissions and Removals	-236	-245	-251	-268	-258	-253	-255	-252	-266	-255	-258	-270	-281
1. Energy	0	0	0	0	0	0	0	0	0	0	0	0	0
1.A. Fuel Combustion Activities	0	0	0	0	0	0	0	0	0	0	0	0	0
1.A.1. Energy Industries	-	-	-	-	0	0	0	0	0	0	0	0	0
1.A.2. Manufacturing Industries and Construction	0	0	0	0	0	0	0	0	0	0	0	0	0
1.A.3. Transport	0	0	0	0	0	0	0	0	0	0	0	0	0
1.A.4. Other Sectors	0	0	0	0	0	0	0	0	0	0	0	0	0
1.A.5. Other	0	0	0	0	0	0	0	0	0	0	0	0	0
1.B. Fugitive Emissions from Fuels	-	-	-	-	-	-	-	-	-	0	0	0	0
2. Industrial Processes and product use	-	-	-	-	-	-	-	-	-	-	-	-	-
3. Agriculture	-238	-246	-252	-267	-257	-250	-250	-245	-258	-246	-247	-257	-266
3.A. Enteric Fermentation	29	30	39	40	45	52	52	58	58	63	69	71	74
3.B. Manure Management	-267	-276	-291	-306	-301	-302	-302	-304	-315	-309	-316	-328	-339
3.F. Field Burning of Agricultural Residues	-	-	-	-	-	-	-	-	-	-	-	-	-
4. Land Use, Land-Use Change and Forestry (net)	4	4	3	2	2	1	1	0	-1	-1	-2	-2	-3
4.A. Forest Land	-	-	-	-	-	-	-	-	-	-	-	-	-
4.B. Cropland	-	-	-	-	-	-	-	-	-	-	-	-	-
4.C. Grassland	5	5	5	5	5	5	5	4	4	4	4	4	4
4.D. Wetlands	-1	-1	-2	-2	-3	-3	-4	-4	-5	-6	-6	-7	-7
5. Waste	-2	-2	-2	-4	-3	-5	-6	-7	-8	-8	-9	-10	-12
5.A. Solid waste disposal	0	0	0	0	0	0	0	0	0	0	0	0	0
5.B. Biological treatment of solid waste	-2	-2	-2	-4	-3	-5	-6	-7	-8	-8	-9	-10	-12
5.C. Incineration and open burning of waste	-	-	-	-	-	-	-	-	-	-	-	-	-
5.D. Waste water treatment and discharge	0	0	0	0	0	-	-	-	0	-	-	-	-
5.E. Other	-	-	-	-	-	-	-	-	-	-	-	-	-

	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Total National Emissions and Removals	-292	-304	-299	-292	-307	-299	-301	-285	-309	-279	-310	-281
1. Energy	0	0	0	0	0	0	0	0	0	0	4	5
1.A. Fuel Combustion Activities	0	0	0	0	0	0	0	0	0	0	4	5
1.A.1. Energy Industries	0	0	0	0	0	0	0	0	0	0	0	0
1.A.2. Manufacturing Industries and Construction	0	0	0	0	0	0	0	0	0	0	0	1
1.A.3. Transport	0	0	0	0	0	0	0	0	0	0	0	0
1.A.4. Other Sectors	-1	0	-1	-1	0	0	0	0	0	0	4	4
1.A.5. Other	0	0	0	0	0	0	0	0	0	0	0	0
1.B. Fugitive Emissions from Fuels	0	0	0	0	0	0	0	0	0	0	0	0
2. Industrial Processes and product use	-	-	-	-	-	-	-	-	-	-	-	-
3. Agriculture	-274	-286	-280	-270	-283	-274	-274	-277	-275	-262	-247	-249
3.A. Enteric Fermentation	71	67	65	67	72	73	69	71	71	73	75	75
3.B. Manure Management	-344	-352	-344	-337	-355	-347	-343	-347	-346	-335	-322	-323
3.F. Field Burning of Agricultural Residues	-	-	-	-	-	-	-	-	-	-	-	-
4. Land Use, Land-Use Change and Forestry (net)	-4	-4	-5	-6	-6	-7	-8	-8	-9	-9	-8	-10
4.A. Forest Land	-	-	-	-	-	-	-	-	0	0	0	0
4.B. Cropland	-	-	-	-	-	-	-	-	-	-	-	-
4.C. Grassland	4	4	4	4	4	4	4	4	4	5	5	4
4.D. Wetlands	-8	-8	-9	-10	-10	-11	-11	-12	-13	-13	-14	-14

Continued

5. Waste	-14	-14	-15	-17	-17	-17	-19	0	-25	-8	-58	-27
5.A. Solid waste disposal	0	0	0	0	0	0	0	0	-2	7	-6	1
5.B. Biological treatment of solid waste	-14	-14	-15	-17	-17	-17	-19	0	-22	-16	-52	-28
5.C. Incineration and open burning of waste	-	-	-	-	-	-	-	-	-	-	-	-
5.D. Waste water treatment and discharge	-	-	-	-	-	-	0	-	-	-	0	0
5.E. Other	-	-	-	-	-	-	-	-	-	-	-	-

Table 9.4 Recalculation for N_2O performed in the 2017 submission for 1990-2014. Differences in kt CO_2 eqv. between this and the November 2016 submission for DK. Excluding Greenland and Faroe Islands.

N_2O, kt CO_2 eqv	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Total National Emissions and Removals	164	152	-55	248	81	144	240	129	200	71	171	162	40
1. Energy	-2	-1	-1	-2	-2	-2	-3	-2	-3	-2	-2	-2	-2
1.A. Fuel Combustion Activities	-2	-2	-2	-2	-2	-3	-3	-3	-3	-3	-3	-3	-2
1.A.1. Energy Industries	-	-	-	-	0	0	0	0	0	0	0	0	0
1.A.2. Manufacturing Industries and Construction	-2	-2	-2	-2	-2	-2	-3	-3	-3	-3	-3	-3	-3
1.A.3. Transport	0	0	0	0	0	0	-1	-1	-1	0	0	0	0
1.A.4. Other Sectors	0	0	0	0	0	0	0	0	0	0	0	0	0
1.A.5. Other	0	0	0	0	0	0	0	0	0	0	0	0	0
1.B. Fugitive Emissions from Fuels	0	1	1	0	0	0	0	1	0	1	1	1	1
2. Industrial Processes and product use	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
3. Agriculture	166	154	-52	250	84	147	244	133	204	75	175	165	44
3.A. Enteric Fermentation	0	-1	-1	-1	0	-1	0	0	0	0	0	0	0
3.B. Manure Management	167	155	-51	251	85	148	244	133	204	74	175	165	44
3.F. Field Burning of Agricultural Residues	-	-	-	-	-	-	-	-	-	-	-	-	-
4. Land Use, Land-Use Change and Forestry (net)	0	0	0	0	0	0	0	0	0	0	0	0	0
4.A. Forest Land	-	-	-	-	-	-	-	-	-	-	-	-	-
4.B. Cropland	0	0	0	0	0	0	0	0	0	0	0	0	0
4.C. Grassland	0	0	0	0	0	0	0	0	0	0	0	0	0
4.D. Wetlands	-	-	-	-	-	-	-	-	-	-	-	-	-
5. Waste	0	0	0	0	0	0	0	0	0	0	0	0	0
5.A. Solid waste disposal	0	0	0	0	-1	-1	-1	-1	-1	-1	-1	-1	-1
5.B. Biological treatment of solid waste	0	0	0	0	-1	-1	-1	-1	-1	-1	-1	-1	-1
5.C. Incineration and open burning of waste	-	-	-	-	-	-	-	-	-	-	-	-	-
5.D. Waste water treatment and discharge	0	0	0	0	0	-	-	-	-	-	-	-	-
5.E. Other	164	152	-55	248	81	144	240	129	200	71	171	162	40

	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Total National Emissions and Removals	158	158	148	54	138	136	186	113	136	182	52	148
1. Energy	-2	-1	-2	-2	-2	-1	0	-1	0	0	0	0
1.A. Fuel Combustion Activities	-2	-2	-2	-2	-2	-2	-1	-1	0	0	0	0
1.A.1. Energy Industries	0	0	0	0	0	0	0	0	0	0	0	0
1.A.2. Manufacturing Industries and Construction	-2	-2	-2	-2	-3	-3	-2	-2	-3	-3	-3	-3
1.A.3. Transport	0	0	0	1	1	1	1	1	2	2	2	1
1.A.4. Other Sectors	0	0	-1	0	0	0	0	0	0	0	2	2
1.A.5. Other	0	0	0	0	0	0	0	0	0	0	0	0
1.B. Fugitive Emissions from Fuels	1	1	0	0	0	0	0	0	0	0	0	0
2. Industrial Processes and product use	-1	-1	-	-	-	-	0	0	0	0	0	0
3. Agriculture	162	161	151	57	140	138	188	96	141	180	84	158
3.A. Enteric Fermentation	0	0	0	0	0	0	0	0	0	0	0	-2
3.B. Manure Management	162	161	151	57	140	138	188	96	141	180	84	160
3.F. Field Burning of Agricultural Residues	-	-	-	-	-	-	-	-	-	-	-	-
4. Land Use, Land-Use Change and Forestry (net)	0	0	0	0	0	0	-1	-1	-1	-1	-1	-1
4.A. Forest Land	-	-	-	-	-	-	-	0	0	0	0	0
4.B. Cropland	0	0	0	0	0	0	0	0	0	0	0	1
4.C. Grassland	0	0	-1	-1	-1	-1	-1	-1	-1	-1	-1	-2

Continued												
4.D. Wetlands	-	-	-	-	-	-	-	-	-	-	-	-
5. Waste	0	0	0	0	0	0	0	0	0	0	0	0
5.A. Solid waste disposal	-1	-1	-1	-1	-1	-1	-1	18	-4	3	-31	-9
5.B. Biological treatment of solid waste	-1	-1	-1	-1	-1	-1	-1	18	-4	3	-31	-10
5.C. Incineration and open burning of waste	-	-	-	-	-	-	-	-	-	-	-	-
5.D. Waste water treatment and discharge	-	-	-	-	-	-	-	-	-	-	0	1
5.E. Other	158	158	148	54	138	136	186	113	136	182	52	148

Table 9.5 Recalculation for f-gases performed in the 2017 submission for 1990-2014. Differences in kt CO_2 eqv. between this and the November 2016 submission for DK. Excluding Greenland and Faroe Islands.

f-gases kt CO_2 eqv	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
HFCs			-	-	-	-	-	-	-	-	-	-	-
PFCs					-	-	-	-	-	-	-	-	-
SF_6	-	-	-	-	-	-	-	-	-	-	-	-	-
	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	
HFCs	-	-	-	-	-	-	7	-	0	0	0	0	
PFCs	-	-	-	-	-	-	-	0	0	0	0	-	
SF_6	-	-	-	-	-	-	-	-	-	-	-	-	

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. The draft of the review report from the centralised review carried out in September 2014 was received 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.

No review took place in 2015.

The review of the 2016 submission took place as an in-country review in September 2016. At the time of final editing of this report (early April 2017), Denmark had not yet received a draft review report.

To keep the table transparent the recommendations that have been completed from the review of the 2008 to 2014 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)			
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
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.	

NOTE: 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)			

10 KP-LULUCF

10.1 General information

In this chapter the following abbreviations are 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:	Revegetation
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 establishment 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 - 2015 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 (1990-2015) 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 activities which has started after 1. January 1990 are included in the inventory. 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:

- 4A21 CL to A
- 4A22 GL to A
- 4A23 WE to A
- 4A24 SE to A
- 4A25 OL to A

Deforestation is estimated as:
- 4B21 to CL
- 4C21 to GL

- 4D21 to WE
- 4E21 to SE
- 4F21 to OL

FM activities are only related to:

- 4A1 Forest remaining Forest

CM activities are related to:

- 4B1 CL remaining CL
- 4B22 GL to CL
- 4B23 WE to CL
- 4B24 SE to CL
- 4B25 OL to CL
- 4D22 CL to WE
- 4E22 CL to SE
- 4F22 CL to OL (not occurring)

GM activities are related to:

- 4C1 GL remaining GL
- 4C22 CL to GL
- 4C23 WE to GL
- 4C24 SE to GL
- 4C25 OL to GL
- 4D23 GL to WE
- 4E23 GL to SE
- 4F23 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 178 hectares from 2014 to 2015 which is caused by a conversion of WE til CM.

Table 10.1 The development in the different KP classes, which are included in the accounting (only Denmark) 1990 to 2015.

	1990	2008	2009	2010	2011	2012	2013	2014	2015
AF	4328	80960	84968	88977	92985	94783	99643	100148	103017
D	242	4464	5126	5787	6449	6772	6913	7387	9986
FM	544420	540077	539415	538754	538092	537769	537628	537154	534555
CM	-	2844229	2843850	2843471	2843093	2836394	2831065	2826507	2837884
GM	-	220643	217013	213383	209753	214654	215123	219175	205108
Other Land	-	615180	615180	615180	615180	615180	615180	615180	615002
Total area, Hectares	4305552	4305552	4305552	4305552	4305552	4305552	4305552	4305552	4305552

The Land Use matrix developed for the purpose of reporting Art. 3.3 and 3.4 activities for 2015 are shown in Table 10.2.

Table 10.2 Land Use matrix for Art. 3.3 and 3.4 activities in 2015, in 1000 hectares.

	ARTICLE 3.3 ACTIVITIES		ARTICLE 3.4 ACTIVITIES			Other	Total area at the end of the previous inventory year
	Afforestation and reforestation	Deforestation	Forest management	Cropland management	Grazing land management		
	(kha)						
Article 3.3 activities							
Afforestation and reforestation	100.15	NO					100.15
Deforestation		7.39					7.39
Article 3.4 activities							
Forest management		2.60	534.55				537.15
Cropland management	2.32		NO	2806.49	17.70		2826.51
Grazing land management	0.55		NO	31.24	187.39		219.18
Other	NO	NO	NO	0.16	0.02	615.00	615.18
Total area at the end of the current inventory year	103.02	9.99	534.55	2837.88	205.11	615.00	4305.55

Table 10.3 Estimated accounting quantities for the period 2013-2015.

GREENHOUSE GAS SOURCE AND SINK ACTIVITIES	Base Year	NET EMISSIONS/REMOVALS				Accounting parameters	Accounting quantity
		2013	2014	2015	Total		
	(kt CO2 eq)						
A. Article 3.3 activities							
A.1. Afforestation/reforestation		22.98	-326.75	-607.62	-911.39		-911.39
A.2. Deforestation		35.83	116.44	252.76	405.03		405.03
B. Article 3.4 activities							
B.1. Forest management					-5652.58		-6631.73
Net emissions/removals		-2546.19	-3774.13	667.73	-5652.58		
Forest management reference level (FMRL)						409.00	
Technical corrections to FMRL						-82.62	
Forest management cap						2419.88	-2419.88
B.2. Cropland management	4416.19	2297.46	3003.94	2542.28	7843.68		-5404.88
B.3. Grazing land management	931.98	1181.58	1091.25	1283.59	3556.42		760.47

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 2015. The preliminary result is an increase in the afforested area of 103 019 hectares, but also that deforestation has taken place of approximately 9 986 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 wooded areas to agricultural crops in rotation or permanent grass. Only to a little extend is forest converted to SE.

Since 1990 almost 34 960 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, 2013, 2014 and 2015 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 - 2015 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 an 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 til 2015. The estimates for the carbon pools in the afforestation are similar to previous estimates, with 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. From 2015 the estimates of removals are based on combined information from a national mapping of biomass and canopy height based on Lidar data (Schumacher et al 2013) and the land use map. By this combination details on the deforestation can be extracted.

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 25 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)".

There are very limited "natural forests" in Denmark and these are designated as protected and no conversion of these natural forests to planted forests are occurring and hence no emissions arising.

Methodological consistency between the reference level and reporting for forest management is ensured.

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 eqv/yr in the second commitment period. For the year 2015 a technical correction has been calculated to -82.6 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 10.4 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 applying first order decay function for HWP
	kt CO_2 eq/year
Decision 2/CMP.7	409
Technical correction	-82.6
Sum	326.4

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 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 an update of C-TOOL to Version 2.3, changes in the Land Use Matrix, inclusion of an emission from abandoned organic soils and correction of errors. The recalculations have decreased the overall emission from CM with approxcimately 1000 kt CO_2-eq for all years. Despite the new version of C-TOOL now is estimating a likely mineral soil in its equilibrium compared the previous version, which showed a net source, the estimated accounting quantity is almost unchanged. This is due to the net-net accounting principle as the recalculation has taken place for the whole time serie.

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 the 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, 2013, 2014 and 2015 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 is a small area in Denmark and mainly unstocked areas inside the forest. These areas will likely be replanted within 10 years and therefore kept as Forest Land.

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.

HWP accounting in the current commitment period is solely based on changes in the HWP pool in this period. Hereby the emissions in the first commitment period have no influence on the current reporting.

Denmark do not utilize SWDS. Wood harvested for energy purposes do not enter the calculations of the HWP pool, and is hence accounted as 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 2014 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 2015 is reported to about 158 000 tonnes. The outflow from the pool is reported to about 112 000 tonnes carbon in 2015. Thus there has been a net carbon sequestration in HWP of about 46 000 tonnes carbon in 2015. This corresponds to 0,13 % of Denmark's total CO_2 emissions for 2015.

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 10.5 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. & Suadicani, K., 2011: Submission of information on forest management reference levels by Denmark. Forest & Landscape Working Papers No. 58-2011, 34 pp. Forest & Landscape Denmark, Frederiksberg. Available 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., 2017).

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.

The indirect CO_2 emission from CH_4 is calculated as the emission of CH_4 multiplied by 44/16, the indirect CO_2 emission from CO is calculated as the emission of CO multiplied by 44/28 and the indirect CO_2 emission from NMVOC is calculated as the emission of NMVOC multiplied with the carbon content multiplied by 44/12. The default carbon fraction as per the 2006 IPCC Guidelines is 0.6. This fraction is used for all other sources than solvent use, where the inventory is based on a chemical specific approach and hence the exact carbon fraction is known. For more information on the estimation of CO_2 emissions from solvent use, road paving with asphalt and asphalt roofing, please see Chapter 4.5.

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. Also, indirect CO_2 has not been calculated for fuels in the combustion sector where an oxidation factor of 1 is already assumed, i.e. for the IPCC default CO_2 emission factors. Denmark only uses the IPCC default emission factors for fuels with a very low consumption, see Chapter 3 for more information.

Table 11.1 Indirect CO_2 emissions for 1990 and 2015, kt CO_2e.

	1990	2015
Indirect CO_2 from solvent use	93.59	60.63
Indirect CO_2 from road paving with asphalt	0.09	0.13
Indirect CO_2 from asphalt roofing	0.03	0.03
Indirect CO_2 from other sources	1216.97	412.49
Total GHG emission excluding all indirect CO_2	69127.02	47970.44
Total GHG emission consistent with CP1	69220.74	48031.24

For indirect N_2O the emissions 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. The indirect N_2O emissions are calculated using the below equation.

$$N_2O = (NO_X - N + NH_3 - N) * EF * 44/28$$

The default emission factor of 0.1 kg N_2O-N per kg NH_3-N or NO_x-N emitted is used for all sources.

11.3 Uncertainties and time-series consistency

Please see Nielsen et al. (2017) 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. (2017) 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. (2017) 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. (2017) 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 (15-02-2017).

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., 2017: Annual Danish Informative Inventory Report to UNECE. Emission inventories from the base year of the protocols to year 2015. Aarhus University, DCE – Danish Centre for Environment and Energy. (In press).

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 3/CMP.11 on 'Implications of the implementation of decisions 2/CMP.7 to 4/CMP.7 and 1/CMP.8 on the previous decisions on methodological issues related to the Kyoto Protocol, including those relating to Articles 5, 7 and 8 of the Kyoto Protocol, part I: implications related to accounting and reporting and other related issues' for the preparation of the information required under Articles 7 of the Kyoto Protocol (UNFCCC, 2015), this chapter and chapters 13, 14 and 15 include information and references to the annual supplementary information under the Kyoto Protocol. Decision 3/CMP.11 states that decisions 13/CMP.1, 15/CMP.1, 18/CMP.1 and 19/CMP.1 shall apply mutatis mutandis, except where otherwise specified in decisions 1/CMP.8 and 2/CMP.8 and in decision 3/CMP.11.

12.1 Information on transferred or acquired units

In accordance with paragraph 10 of the annex to Decision 15/CMP.1 information on emission reduction units (ERUs), certified emission reductions (CERs), temporary certified emission reductions (tCERs), long-term certified emission reductions (lCERs), assigned amount units (AAUs) and removal units (RMUs) 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 Standard Electronic Format (SEF) report for 2016 CP2 has been submitted to the UNFCCC Secretariat electronically and the contents of the reports can also be found in annex 6.

12.3 Discrepancies and notifications

Annex I parties are inter alia 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. List not included as o discrepant transactions occurred in 2016.
- Paragraph 13/14 – List of notifications from the CDM Executive Board regarding lCERs. No CDM notifications occurred in 2016.
- Paragraph 15 – List of non-replacement identified by the ITL. No non-replacements occurred in 2016.
- Paragraph 16 – List of invalid Kyoto units. No invalid units exist as at 31 December 2016.

No actions were taken or changes made to address discrepancies for the period under review.

12.4 Publicly accessible information

Information from the SEF available to the public will be included in the Danish SEF report 2016. The report will be available on the Danish Business Authority's website in addition to other public reports (pursuant to paragraphs 44 to 48 of the annex to Decision 13/CMP.l) as well as in the ETS registry:

In English: https://danishbusinessauthority.dk/public-information

In Danish: http://erhvervsstyrelsen.dk/offentlig_information

Link to reports available from the ETS registry: https://ets-registry.webgate.ec.europa.eu/euregistry/DK/public/reports/publicReports.xhtml

The reports are updated every month.

The reports include information on each account as required in paragraph 45 of the annex to Decision 13/CMP.1. Please note that publishing the contact information (paragraph 45 (d) and (e)) requires the consent of the account holder according to EU legislation. Thus, none of this information is publically available. The Danish Business Authority complies with the requirements stipulated in the European Commission's Union Registry Regulation, No. 389/2013, concerning the publication of confidential information.

Other information that is required to be publically available can be found on the EUTL website:

http://ec.europa.eu/environment/ets/

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

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

The accounting of RMUs based on the 2015 and 2016 submission will not begin until after publication of the review report from the review of the submission. Table 12.1 below contains data as submitted under the Kyoto Protocol for the purposes of the Doha Amendment.

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												
A.1. Afforestation and Reforestation		22.98	-326.75	-607.62						-911.39		-911.39
A.2. Deforestation		35.83	116.44	252.76						405.03		405.03
B. Article 3.4 activities												
B.1. Forest Management										-5652.58		-6631.73
Net emissions/removals		-2546.19	-3774.13	667.73						-5652.58		
Forest management reference level (FMRL)											409.00	
Technical corrections to FMRL											-82.62	
Forest management cap											2418.28	-2418,28
B.2. Cropland Management	3252.00	1466.27	1218.26	1905.74						4590.26		-5165.74
B.3. Grazing Land Management	931.98	1181.58	1091.25	1283.59						3556.42		760.47

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, 2015: Report of the Conference of the Parties serving as the meeting of the Parties to the Kyoto Protocol on its eleventh session, held in Paris from 30 November to 13 December 2015. Available at:
http://unfccc.int/resource/docs/2015/cmp11/eng/08a01.pdf#page=5

13 Information on changes in the national system

Since the 2016 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 certain GHG 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. Emissions from aircraft operators performing aviation activities in the EU and EFTA states are also included in the ETS.

The following changes to the National Registry of Denmark have occurred in 2016:

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 https://erhvervsstyrelsen.dk/eus-co2-kvoteregister-og-det-danske-kyoto-register https://danishbusinessauthority.dk/eu-ets-registry-and-danish-kyoto-registry The registry staff has changed to: Registry Manager Ms. Susanne Petersen Phone: +45 3529 1884 E-mail: susbod@erst.dk Ms. Anita Smed Phone: +45 3529 1622 E-mail: anisme@erst.dk Ms. Eydis Ingimundardottir Phone: +45 3529 1817 E-mail: eyding@erst.dk Mr. Joachim Peter Tilsted Phone: +45 3529 1492 E-mail: joapet@erst.dk
15/CMP.1 annex II.E paragraph 32.(b) Change regarding cooperation arrangement	No change of cooperation arrangement occurred during the reported period.

Reporting Item	Description
15/CMP.1 annex II.E paragraph 32.(c) Change to database or the capacity of national registry	New tables were added to the CSEUR database for the implementation of the CP2 SEF functionality. Versions of the CSEUR released after 6.7.3 (the production version at the time of the last Chapter 14 submission) introduced other minor 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. The database model, including the new tables, is provided in Annex A. 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 6.7.3 of the national registry are listed in Annex B. 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 was completed in January 2017 and the test report will be provided at a later date. 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	Changes to the national security procedures are attached in annex 6. The mandatory use of hard tokens for authentication and signature was introduced for registry administrators.

Reporting Item	Description
15/CMP.1 annex II.E paragraph 32.(g) Change to list of publicly available information	In English: https://danishbusinessauthority.dk/public-information https://danishbusinessauthority.dk/danish-emission-trading-registry In Danish: http://www.erhvervsstyrelsen.dk/offentlig_information http://www.erhvervsstyrelsen.dk/kyoto-registeret The publicly available information is updated on a monthly basis and confidential 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 considered confidential. This information is not publicly available before year x+3 ("x" denotes 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 except for the retirement transaction. No public information is available concerning article-6 projects, as Denmark has not approved any joint implementation projects in the country. No change to the list of publicly available information occurred during the reporting period in regards of information from the European Commission.
15/CMP.1 annex II.E paragraph 32.(h) Change of Internet address	No change of the registry internet address occurred during the reporting period. The internet address of the Danish registry is: https://ets-registry.webgate.ec.europa.eu/euregistry/DK/index.xhtml No change of the EU ETS registry internet address occurred during the reporting period.
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 6.7.3 of the national registry are listed in Annex B. 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 was carried out in January 2017 and the test report will be provided at a later date.
The previous Annual Review recommendations	The 2015 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

This chapter is Greenland's National Inventory Report (NIR) 2017 for submission to the United Nations Framework Convention on Climate change and the Kyoto Protocol.

The following sections contain detailed information on Greenland's inventories for alle the years from 1990 to 2015. The structure of the report follows the UNFCCC guidelines on reporting and review.

The issues addressed in this report are trends in greenhouse gas emission, 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 1990-2015 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 emission 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 behalt 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 has been made in the ratification of the Doha Amendment. Hence, in the second commitment period Greenland does not have a commitment.

The information in this chapter relates to Greenland only. Chapter 17 contains information on the aggregated submission of Denmark and Greenland under the Kyoto Protocol. A full set of CRF tables is not included in this report. However, the full set of CRF tables for Greenland is available

This report 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 Environment Agency:
http://cdr.eionet.europa.eu/dk/Air_Emission_Inventories/Submission_UNFCCC

The greenhouse gas inventory submitted in 2017 is completed by Statistics Greenland and the Ministry of Independent, Nature, Environment and Agriculture under the Greenland Government with technical support from the Danish National Center of Environment and Energy (DCE). This report on methodology is written by Statistics Greenland with documental support by DCE.

16.1.1 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 triflouride NF_3

According to the IPCC and their Fourth Assessment Report, which UNFCCC has decided to use as reference for reporting 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 a 25 times more powerful greenhouse gas than CO_2, and nitrous oxide is 298 times more powerful. Some of the other greenhouse gases (hydrofluorocarbons, perfluorocarbons and sulphur hexafluoride) have considerably higher global warming potential values.

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

16.1.2 A description of the institutional arrangement for inventory preparation

On behalf of the Greenlandic Ministry of Independent, Nature, Environment and Agriculture Statistics Greenland is responsible for the calculations and reporting of the Greenlandic national emission inventory to DCE in the Common Reporting Format in accordance with the UNFCCC guidelines. A formal agreement on the annual reporting has been made between the Greenlandic Ministry of Nature, Environment and Justice, Statistics Greenland and DCE. Acording to this agreement Statistics Greenland report the Greenlandic data and documentation to DCE within an agreed deadline.

DCE is responsible for reporting the national inventory for the Kingdom of Denmark to tge UNFCCC and for reporting the national inventory under the Kyoto Protocol for both Denmark and Greenland.

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.

The work concerning the annual greenhouse gas emission inventory is carried out in cooperation with Greenlandic ministries, research institutes, organisations and companies.

Statistics Greenland (Ministry of Finance and Taxes)

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 Independent, Nature, Environment and Agriculture)
Background data on cropland and grassland, and statistics on livestock (sheep and reindeer).

Former Ministry of Domestic Affairs, Nature and Environment
Data on waste and emissions of F-gases. Annual Survey carried out by the former Ministry of Domestic Affairs, Nature and Environment until 2008 and by Statistics Greenland from 2009 and onwards.

Ministry of Fisheries and Hunting and the Greenlandic Arboretum
Background data on forestry.

Greenland Airport Authority (Ministry of Municipalities, Settlements, Remote Districts, Infrastructure and Housing)
Statistics on domestic flights and foreign flights to and from Greenland.

16.1.3 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/WPS format and handled with the World Programming System (WPS) software. The WPS 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.

For each submission, databases and additional tools and submodels are frozen together with the resulting CRF-reporting format. 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.

16.1.4 Brief general description of methodologies and data sources used

The Greenlandic air emission inventory is based on the Intergovernmental Panel on Climate Change (IPCC) Guidelines for Nation Greenhouse Gas Inventories (IPCC, 2006), 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 program 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 program 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 Greenlandic 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 emission 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 as 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.

The greenhouse gas 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. Descriptions that are more thorough 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. However, 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

Previously, emissions from international aviation bunkers have been considered to be of neglible importance in terms of Greenland. For that matter the annual amount of jet fuel loaded into foreign aircrafts has been included as part of the IPCC category 1A3a Domestic Aviation. However, some misunderstanding has taken place and this assumption seems to be incorrect! New data has emerged regarding the distinction between domestic and international flights, and it seems possible that combustion of jet fuel in international bound aircrafts taking off from Greenland can be determined and reported as international aviation bunkers as from the coming 2018 submission. However, in this 2017 submission jet fuel loaded into foreign aircrafts is still 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 emissions

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 Scottish 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. Since the 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 Scottish 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 Scottish 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 2015 has been estimated to a net source of 1.04 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 2015 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.

An additional 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 2015, 10.5 ha of cropland were 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, there are some smaller areas, which have become improved fertilised grassland. The total area with improved grassland has increased from 490 ha in 1990 to 1,096 ha in 2015.

Wetlands

Reported area with wetlands consists only of water-reservoirs. Due to lack of methodology for methane emissions under arctic conditions, no emission estimates has been made, which is in accordance with the IPCC Good Practice Guidance 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 Good Practice Guidance guidelines.

Harvested wood products

Due to an only marginal 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 second 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.

16.1.5 Brief description of key categories

A key category analysis (KCA) for year 1990 and 2015 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

2015, seven categories were identified as key categories due to the level whereas eight categories were key categories due to the trend.

Of the seven key sources due to level for the reporting year 2015 five are in the energy sector, of which CO_2 from liquid fuels excluding transport in the analysis contributes most with 73.2 % 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 navigation, domestic aviation and road transportation comprise respectively 7.2 %, 6.0 % and 5.5 % of the national total. The last key categories are HFCs from the consumption of HFCs and CH_4 from enteric fermentation.

The trend assessment shows that N_2O from wastewater treatment and discharge and CO_2 from incineration and open burning of waste are key categories to the trend. Further four sources from the energy sector are also key categories to the trend as well as HFCs from the consumption of HFCs and CO_2 from the LULUCF category grassland remaining grassland.

The categorisation used, results, etc. are included in Section 16.11 (Annex 1).

16.1.6 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.

16.1.7 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 -14.4 % ± 3.5 %-age points. The GHG uncertainty estimates do not take into account the uncertainty of the GWP factors.

The largest sources with regard to uncertainty in the Greenlandic GHG Inventory are CO_2 and N_2O from liquid fuels in fuel combustion, N_2O emission from waste water treatment, CH_4 emission from enteric fermentation, CH_4 emission from solid waste disposal and HFC from consumption of HFC. 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 1990-2015.

	Uncertainty [%]	Trend [%]	Uncertainty in trend [%-age points]
GHG	± 4.3	-14.4	± 3.5
CO_2	± 3.5	-16.0	± 3.5
CH_4	± 56.0	-13.5	± 9.3
N_2O	± 122	-21	± 24.3
F-gases	± 51	+16 541	± 6 954

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	620	513	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	10	10	50
2G Consumption of SF6	SF_6	0	0	10	50
3A Enteric Fermentation	CH_4	8	6	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	4	30	100

16.1.8 General assessment of completeness

The present Greenlandic greenhouse gas emission inventory includes all major sources identified by the Revised IPCC Guidelines.

16.1.9 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).

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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 2015 total emission of greenhouse gases excluding LULUCF was 557.41 Gg CO_2 equivalent, and 558.46 Gg CO_2 equivalent including LULUCF.

Figure 16.2.1 shows total greenhouse gas emission in CO_2 equivalents from 1990 to 2015. The emissions are not corrected for temperature variations. CO_2 is the most important greenhouse gas. In 2015 CO_2 contributed to the total emission in CO_2 equivalent excluding LULUCF with 94.0 %, followed by CH_4 2.5 %, F-gases (HFCs and SF_6) with 1.9 % and N_2O 1.7 %.

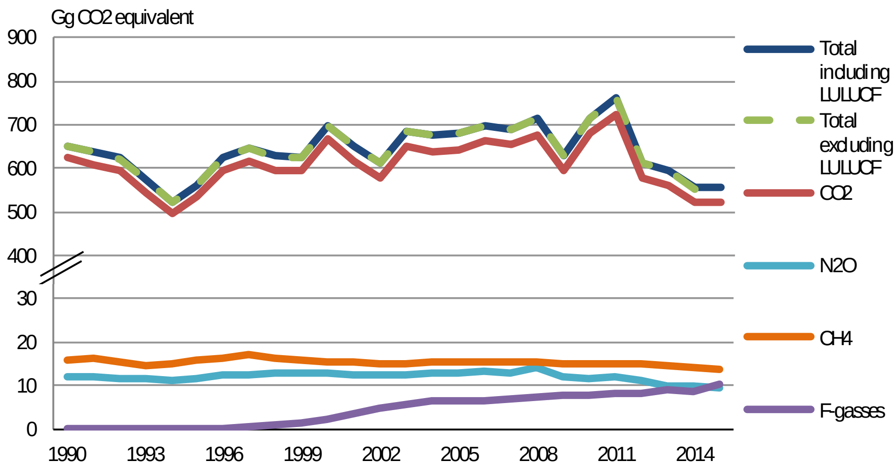

Figure 16.2.1 Greenhouse gas emission in CO_2 equivalents, time-series 1990-2015.

Stationary combustion plants and transport represent the largest categories. Energy excluding transport contributed to the total emission in CO_2 equivalents excluding LULUCF with 75.1 % in 2015; see Figure 16.2.2. Transport contributed with 18.9 %. Industrial processes and product use, agriculture and waste contributed to the total emission in CO_2 equivalents with 6.0 %.

The net CO_2 emission forestry etc. is 0.2 % of the total emission in CO_2 equivalents in 2015. Total GHG emission in CO_2 equivalents excluding LULUCF has decreased by 14.6 % from 1990 to 2015 and decreased 14.4% 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.

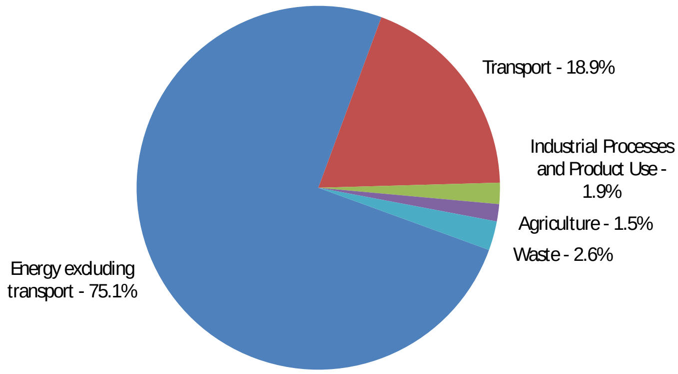

Figure 16.2.2 Greenhouse gas emission in CO_2 equivalents distributed on main sectors for 2015.

16.2.2 Description and interpretation of emission trends by gas

Carbon Dioxide

Emission of CO_2 accounted for 94.0 % of the total GHG emission in 2015. The largest source to emission of CO_2 is the energy sector comprising Fuel Combustion (Sectoral Approach). In 2015, the energy sector contributed to 99.3 % 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, Forestry and Fisheries (AFF) contributes with 23.7 % making AFF the largest contributor in 2015 followed by Energy Industries 21.0 %, Transport 19.9 % and Residental 19.4 %.

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. Since 2011, there has been a standstill in the oil exploring activities. Combined with a recession in the Greenlandic economy this has send energy combustion in Energy Industries to the lowest level ever in the time series since 1990; see the blue curve in Figure 16.2.3.

Commercial and Institutions contributes with 9.0 % of the total CO_2 emission and Manufacturing Industries and Construction with 4.5 %. The category *Other* (containing the remaining sectors) contributed with 2.5 % of the CO_2 emissions in 2015.

Overall CO_2 emissions excluding LULUCF increased by 0.6 % from 2014 to 2015. In 2015, the actual CO_2 emission was 16.1 % lower than the emission in 1990 excluding LULUCF.

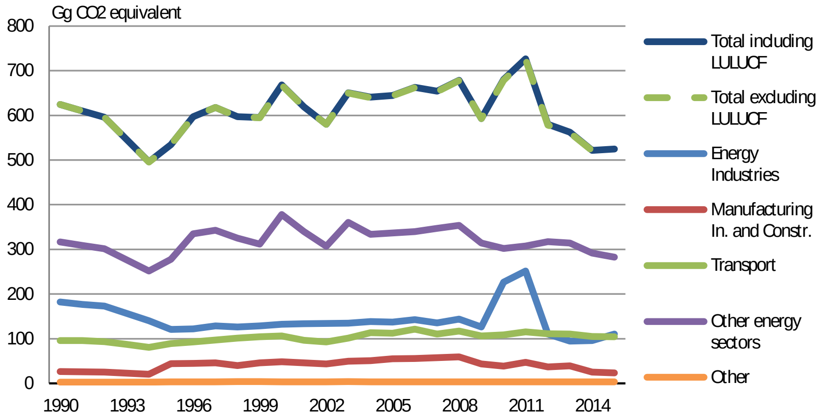

Figure 16.2.3 CO_2 emissions, time-series for 1990-2015.

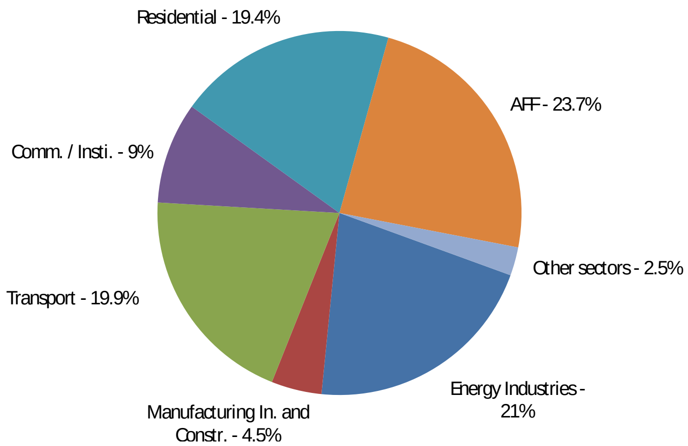

Figure 16.2.4 CO_2 emissions, distribution according to the main sectors for 2015.

Nitrous oxide

Waste, particularly waste water treatment and discharge is the most important N_2O emission source in 2015 contributing 50.7 % to the total N_2O emissions, see Figure 16.2.6. Agricultural activities contributed 24.4 % to the total N_2O emissions in 2015. Fuel combustion including transport contributed 24.9 %. Since 1990, total emission of N_2O has decreased by 20.6 %.

Besides from a temporary increase in 2011 total N_2O emission has been reduced in later years, 2009-2010 and 2011-2015 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.

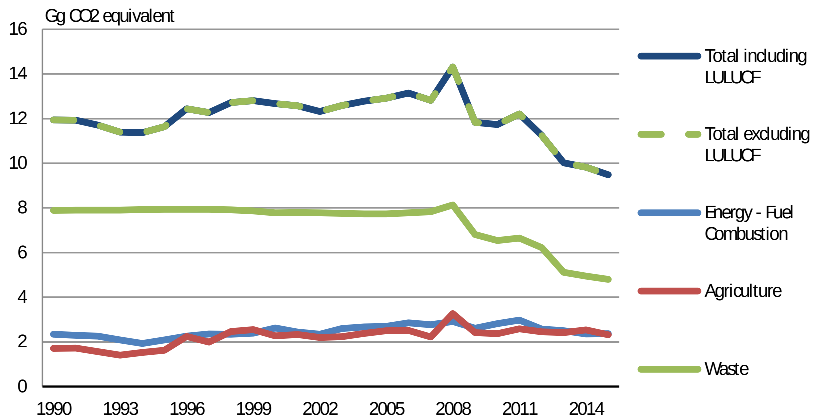

Figure 16.2.5 N_2O emissions, time-series for 1990-2015.

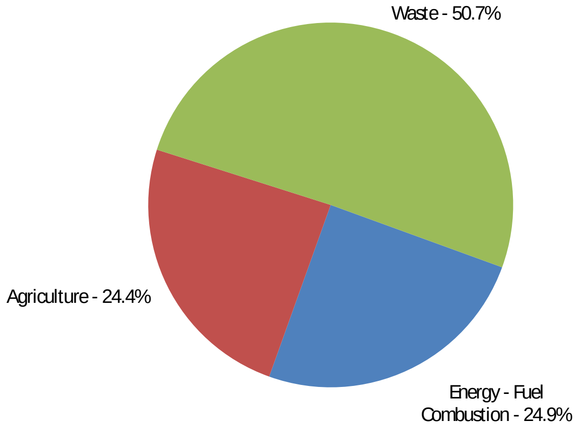

Figure 16.2.6 N_2O emissions, distribution according to the main sectors in 2015.

Methane

The largest sources of anthropogenic CH_4 emissions are waste handling activities contributing with 46.5 % of total CH_4 emission in 2015; see Figure 16.2.8. Agriculture contributes to 44.8 % of total emission and the energy sector with 8.7 % of total CH_4 emission in 2015.

The emission from agriculture derives from enteric fermentation (98 %) and management of animal manure (2 %). Since 1990, the number of sheep and reindeer has decreased. From 1990 to 2015, the emission of CH_4 from agricultural activities has decreased by 20.1 %.

The emission of CH_4 from waste derives from solid waste disposal (71 %) and incineration and open burning (29 %). From 1990 to 2015, the emission of CH_4 from solid waste disposal has increased by 5.4 %, while emissions from waste incineration have decreased by 29.6 %. Overall emission of CH_4 from waste handling has decreased by 8.0 % from 1990 to 2015.

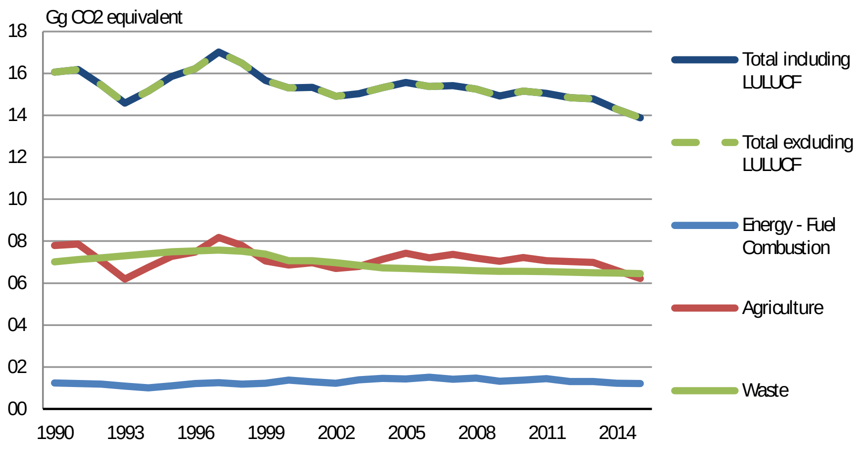

Figure 16.2.7 CH_4 emissions, time-series for 1990-2015.

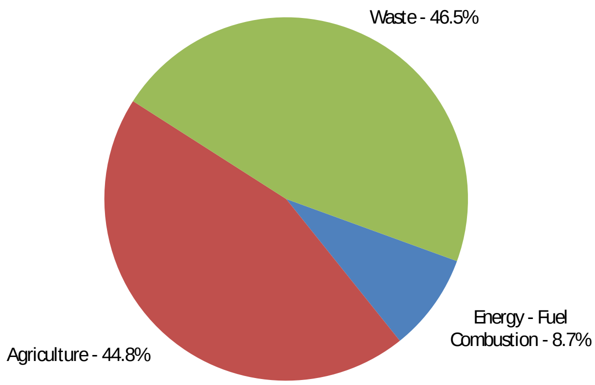

Figure 16.2.8 CH_4 emissions, distribution according to the main sectors in 2015.

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. Since 1995 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 increasing emission from 1995 to 2015 is caused by an increase in the emission of HFCs. For the years 2004-2015, the relative increase is lower than for the years 1995 to 2004. The increase from 1995 to 2004 is 10,290 %. From 2004 to 2015 total emission increased by 60.2 %. 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 2015, 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 2015. HFCs are mainly used as a refrigerant.

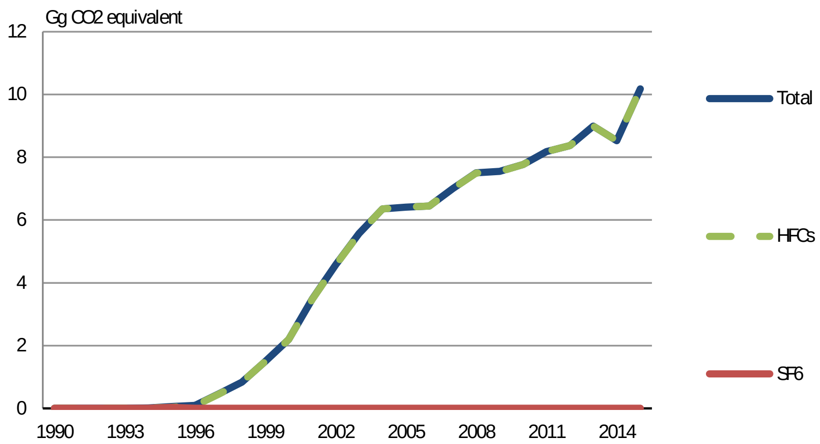

Figure 16.2.9 F-gas emissions, time-series for 1990-2015.

16.2.3 Description and interpretation of emission trends by category

Energy

The emission of CO_2 from energy has decreased by 16.3 % from 1990 to 2015. 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 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, since 2011 oil exploration activities came to a standstill. At the same time, Greenlands fifth hydro power plant went into operation. The rise in waterpower supply combined with an overall recession in the Greenlandic economy caused CO_2 emissions from energy to decrease by 20 % in 2012, 3 % in 2013 and 7 % in 2014. In 2015, the economy recovered a little causing CO2 emissions from fuel cunsumption to rise by 0.6 %.

Overall emission of CH_4 from energy has decreased by 3.0 % from 1990 to 2015. The CH_4 emission from transportation has increased by 80 % from 1990 to 2015, mainly due to increasing domestic aviation.

Emission of N_2O has increased by 1 % from 1990 to 2015.

Industrial processes and product use

Emissions from industrial processes and product use (consumption of halocarbons and SF_6) other than fuel combustion amount to 1.9 % of the total emission in CO_2 equivalents excluding LULUCF in 2015. The main source is consumptions of HFCs. Emission of F-gases have increased considerable since 1990.

Agriculture

The agricultural sector contributes with 1.5 % of the total GHG emissions excluding LULUCF in 2015, 44.8 % of the total CH_4 emission and 24.4 % of the total N_2O emission. The total emission from the sector has decreased by 10.2 % from 1990 to 2015. This decrease is due to a fall in the number of reindeer from 6,000 heads in 1990 til 3,000 heads in 2015 and a fall in the number of sheep from 19,929 in 1990 to 17,501 in 2015. The use of inoranic fertilizers has overall increased since 1990. CH_4 emission has decreased by 20.1 % from 1990 to 2015, primarily due to the fall in the number of livestock; sheep and reindeer. In the same period N_2O emission has increased by 35.5 % due to a significantly increase in the use of fertilizers.

LULUCF

Emissions from the LULUCF sector amount to just 0.2 % of total emissions in CO_2 equivalents in 2015. Forests are assumed to be a sink for the whole period increasing from approximately zero in 1990 to 50.7 tonnes CO_2 in 2015. The emission from cropland is estimated to zero in 1990, as there were no cropland in Greenland in 1990 and a net source in 2015 of 48.1 tonnes CO_2. The emission from grassland has been estimated to 206 tonnes CO_2 in 1990 increasing to 1,044 tonnes CO_2 in 2015.

Waste

The waste sector contributes with 2.6 % of the total greenhouse gas emissions in 2015, 46.5 % of the total CH_4 emission and 50.7 % of the total N_2O emission. Total emission from the sector has decreased by 17.5 % from 1990 to 2015. 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 40.7 %.

Total GHG emission from waste incineration without energy recovery has decreased by 6.4 % from 1990 to 2015 due to an increasing amount of waste incineration with energy recovery and a continuously decrease in waste water from industrial fishing plants in 2015. 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 2015, 50.7 % 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 28.9 % of total emissions in 2015.

From 1990 to 2015, emission of NO_X from AFF has increased by 18.0 %, while emissions from transport have increased by 17.4 %. In the same period, total emission of NO_X has increased by 6.0 %.

The emissions from energy industries obtain 7.7 % of total emission in 2015. The emission from energy industries have decreased by 38.5 % from 1990 to 2015. The decrease is due to a continuous substitution of fossil fuels with hydro power and lately to a recession in the Greenlandic economy.

Emission of NO_X from waste handling obtains 1 % of total emission, see Figure 16.2.10.

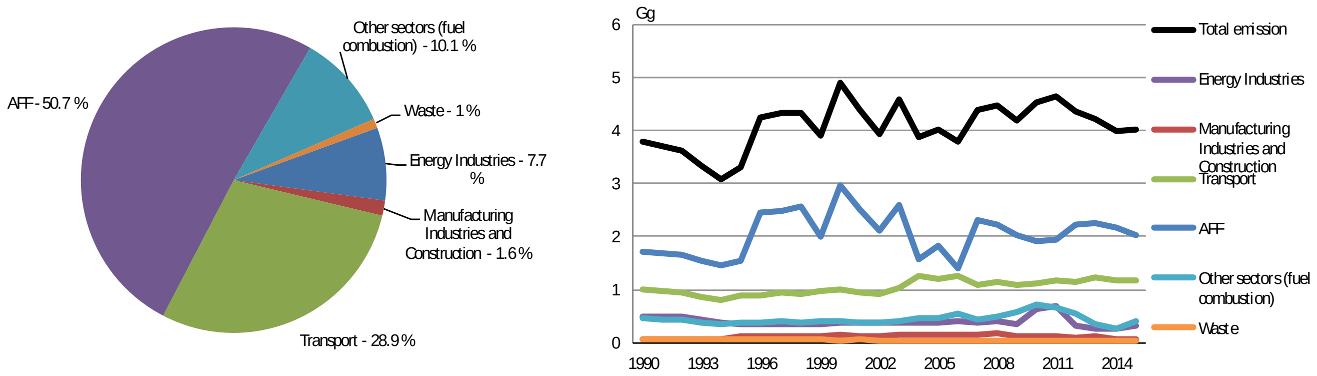

Figure 16.2.10 NO_X emissions. Distribution according to the main sectors (2015) and time series (1990-2015).

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 28.5 % from 1990 to 2015, largely due to increasing emissions from road transportation and civil aviation. Emissions from energy industries have been cut by 39.7 % since 1990, while emissions from transport almost doubled since 1990.

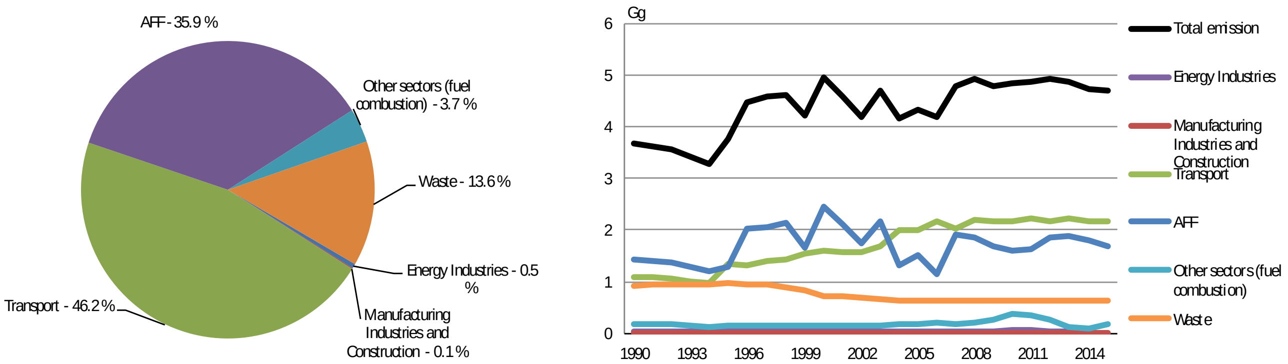

Figure 16.2.11 CO emissions. Distribution according to the main sectors (2015), and time series (1990-2015).

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 45.9 % of the total NMVOC emission in 2015. Fishing vessels are included under AFF (agriculture, forestry and fisheries), which obtain 35.8 % of total NMVOC emission in 2015, 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. The emission from this sector has decreased by 3.4 % from 1990 to 2015.

Total anthropogenic emissions have increased by 33.7 % from 1990 to 2015, largely due to the increase in road transportation and AFF activities.

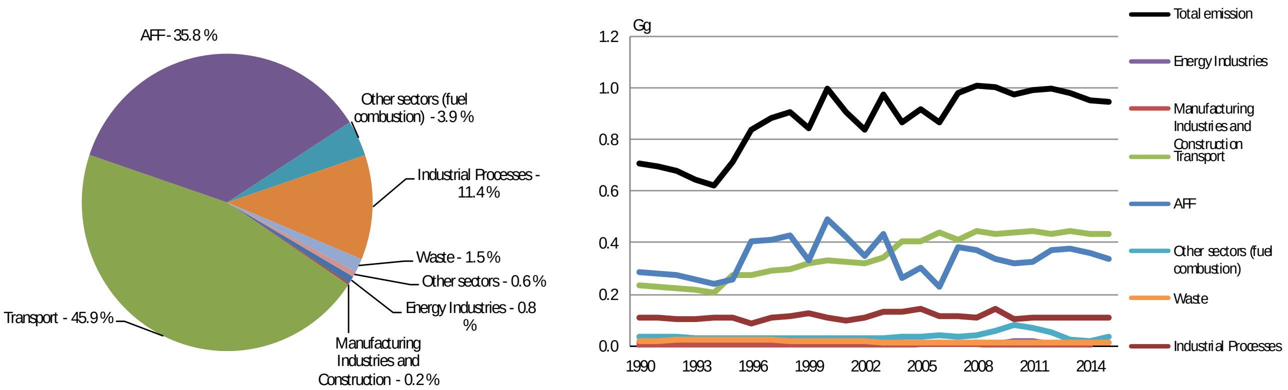

Figure 16.2.12 NMVOC emissions. Distribution according to the main sectors (2015), and time series (1990-2015).

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 2015, total emission of SO_2 decreased by 4.6 %.

Emissions from AFF (Agriculture, Forestry and Fisheries) obtain 30.7 % of total SO_2 emission in 2015 followed by Energy Industries obtaining 21.8 % in 2015. Emissions from other industrial combustion plants, non-industrial combustion plants and mobile sources are likewise important. Transportation contributed with 14.9 % of total SO_2 emission in 2015.

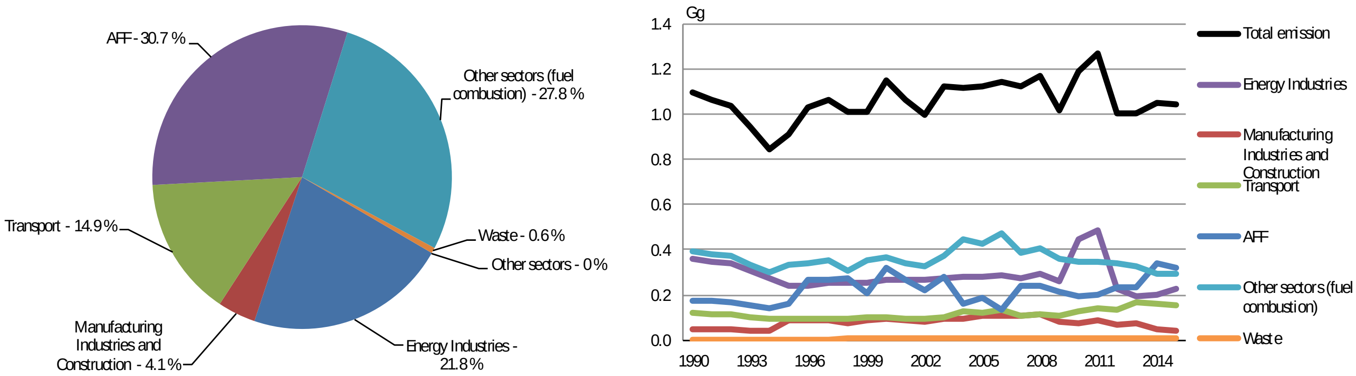

Figure 16.2.13 SO_2 emissions. Distribution according to the main sectors (2015), and time series (1990-2015).

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 Emission of CO_2 from the Energy Sector.

Greenhouse gas source and sink categories	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
						Gg				
1. Energy	621.6	606.8	592.7	542.8	492.7	531.1	593.6	614.2	593.0	590.7
A. Fuel Combustion (Sectoral Approach)	621.6	606.8	592.7	542.8	492.7	531.1	593.6	614.2	593.0	590.7
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	26.5	25.7	25.1	22.6	20.2	43.8	44.5	46.2	40.0	45.8
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	308.6	300.6	293.5	269.5	245.5	271.1	328.1	336.2	318.7	305.1
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	664.0	614.5	576.2	646.2	636.4	640.5	658.8	649.7	674.3	589.4
A. Fuel Combustion (Sectoral Approach)	664.0	614.5	576.2	646.2	636.4	640.5	658.8	649.7	674.3	589.4
1 . Energy Industries	132.1	133.2	133.9	134.4	138.5	137.1	142.3	135.1	144.0	126.0
2 . Manufacturing Industries and Construction	48.1	45.7	43.2	49.8	50.7	55.1	55.7	57.4	59.4	43.2
3 . Transport	105.9	96.1	92.4	101.4	113.6	111.9	121.2	110.4	117.1	105.9
4 . Other Sectors	371.2	332.9	300.1	354.0	326.2	329.1	330.0	339.1	343.9	298.3
5 . Other	6.6	6.6	6.6	6.6	7.5	7.3	9.7	7.7	10.0	16.0
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	2010	2011	2012	2013	2014	2015				
1. Energy	675.4	721.9	575.0	557.8	517.3	520.4				
A. Fuel Combustion (Sectoral Approach)	675.4	721.9	575.0	557.8	517.3	520.4				
1 . Energy Industries	226.5	251.7	110.7	94.4	95.8	110.1				
2 . Manufacturing Industries and Construction	38.7	47.3	36.5	39.3	25.2	23.4				
3 . Transport	108.5	115.5	110.7	110.1	104.7	104.1				
4 . Other Sectors	277.4	286.0	301.4	309.0	289.1	273.0				
5 . Other	24.4	21.3	15.6	4.9	2.4	9.7				
B . Fugitive Emissions from Fuels	NA	NA	NO	NO	NO	NO				
C . CO_2 Transport and Storage	NO	NO	NO	NO	NO	NO				

Table 16.3.2 Emission of CH_4 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	2014	2015				
1. Energy	0.06	0.06	0.05	0.05	0.05	0.05				
A. Fuel Combustion (Sectoral Approach)	0.06	0.06	0.05	0.05	0.05	0.05				
1 . Energy Industries	0.01	0.02	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				
3 . Transport	0.01	0.01	0.01	0.01	0.01	0.01				
4 . Other Sectors	0.03	0.03	0.03	0.03	0.03	0.03				
5 . Other	0.00	0.00	0.00	0.00	0.00	0.00				
B . Fugitive Emissions from Fuels	NA	NA	NO	NO	NO	NO				

Table 16.3.3 Emission of N_2O 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	2014	2015				
1. Energy	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				
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	0.00	0.00	0.00				
4 . Other Sectors	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				
B . Fugitive Emissions from Fuels	NA	NA	NO	NO	NO	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 589 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 2015, total fuel combustion was 7,244 TJ of which 7.048 TJ was liquid fossil fuels.

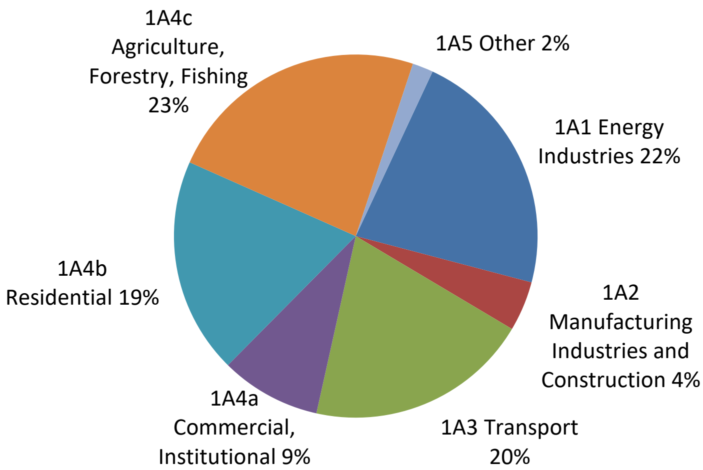

Figure 16.3.1 Fuel combustion rates, fossil fuels 2015 (Statistics Greenland).

In Greenland gasoil, kerosene and gasoline are used in fuel combustion. Fueloil is imported from 2010 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 dropped again in 2012 and onwards also due to an overall economic recession.

Kerosene is primarily used in aviation, but also for heating in minor 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. Prior to this 2017 inventory, the time-series on LPG started in 2004. However, with help from the Greenlandic oil importer Polaroil it has been possible to take the time-series on LPG all the way back to 1990 causing minor revisions in this inventory.

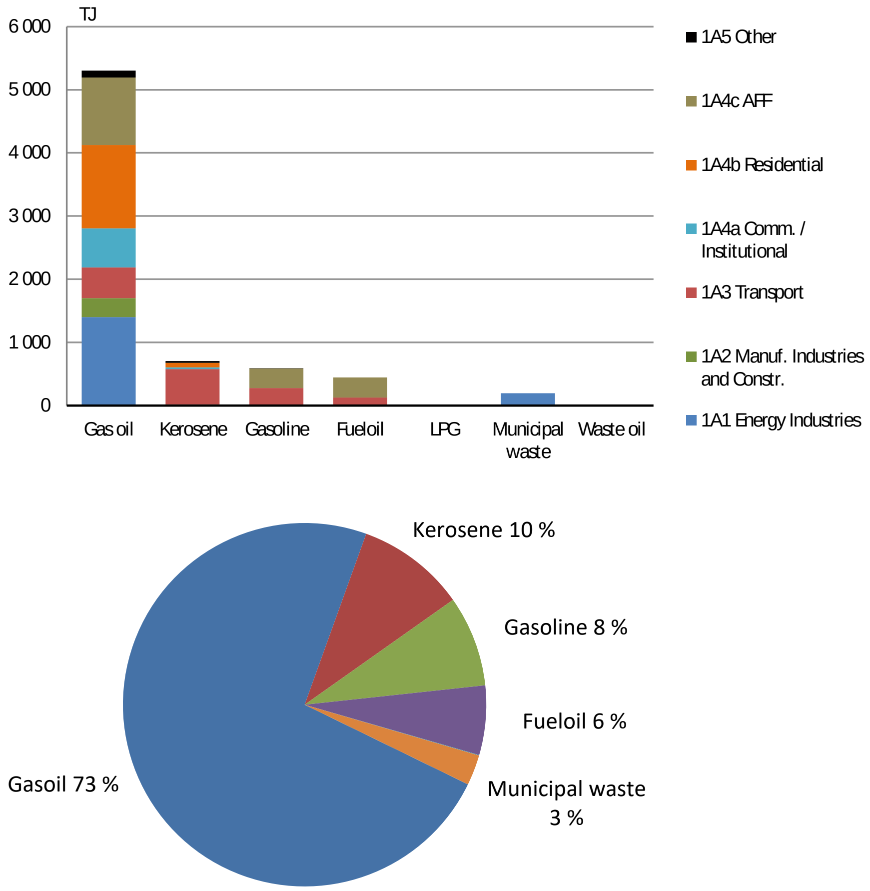

Figure 16.3.2 Fuel combustion, 2015 (Statistics Greenland).

Time-series on fuel consumption are presented in Figure 16.3.3. Total fuel consumption has decreased by 15.5 % from 1990 to 2015. This overall decrease in fuel consumption is caused by a drop in the consumption of liquid fossil by 17.3 %. Consumption of renewable waste-energy has increased continuously with a total increase of more than 300 % from 1990 to 2015. The dropping fuel consumption in 2011-2014 was caused by an overall recession in the Greenlandic economy and the continuous substitution of liquid fuel with waterpowered electricity in the energy sector. In 2015 fuel consumptions increased by 0.6 % due to a recovery in the Greenlandic economy.

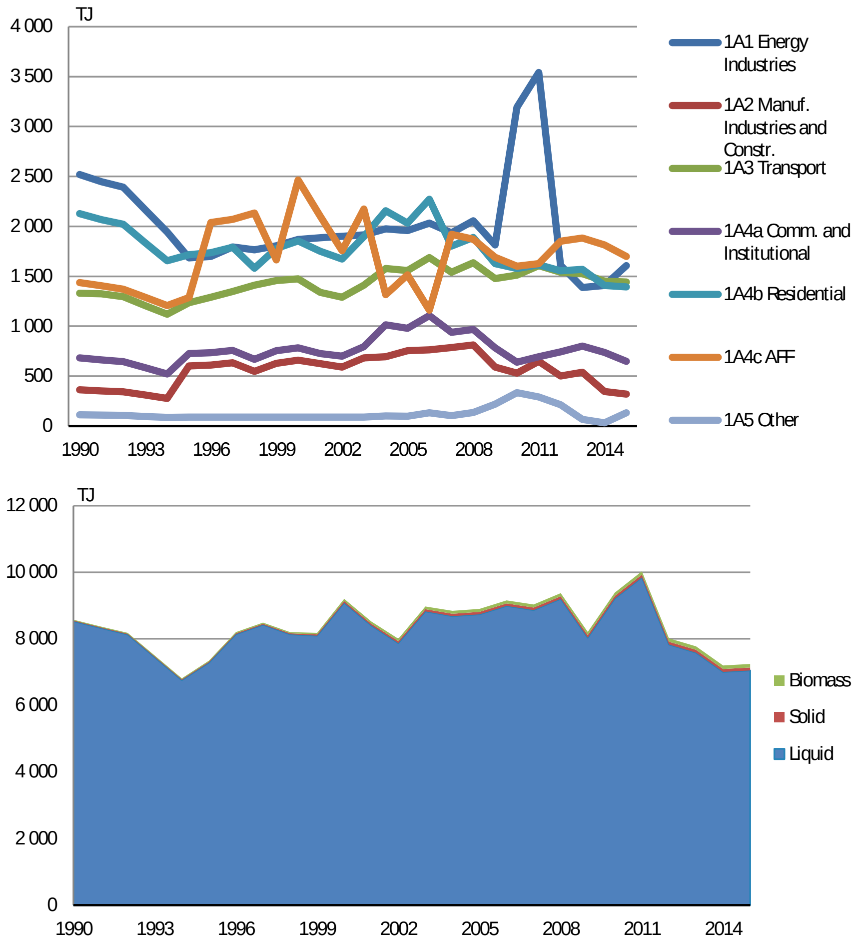

Figure 16.3.3 Fuel consumption time-series 1990-2015 (Statistics Greenland).

Fuel consumption is dominated by liquid fuels e.g. gasoil, kerosene and gasoline. In 2015, total fuel consumption consists of 97.3 % liquid fuels, 1.2 % solid fuels and 1.5 % biomass.

In 2015, Energy Industries accounted for 22 % 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 2012-2014, fuel consumption decreased once again due to a standstill in the oil exploration, the opening of the fifth hydro power plant and a general recession in the Greenlandic economy. This all changed in 2015 when the economy recovered causing fuel consumptions in Energy Industries to increase as well.

Fuel consumption regarding Agriculture, Forestry and Fisheries (AFF) accounted for 23 % of total fuel sonsumption in 2015 making AFF the largest energy consuming sector. Before 2004, time-series on 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.

Fuel consumption concerning Transportation accounted for 20 % of total fuel consumption in 2015 making AFF the third largest energy consuming sector.

Residential fuel consumption accounted for 19 % of total fuel consumption in 2015. 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 2004-2015, Statistics Greenland has conducted statistics on energy including detailed information on fuel consumption in businesses 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 coalmines, 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 Scottish company initiated a search for oil along the westcoast of Greenland. Three wells were drilled and tested in 2010. Five wells in 2011. There has been no drilling activitiy since 2011.

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. As from the 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 Scottish 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 Scottish 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 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

Currently 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.

Next, total domestic fuel combustion is divided into business 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 47.5 % of total GHG emission from energy combustion in 2015, see Table 16.3.4.

By using detailed information on sales from Polaroil and local fuel distributors it is possible to determine fuel combustion in private businesses and public offices with an automatic deal on supply. Sales data covered 11.2 % of total GHG emission from energy combustion in 2015, see Table 16.3.4.

Tax accountings in DKK are used to determine annual consumption of fuel in private businesses, 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 16.9 % of total GHG emission from energy combustion in 2015, see Table 16.3.4.

The remaining amount of total inland fuel combustion 24.4 % - 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 2008-2016. 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 (2006-2015).

	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
					Pct.					
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Survey	47.9	49.6	50.3	52.8	63.0	61.3	53.2	52.2	44.8	47.5
Sales data from Polaroil	3.7	3.6	3.4	3.0	4.2	5.0	5.7	6.3	6.8	7.0
Sales data from local fuel distributors	3.2	5.1	6.6	6.5	5.0	5.6	6.1	5.2	4.6	4.2
Accountings	12.9	12.8	12.2	12.7	10.8	11.0	13.1	15.4	15.6	16.9
Estimation	32.3	29.0	27.5	25.0	17.0	17.0	21.8	21.0	28.3	24.4

The procedure described above is used to determine fuel combustion in sectors and private households during the period 2004-2015. 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 1990-2015.

Table 16.3.5 Activity data on fuel combustion (SINK categories).

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
					TJ					
Total	8 572	8 370	8 179	7 496	6 812	7 342	8 201	8 486	8 201	8 178
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	363	353	344	311	278	601	610	633	549	628
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	683	663	647	584	521	726	734	759	669	754
Residential	2 127	2 068	2 020	1 838	1 657	1 716	1 737	1 792	1 581	1 780
AFF	1 437	1 406	1 372	1 289	1 206	1 288	2 040	2 071	2 134	1 664
Other	113	110	107	97	86	91	91	91	91	91
continued	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Total	9 199	8 521	8 002	8 970	8 840	8 898	9 153	9 031	9 371	8 207
Energy industries	1 868	1 885	1 900	1 915	1 972	1 955	2 028	1 928	2 045	1 795
Manufacturing industries and construction	660	626	592	682	700	758	768	794	825	610
Domestic aviation	738	632	603	646	608	633	691	701	753	635
Road transport	417	399	388	433	508	504	575	504	535	493
Domestic navigation	321	308	297	334	464	420	421	334	347	350
Commercial/Institutional	784	726	700	797	1 014	979	1 107	939	969	784
Residential	1 854	1 751	1 674	1 899	2 155	2 032	2 271	1 804	1 888	1 628
AFF	2 466	2 101	1 756	2 174	1 317	1 516	1 161	1 921	1 871	1 691
Other	91	91	91	91	103	100	132	105	138	219
continued	2010	2011	2012	2013	2014	2015				
Total	9 387	10 026	8 014	7 773	7 199	7 244				
Energy industries	1 551	1 522	1 578	1 343	1 379	1 566				
Manufacturing and construction	2 173	2 669	532	583	375	361				
Domestic aviation	654	723	660	593	555	560				
Road transport	478	479	469	462	434	427				
National navigation	378	405	413	471	463	457				
Commercial/Institutional	641	694	742	800	737	648				
Residential	1 577	1 615	1 554	1 570	1 408	1 394				
AFF	1 600	1 628	1 851	1 883	1 814	1 698				
Other	335	292	215	67	33	134				

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 1990-2015.

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*. 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 1990-2015.

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 was revised in the 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 1990-2015 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 1990-2015.

		Liquid fuel						Biomass	Other fuel
CRF sector		Gasoil	Kerosene	Gasoline	Fuel-oil	LPG	Wasteoil	Municipal waste	
		g CH_4 per GJ							
1A1	Energy Industries	3	3	3	3	1	3	30	30
1A2	Manufacturing Industries and Construction	2	2	2	2	5	-	-	-
1A3a	Transport - Domestic aviation	0.5	0.5	0.5	0.5	-	-	-	-
1A3b	Transport - Road transportation	3.9	20	25	5	50	-	-	-
1A3d	Transport - Domestic navigation	5	5	5	5	-	-	-	-
1A4a	Other sectors - Commercial, Institutional	10	10	10	10	5	-	-	-
1A4b	Other sectors - Residential	10	10	10	10	5	-	-	-
1A4c	Other sectors - AFF stationary	10	10	10	10	5	-	-	-
1A4c	Other sectors - AFF mobile	5	5	5	5	5	-	-	-
1A5b	Other - Military mobile	5	5	5	5	-	-	-	-

Source:
- IPCC Guidelines 2006: Gasoil, kerosene, gasoline, fueloil, LPG and waste oil.
- Nielsen et al. (2010): Biomass and other fuel, both municipal waste.

N_2O

The N_2O emission factors applied for 1990-2015 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 1990-2015.

		Liquid fuel						Biomass	Other fuel
CRF sector		Gasoil	Kerosene	Gasoline	Fueloil	LPG	Wasteoil	Municipal waste	
		g N_2O per GJ							
1A1	Energy Industries	0.6	0.6	0.6	0.6	0.1	0.6	4	4
1A2	Manufacturing Industries and Construction	0.6	0.6	0.6	0.6	0.1	-	-	-
1A3a	Transport - Domestic aviation	2	2	2	2	-	-	-	-
1A3b	Transport - Road transportation	3.9	0.6	8	0.6	0.1	-	-	-
1A3d	Transport - Domestic navigation	0.6	0.6	0.6	0.6	-	-	-	-
1A4a	Other sectors	0.6	0.6	0.6	0.6	0.1	-	-	-
1A5b	Other - Military mobile	0.6	0.6	0.6	0.6	0.1	-	-	-

Source:
- IPCC Guidelines 2006: Gasoil, kerosene, gasoline, fueloil, LPG and waste oil.
- Nielsen et al. (2010): Biomass and other fuel, both municipal waste.

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 1990-2015.

Table 16.3.9 SO_2, NO_X, NMVOC and CO emission factors 1990-2015 (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 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 94.0 % of total Greenlandic GHG emission in 2015.

CO_2 emission from energy accounts for 99.3 % 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 8.7 % of the Greenlandic emission and the N_2O emission from fuel combustion accounts for 24.9 % of the Greenlandic N_2O emission, see Table 16.3.10.

Table 16.3.10 Greenhouse gas emission 2015.

		CO_2	CH_4	N_2O
		Gg CO_2 equivalent		
1A1	Fuel consumption, Energy Industries	110.1	0.3	0.5
1A2	Fuel consumption, Manufacturing Industries and Construction	23.4	0.0	0.1
1A3	Fuel consumption, Transport	104.1	0.2	1.1
1A4	Fuel consumption, Other sectors	282.7	0.7	0.7
1B	Fugitive emissions from fuel, Oil and natural gas	NO	NO	NO
Total emission from energy		520.4	1.2	2.4
Greenlandic emission (excluding net emission from LULUCF)		523.9	13.9	9.5
			%	
Emission share for energy		99.3	8.7	24.9

CO_2 is the most important GHG pollutant and accounts for 99.3 % of the GHG emission in CO_2 equivalents from energy in 2015, see Figure 16.3.4.

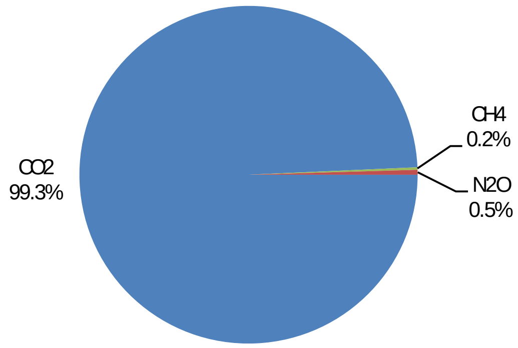

Figure 16.3.4 GHG emissions (CO_2 equivalent) from stationary combustion plants 2015.

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 16.8 % and 16.7 % lower in 2015 compared to 1990.

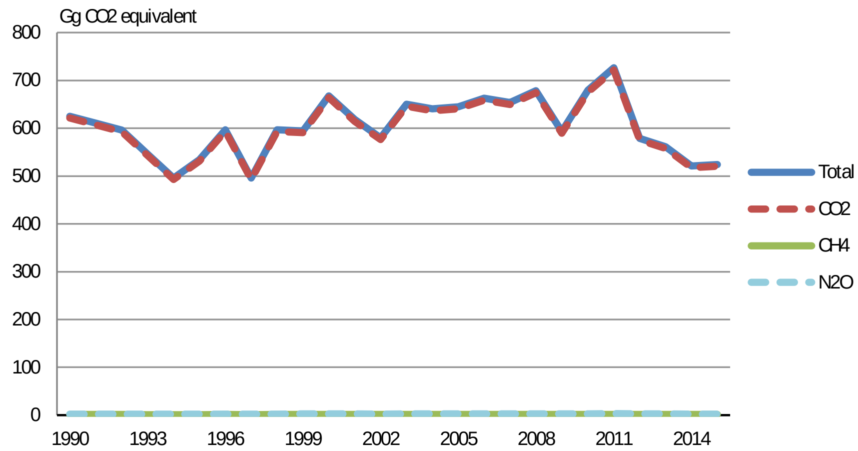

Figure 16.3.5 GHG emission time-series for the Energy Sector.

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 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 more recent years, 2012-2014 GHG emission has decreased by 20.3 %, 3.0 % and 7.3 % respectively due to the standstill in the oil exploration activities, a drop in fuel combustion in Energy Industries due to the opening of Greenlands fifth hydro power plant, and the overall recession in the Greenlandic economy. In 2015, GHG emission increased once again by 0.6 percent due to an increase in fuel combustion caused by a recovering Greenlandic economy.

CO_2

CO_2 emission from fuel combustion accounts for 99.3 % of the total Greenlandic CO_2 emission. Table 16.3.11 lists the CO_2 emission inventory for the energy sector in 2015 as well as the relative percentage for each category under the sectoral approach.

The table reveals that Agriculture, Forestry and Fisheries (AFF) accounts for 23.9 % of the CO_2 emission. Other large CO_2 emission sources are Energy Industries with a share of 21.2 % and Transport with 20.0 % as well as Residential with a share of 19.5 %. These are sectors, which also account for a considerable share of fuel consumption.

Table 16.3.11 Emission of CO_2 from fuel combustion 2015.

		2015	
		Gg	%
1A1	Energy Industries	110.1	21.2
1A2	Manufacturing Industries	23.4	4.5
1A3	Transport	104.1	20.0
1A4a	Commercial / Institutional	47.2	9.1
1A4b	Residential	101.6	19.5
1A4c	Agriculture / Forestry / Fisheries	124.2	23.9
1A5	Other	9.7	1.9
1B	Fugitive emissions from fuel	NO	NO
1C	CO_2 Transport and Storage	NO	NO
Total		520.4	100.0

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 2015, the CO_2 emission from biomass combustion was 14.7 Gg.

Time-series for CO_2 emissions are provided in Figure 16.3.6. Since 1990, emission of CO_2 has decreased by 10.3 %. 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". Since 2011, there has been no drilling for oil in Greenland.

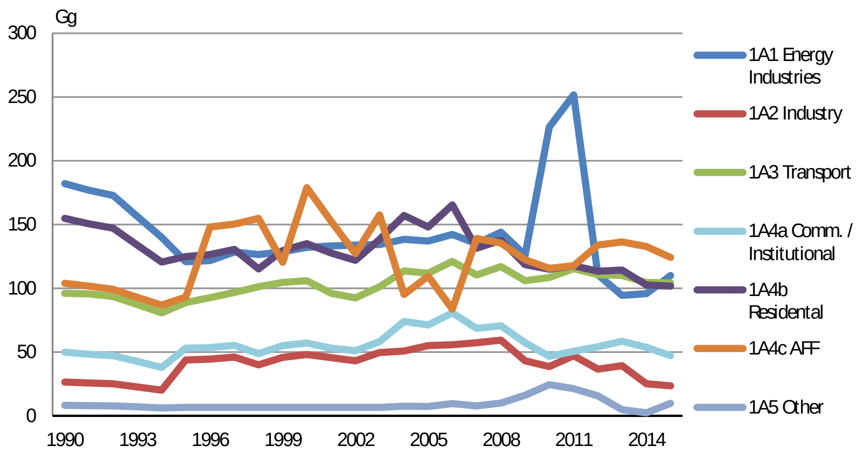

Figure 16.3.6 CO_2 Emission time-series for Fuel Combustion (Sectoral Approach).

Detailed trend discussion on CRF category level is available in Section 16.2.

CH_4

CH_4 emission from fuel combustion accounts for 8.7 % of the Greenlandic CH_4 emission. Table 16.3.12 lists the CH_4 emission inventory for energy in 2015. The table reveals that residental plants accounted for 28.8 % of the CH_4 emission from energy in 2015. Energy Industries accounted for 20.9 % of the emission in 2015, and Agriculture, Forestry and Fisheries for 17.6 %.

Table 16.3.12 Emission of CH_4 from fuel combustion 2015.

		2015	
		Mg	%
1A1	Energy Industries	10.1	20.9
1A2	Industry	0.6	1.3
1A3	Transport	8.0	16.5
1A4a	Commercial / Institutional	6.5	13.4
1A4b	Residential	13.9	28.8
1A4c	Agriculture / Forestry / Fisheries	8.5	17.6
1A5	Other	0.7	1.4
1B	Fugitive emissions from fuel	NO	NO
Total		48.3	100.0

Emission of CH_4 from fuel combustion has decreased by 3.0 % since 1990. 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.

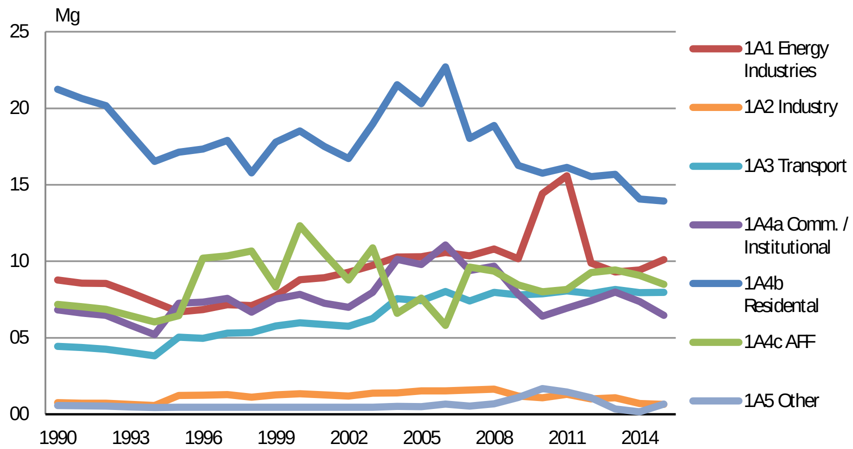

Figure 16.3.7 CH_4 emission time-series for energy.

Detailed trend discussion on CRF category level is available in Section 16.2.

N_2O

Emission of N_2O from fuel combustion accounts for 24.9 % of the Greenlandic N_2O emission. Table 16.3.13 lists the N_2O emission inventory for energy in 2015. The table reveals that Transportations accounted for 47.7 % of the N_2O emission from the energy sector while Energy Industries accounted for 20.6 % of the emissions in 2015.

Table 16.3.13 Emission of N_2O from fuel combustion 2015.

		2015	
		Mg	%
1A1	Energy Industries	1.6	20.6
1A2	Industry	0.2	2.4
1A3	Transport	3.8	47.7
1A4a	Commercial / Institutional	0.4	4.9
1A4b	Residential	0.8	10.5
1A4c	Agriculture / Forestry / Fisheries	1.0	12.8
1A5	Other	0.1	1.0
1B	Fugitive emissions from fuel	NO	NO
Total		7.9	100.0

Figure 16.3.8 shows the time-series for the N_2O emission from energy. N_2O emission has increased by 1.0 % from 1990 to 2015 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.

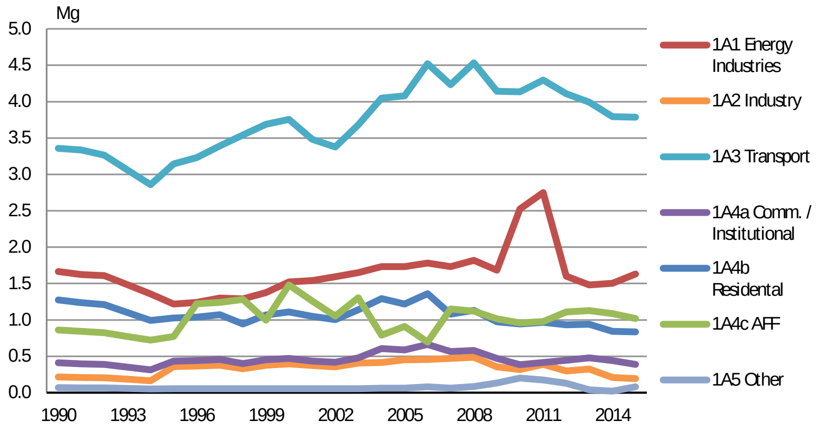

Figure 16.3.8 N_2O emission time-series for energy.

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 2015 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 %, 86.4 % and 86.5 % respectively, of the Greenlandic emissions for these substances.

Table 16.3.14 Emission of SO_2, NO_X, NMVOC and CO from fuel combustion 2015.

	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	0.0
1A3 Fuel consumption, Transport	1.2	2.2	0.4	0.2
1A4 Fuel consumption, Other sectors	2.4	1.9	0.4	0.6
1B Fugitive emissions from fuel	NO	NO	NO	NO
Total emission from fuel consumption and fugitive emissions from fuel	4.0	4.1	0.8	1.0
Greenlandic emission	4.0	4.7	0.9	1.0
		%		
Emission share for fuel consumption	99.0	86.4	86.5	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

With regard to uncertainty, the CO_2 emission factors are considered the most certain. Due to a technical analysis a country specific emission factor is 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 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 since. 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 1990-2015 %	Trend uncertainty %
GHG	± 4.1	-16.2	± 3.5
CO_2	± 3.6	-16.3	± 3.5
CH_4	± 88	-3.0	± 11.8
N_2O	± 451	1.0	± 42.7

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 on 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 2015, fuel consumption rates in the two approaches differ by 0 % and the CO_2 emission differs by 0.1 %. In the period 1990-2015, the CO_2 emission differs by 0.1 % 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.

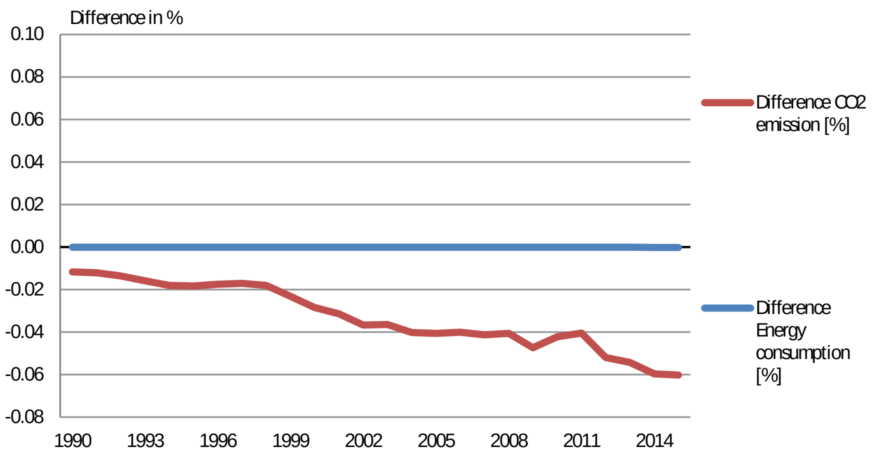

Figure 16.3.9 Comparison of the reference approach and the national approach.

16.3.7 Source specific recalculations and improvements

Improvements and recalculations since the 2016 emission inventory submission include:

- Update on fuel rates according to the latest energy statistics. The update includes the year 2015.
- Revised time-series on LPG now also covering the period 1990-2003.

Table 6.3.17 shows recalculations in the energy sector compared with the 2016 submission.

Table 16.3.17 Changes in GHG emission in the energy sector compared to the 2016 submission.

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Previous inventory, Gg CO_2 eqv.	624.4	609.6	595.4	545.2	494.9	533.5	596.4	617.1	595.8	593.9
Recalculated, Gg CO_2 eqv.	625.2	610.4	596.2	545.9	495.7	534.3	597.1	617.8	596.5	594.3
Change in Gg CO_2 eqv.	0.8	0.8	0.8	0.8	0.7	0.7	0.7	0.7	0.7	0.4
Change in pct.	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
continued	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Previous inventory, Gg CO_2 eqv.	667.6	617.8	579.4	649.8	640.5	644.6	663.1	653.9	678.7	593.3
Recalculated, Gg CO_2 eqv.	668.0	618.2	579.8	650.2	640.5	644.6	663.1	653.9	678.7	593.3
Change in Gg CO_2 eqv.	0.4	0.4	0.4	0.4	-	-	-	-	-	-
Change in pct.	0.1	0.1	0.1	0.1	-	-	-	-	-	-
continued	2010	2011	2012	2013	2014	2015				
Previous inventory, Gg CO_2 eqv.	679.6	726.3	578.9	561.6	520.9	-				
Recalculated, Gg CO_2 eqv.	679.6	726.3	578.9	561.6	520.9	524.0				
Change in Gg CO_2 eqv.	-	-	-	-	-	-				
Change in pct.	-	-	-	-	-	-				

16.3.8 Source specific planned improvements

Some planned improvements to the emission inventories are discussed below.

1) Memo Items, International Aviation Bunkers

Previously, emissions from international aviation bunkers have been considered to be of neglible importance in terms of Greenland. For that matter the annual amount of jet fuel loaded into foreign aircrafts has been included as part of the IPCC category 1A3a Domestic Aviation. However, some misunderstanding has taken place and this assumption seems to be incorrect! New data has emerged regarding the distinction between domestic and international flights, and it now seems possible that combustion of jet fuel in international bound aircrafts taking off from Greenland can be determined and reported as international aviation bunkers as from the 2018 submission. However, in this 2017 submission jet fuel loaded into foreign aircrafts is still included as part of the IPCC category 1A3a Domestic Aviation.

2) 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.

3) 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.

4) 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.

5) 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. Due to this technical analysis, a new country specific emission factor on gas oil was implemented as from the 2014 submission. The arctic grade gas oil stands for 76 % of all liquid fuels in 2014.

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). This section also includes 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 eventually evaporates. A small fraction of the solvents 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 1990-2015 are summarised. The method is based on the detailed approach described in EMEP/CORINAIR (2013) 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 2015. Emissions are extracted from the CRF tables.

Table 16.4.1 Overview of greenhouse gas sources 2015.

Process	IPCC Code	Substance	Emission tonnes CO_2 eqv.	%
Mineral Industry				
Limestone and Dolomite Use	2A4	CO_2	0.01	0.0
Non-Energy Products of Fuels and Solvent use				
Paraffin Wax Use	2D2	CO_2	101.37	1.0
Solvent Use	2D3	CO_2	214.31	2.0
Road Paving with Asphalt	2D3	CO_2	0.41	0.0
Asphalt Roofing	2D3	CO_2	0.04	0.0
Product uses as substitutes for ODS				
Refrigeration and Air Conditioning Equipment	2F1	HFCs	10 176.18	97.0
Other product manufacture and use				
Electrical Equipment	2G	SF_6	2.68	0.0
Total emission			10 495.00	100.0

The subsector *Product uses as substitutes for ODS* (2F) constitutes 97.0 % 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 3.0 % of the industrial emission of greenhouse gases. In this subsector, we find emissions from paraffin wax use and solvents as well as road paving with asphalt and asphalt roofing.

The total emission of greenhouse gases (excl. LULUCF) in Greenland is estimated to 557.4 Gg CO_2 equivalents in 2015, of which industrial processes contribute with 10.495 Gg CO_2 equivalents (1.9 %). The emission of greenhouse gases from industrial processes from 1990-2015 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.

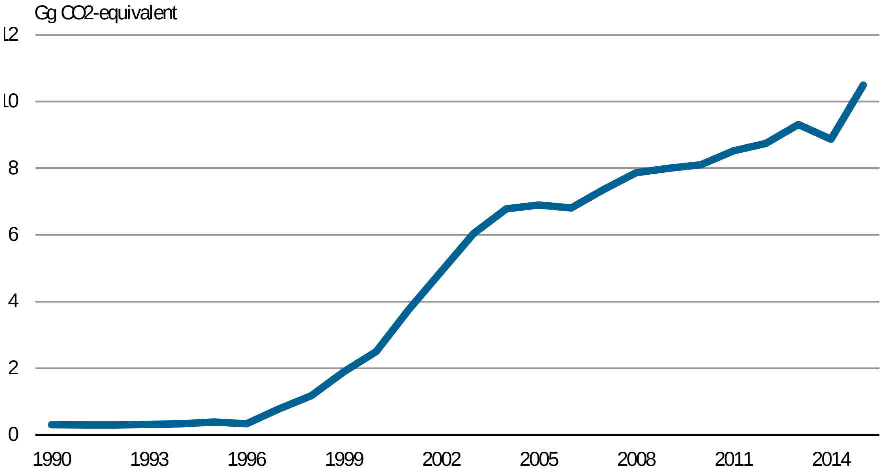

Figure 16.4.1 Emission of greenhouse gases from industrial processes 1990-2015.

The key category in the industrial sector *Consumption of Halocarbons* constitutes 1.8 % of the total emission of greenhouse gases. The trends in greenhouse gases from the industrial sector andsubsectors are presented in Table 16.4.2. The emissions are extracted from the CRF tables.

Table 16.4.2 Emission of GHG from industrial processes and product use in different subsectors from 1990-2015.

	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	475	421	489	354	354	355	453
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	2014	2015				
CO_2 (tonnes CO_2)										
A. Mineral Industry	4.94	0.00	19.57	0.00	6.64	0.01				
D. Non-energy products from fuels and solvent use	329	334	352	316	330	316				
CH_4	NO	NO	NO	NO	NO	NO				
N_2O	NO	NO	NO	NO	NO	NO				
HFCs (tonnes CO_2 eqv.)										
F. Product uses as ODS substitutes	7 770	8 180	8 373	8 993	8 525	10 176				
PFCs (tonnes CO_2 eqv.)										
F. Product uses as ODS substitutes	NO	NO	NO	NO	NO	NO				
SF_6 (tonnes CO_2 eqv.)										
G. Other product manufacture and use	2.8	2.8	2.8	2.7	2.7	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 1996-2015.

In December 2015 Statistics Greenland aqquired the following information from Nukissiorfiit; the main supplier of electricity and heat in Greenland:

Acording to Nukissiorfiit the switchgears in all netstations were changed from regular switches without gas to gaseous switches containing SF_6 in 2002-2004. The new gaseous switchgears from Spanish Ormazabal are closed and sealed switches that do not need any filling of gas. For that reason, the switchgears are considered to be complete tight with no leeks of gas. When Nukissiorfiit replace the gaseous Ormazabal switches, the switchgears are returned directly to Ormazabal in Spain where the SF_6 within the switch are recycled.

Due to this new information the Greenlandic switchgears in plants and netstations containing SF_6 are considered to be completely free from leeks from 2005 an onwards. This consideration is supported by the fact that Nukissiorfiit has not been buying any SF_6 for stockpiling or filling for many years and today has no record of any SF_6 in stock at all.

However, for the sake of good practice it has been decided to keep the SF_6-plant from 1995 within this material for 25 full years, which in 1995 was considered to be the lifetime of that specific switchgear. Due to that decision, the plant and the estimated emission of SF_6 from that plant will be left in the material until 2020. From 2021, the plant will be deleted from the material as well as all emission from it. We hope that the UNFCCC team of reviewer will approve to this decision.

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.

Emission 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 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	2014	2015				
4d Limestone and dolomite use	4.94	0.00	19.57	0.00	6.64	0.01				

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.

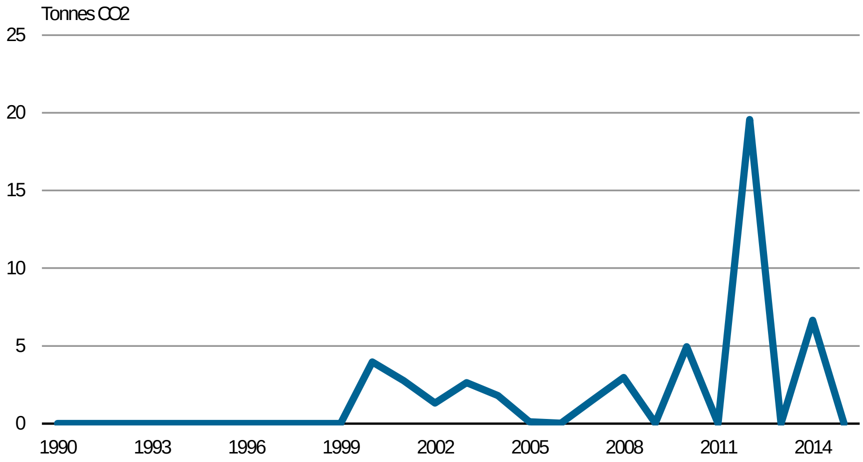

Figure 16.4.2 Emission of CO_2 from Mineral Industry.

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 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	339.9
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	452.8
continued	2010	2011	2012	2013	2014	2015				
2. Paraffin Wax Use	115.8	110.8	120.3	91.3	97.1	101.4				
3a. Solvent Use	213.4	223.3	231.2	224.9	232.6	214.3				
3b. Asphalt roofing	0.1	0.3	0.1	0.2	0.1	0.4				
3c. Road paving	0.1	0.0	0.0	0.0	0.0	0.0				
Total	329.4	334.4	351.6	316.4	329.9	316.1				

In 2015, the most significant CO_2 emission came from the use of solvents, which constituted 67.8 % of total CO_2 emission from *Non-energy Products from Fuels and Solvent Use* that year. Emission of CO_2 from paraffin wax use accounted for 32.1 % of total CO_2 emission from this subsector in 2015, while CO_2 emission from asphalt roofing and road paving constituted 0.1 and less in 2015.

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.

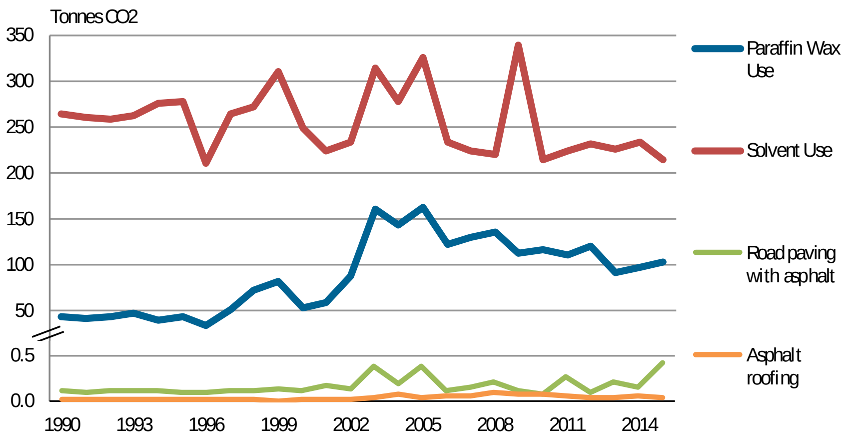

Figure 16.4.3 Emission of CO_2 from Non-energy Products from Fuels and Solvent Use.

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 1990-1994 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	2014	2015				
HFC32	0.01	0.01	0.01	0.01	0.01	0.01				
HFC125	0.80	0.84	0.87	0.94	0.90	1.11				
HFC134a	0.62	0.63	0.59	0.56	0.47	0.43				
HFC143a	0.91	0.97	1.00	1.09	1.05	1.27				
Unspecified HFCs	0.00	0.00	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.

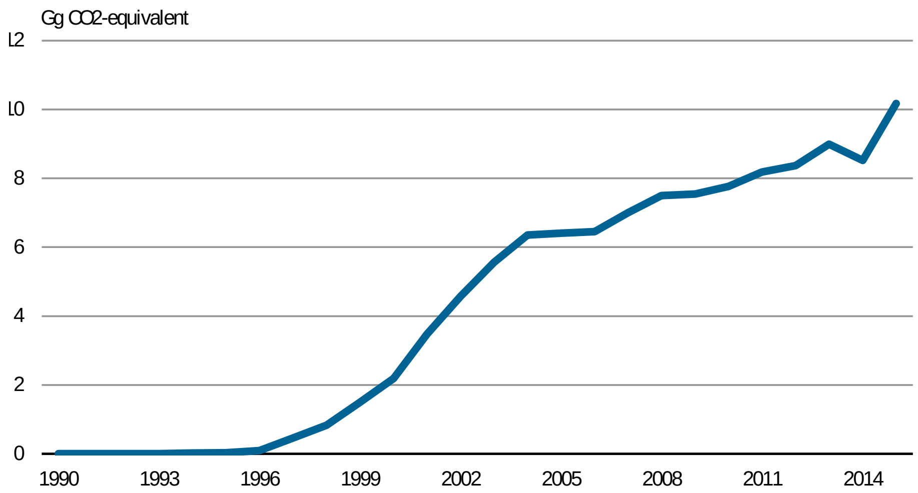

Figure 16.4.4 Emission of HFCs (from refrigeration).

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 1990-1994 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	2014	2015				
SF_6	0.12	0.12	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 2015, the emission of SF_6 was 0.12 kg. Emission of SF_6 from electrical equipment is shown in Figur 16.4.5.

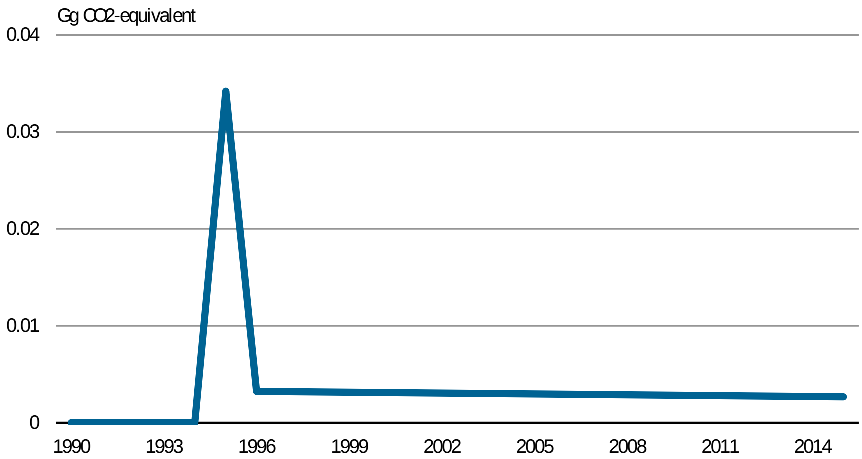

Figure 16.4.5 Emission of SF_6 (from electrical equipment).

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	2014	2015				
HFCs	7 770	8 180	8 373	8 993	8 525	10 176				
SF_6	2.8	2.8	2.8	2.7	2.7	2.7				

HFCs is by far the most dominant group among the F-gases. HFCs constitute a key category with regard to both 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, 2013). 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 (2016b).

Production of beer including a fermentation process has taken place at the brewery "Godthåb Bryghus" since 2005 (Godthåb Bryghus, 2016). 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 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	64 480	67 787	60 665	62 248	67 250	63 753
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	329
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	2014	2015				Source
Mineral Industry										
2A4d Limestone and dolomite use (t)	11	0	45	0	15	0				1
Non-energy Products from Fuels and Solvent Use										
2D2 Paraffin wax use (t)	234	224	243	185	197	205				1
2D3a Solvent use (t)	225	234	299	275	292	244				1
2D3b Road paving with asphalt (t)	443	1 529	583	1 200	824	2 445				1
2D3c Asphalt roofing (t)	256	173	142	160	191	144				1
Other Production, Food and Beverage Industry										
2H2 Beans roasted to produce coffee (t)	0	0	1	3	1	1				2
2H2 Production of bread (t)	790	584	563	567	606	985				2
2H2 Landings of fish and seafood (t)	97 955	104 020	105 506	102 677	104 615	104 179				3
2H2 Production of beer (hl)	2 010	2 115	2 080	1 985	1 628	1 800				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 activitydata on HFCs and SF_6 are obtained by annual registrations on import and export of HFCs and SF_6, and by annual surveys among importers, wholesalers and suppliers as well as consumers of HFCs and SF_6. This means that the obtaining of acitvitydata 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, 2016a):

- 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 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	2014	2015				
HFC-134										
Domestic	-	-	-	-	-	-				
Commercial and Industry	484	340	207	0	178	134				
Transport	-	-	-	-	-	-				
HFC-404a										
Commercial and Industry	2 993	2 687	4 596	2 300	3 909	4 157				
Transport	205	205	479	146	345	512				
HFC-407c										
Commercial and Industry	-	90	45	-	-	33				
HFC-507a										
Transport	-	180	-	45	2 160	270				
Unspecified HFCs										
Commercial and Industry	576	600	35	10	40	20				
SF_6										
Electrical Equipment	-	-	-	-	-	-				

Source: Statistics Greenland (2016a)

Emission factors

The CO_2 emission factors applied for products in 2015 are presented in Table 16.4.11. The same emission factor has been applied for 1990-2015.

Table 16.4.11 CO_2 emission factors 2015.

Product	Emission factor	Unit	Reference	IPCC Category
Limestone and dolomite use	440	kg pr tonne	IPCC, 1997	2A4d
Paraffin wax use	494	kg pr tonne	IPCC, 1997	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 2015 are presented in Table 16.4.12. The same emission factor has been applied for 1990-2015.

Table 16.4.12 CO emission factors 2015.

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 2015 are presented in Table 16.4.13. The same emission factor has been applied for 1990-2015.

Table 16.4.13 NMVOC emission factors 2015.

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 1.9 % 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 2015.

		CO_2	HFC	SF_6
		Tonne CO_2 equivalent		
2A4	Limestone and Dolomite Use	0.01	NA	NA
2D2	Paraffin Wax Use	101.37	NA	NA
2D3	Solvent use	214.31	NA	NA
2D3	Road paving with asphalt	0.41	NA	NA
2D3	Asphalt roofing	0.04	NA	NA
2F1	Refrigeration and air conditioning	NA	10 176	NA
2G1	Electrical Equipment	NA	NA	2.7
Total emission from industrial processes and product use		316.14	10 176	2.7
Greenlandic emission (excluding net emission from LULUCF)		523 861	10 176	2.7
			%	
Emission share for industrial processes and product use		0.06	100.0	100.0

HFC is the most important GHG pollutant and accounts for 97.0 % 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 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 solvents, i.e. 2008, 2010 and onwards, CO_2 emission from solvent use are also on a lower lever.

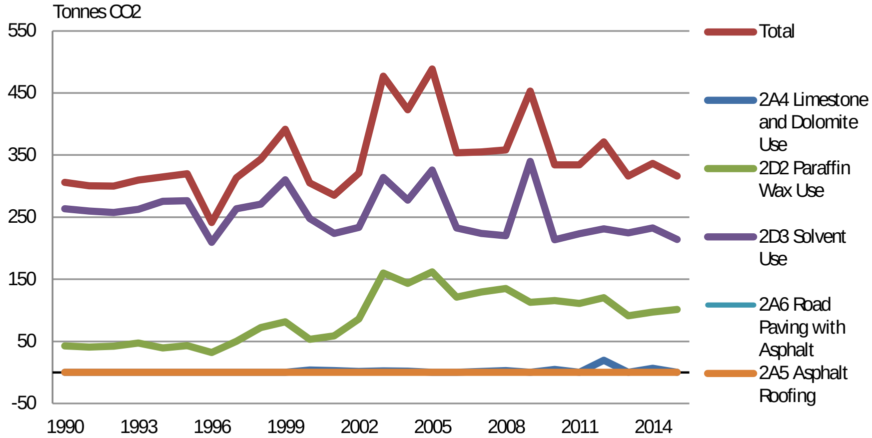

Figure 16.4.6 Emission of CO_2 from industrial processes and product use.

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 2015 are presented in Table 16.4.15. NMVOC and CO account for 11.39 % and 0.004 % respectively, of the Greenlandic emissions for these substances.

Table 16.4.15 NMVOC and CO emission from industrial processes 2015.

		NMVOC	CO
		Tonnes	
2D3	Solvent Use	68.70	NA
2D3	Asphalt Roofing	0.01	0.00
2D3	Road Paving with Asphalt	0.04	0.18
2H2	Food and beverages industry	39.25	NA
Total emission from industrial processes and product use		107.99	0.18
Greenlandic emission		947.91	4 717.01
		%	
Emission share for industrial processes and product use		11.39	0.004

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. Thus, 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 %.

With regard to 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 propose an uncertainty of 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 1990-2015[1] %	Trend uncertainty %
GHG	± 49	2 758	± 1 435
CO_2	± 19	3.3	± 8.6
HFC	± 51	37 637	± 5 337
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

In this 2017 submission there has been no revisions in the sector on industrial processes and product use.

Table 16.3.18 shows recalculations in the waste sector compared to the 2016 submission. No changes occur.

Table 16.3.18 Changes in GHG emission in Industrial Processes and Product Use compared to the 2016 submission.

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Previous inventory, Gg CO_2 eqv.	0.3	0.3	0.3	0.3	0.3	0.4	0.3	0.8	1.2	1.9
Recalculated, Gg CO_2 eqv.	0.3	0.3	0.3	0.3	0.3	0.4	0.3	0.8	1.2	1.9
Change in Gg CO_2 eqv.	-	-	-	-	-	-	-	-	-	-
Change in pct.	-	-	-	-	-	-	-	-	-	-
continued	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Previous inventory, Gg CO_2 eqv.	2.5	3.8	4.9	6.0	6.8	6.9	6.8	7.4	7.9	8.0
Recalculated, Gg CO_2 eqv.	2.5	3.8	4.9	6.0	6.8	6.9	6.8	7.4	7.9	8.0
Change in Gg CO_2 eqv.	-	-	-	-	-	-	-	-	-	-
Change in pct.	-	-	-	-	-	-	-	-	-	-
continued	2010	2011	2012	2013	2014	2015				
Previous inventory, Gg CO_2 eqv.	8.1	8.5	8.7	9.3	8.9	-				
Recalculated, Gg CO_2 eqv.	8.1	8.5	8.7	9.3	8.9	10.5				
Change in Gg CO_2 eqv.	-	-	-	-	-	-				
Change in pct.	-	-	-	-	-	-				

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, 2016a: Annual survey among importers, suppliers and consumers of F-gases in Greenland in 2015. Not published.

Statistics Greenland, 2016b: Foreign Trade, Import and Export. Available at: http://www.stat.gl/publ/da/IE/201601/pdf/Udenrigshandel%202015%20revideret%20version.pdf as "Grønlands udenrigshandel 2015" (21-10-2016).

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 1.5 % of the overall greenhouse gas emission (GHG) in 2015. From 1990 to 2015 emissions decreased from 9.50 Gg CO_2 equivalents to 8.54 Gg CO_2 equivalents, which correspond to a decrease of 10.1 %, 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 1990-2015 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	1.71	1.73	1.56	1.40	1.52	1.62	2.24	1.98	2.46	2.55
Total	9.50	9.58	8.62	7.60	8.28	8.89	9.72	10.17	10.26	9.61
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	2.27	2.33	2.19	2.23	2.38	2.49	2.52	2.22	3.27	2.41
Total	9.12	9.31	8.90	9.03	9.52	9.92	9.72	9.58	10.46	9.45
continued	2010	2011	2012	2013	2014	2015				
CH_4	7.22	7.07	7.03	6.99	6.61	6.22				
N_2O	2.37	2.59	2.45	2.41	2.54	2.32				
Total	9.59	9.66	9.48	9.41	9.14	8.54				

As showed in Figure 16.5.1, CH_4 emission contributed with 71 % of the total GHG emission from the agricultural sector in 2015. N_2O contributed with 18 %. 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.

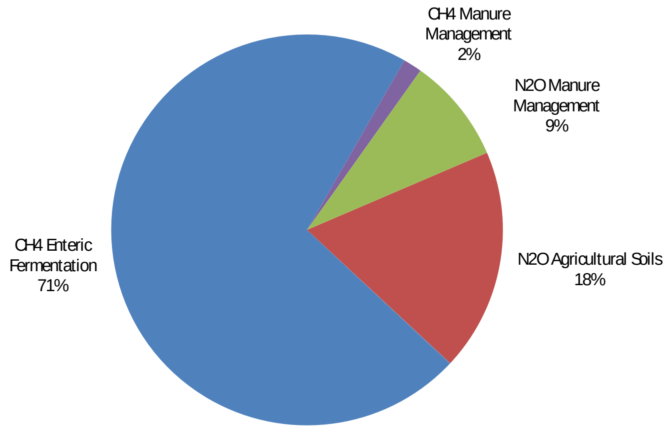

Figure 16.5.1 Emission of greenhouse gases from agriculture in 2015.

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	Abbreviation	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 2015, this source accounts for 71 % of the total GHG emission from agricultural activities. The emission is primarily related to ruminants, which in Greenland is sheep. In 2015 sheep contributed with 87 % and the remaining 13 % 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 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 1990-2015 (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	2014	2015				
Sheep	20 729	20 232	20 107	19 994	18 738	17 501				
Reindeer	3 000	3 000	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 2015, the emission has decreased by 20.1 % specifically due to a fall in number of reindeer but recently also a larger fall in the number of sheep.

Table 16.5.5 Emission of CH_4 from Enteric Fermentation 1990-2015, 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	2014	2015				
Sheep	251	245	243	242	227	212				
Reindeer	32	32	32	32	32	32				
Total, tonnes CH_4	283	277	275	274	259	244				
Total, tonnes CO_2 eqv.	7 067	6 917	6 879	6 845	6 465	6 091				

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 10.3 % of the total emission from the agricultural sector in 2015. 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 2015. 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 2015 by 20.7 % related to the fall in both the number of reindeer and sheep.

Table 16.5.7 Emission of CH_4 from Manure Management 1990-2015, 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	2014	2015				
Sheep	5.4	5.3	5.2	5.2	4.9	4.6				
Reindeer	0.8	0.8	0.8	0.8	0.8	0.8				
Total, tonnes CH_4	6.1	6.0	6.0	5.9	5.6	5.3				

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 decreased by 20.7 % from 1990 to 2015 (Table 16.5.8) due to a drop in the number of livestock.

Table 16.5.8 Total nitrogen excretion for sheep, 1990-2015, 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	2014	2015				
N-excreted, tonnes in total	142	139	138	137	130	122				
N-excretion, tonnes in stable	68	67	66	66	62	58				

Time-series consistency

As shown in Table 16.5.9, total emission from manure management has decreased by 15.3 % from 1990 to 2015 due to a decrease in the number of sheep and reindeer.

Table 16.5.9 Emissions of N_2O and CH_4 from Manure Management 1990-2015.

	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	2014	2015				
N_2O emission, tonnes CO_2 eqv.	878	857	852	848	796	745				
CH_4 emission, tonnes CO_2 eqv.	153	150	149	149	141	133				
Total, tonnes CO_2 eqv.	1 031	1 008	1 002	996	936	877				

16.5.5 N_2O emission from Agricultural Soils (CRF sector 3D)

Description

N_2O emissions from agricultural soils CRF Table 3.D contributed with 19.1 % of the total emission from the agricultural sector in 2015. Figure 16.5.2 shows the overall development from 1990 to 2015 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 2014, the use of inorganic fertilizer increased by of 26.3 % compared to 2013. The year after, in 2015 the use of inorganic fertilizers returned to the 2012-2013 level causing emissions to drop as well.

Emission from inorganic fertilizer and nitrogen leaching is an essential part of the total emission from agricultural soils and contributes totally with 55.2

%. Of the remaining sources the greatest part of the emission, by 17.9 %, origins from urine and dung deposited by grazing animals. Emissions from all sources have increased from 1990 to 2015 except from animal manure applied to soils and grassing animal both due to a fall in number of reindeer and sheep.

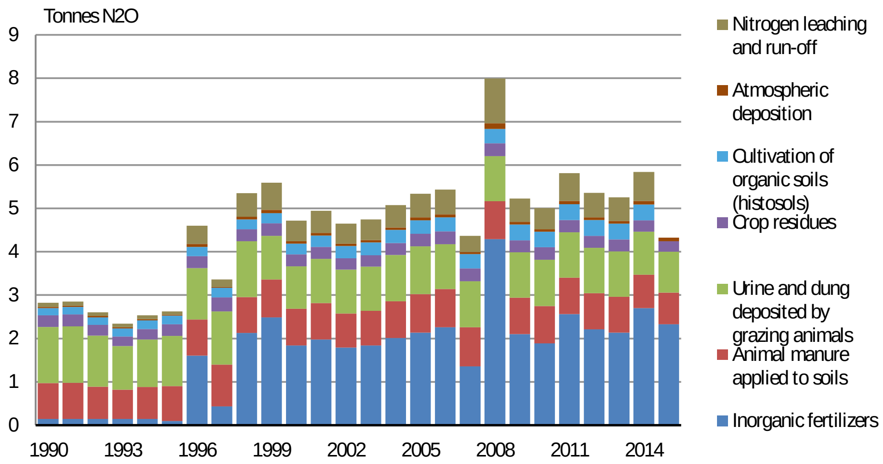

Figure 16.5.2 N_2O emissions from agricultural soils 1990-2015.

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 1990-2015.

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 in 2015. 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 Consumption of inorganic fertilizer 2015 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	1.6
Calcium ammonium nitrate	0.0370	3.70	NO
Anhydrous ammonia	0.0110	1.10	NO
Urea	0.2430	24.30	3.8
Nitrogen solutions	0.0481	4.81	NO
Ammonium phosphates	0.1130	11.30	NO
Other NK and NPK	0.0370	3.70	143.0
Total use of N in inorganic fertilizer			148.3
National emission of NH_3-N, tonnes	5.2		
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 2015, 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 0.16-0.20.

Table 16.5.12 FracGASF, 1990-2015.

	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	2014	2015				
FracGASF	0.03	0.03	0.03	0.03	0.03	0.03				

Table 16.5.13 shows a general increase in use of fertilizer and a particularl jump upwards 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.

Table 16.5.13 Nitrogen applied as fertilizer to agricultural soils 1990-2015.

	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	2014	2015				
N content in inorganic fertilizer, tonnes N	120	163	141	136	172	148				
NH_3-N emission, tonnes	4	5	4	4	5	5				
N in fertilizer applied on soil, tonnes N	116	158	136	132	166	143				
N_2O emission, tonnes	1.89	2.56	2.21	2.13	2.70	2.33				

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 1990-2015.

	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	2014	2015				
N-excretion in stable, tonnes N	68	67	66	66	62	58				
NH_3-N emission, tonnes N	14	13	13	13	12	12				
N in manure applied on soil, tonnes N	55	53	53	53	49	46				
N_2O emission, tonnes N_2O	0.86	0.84	0.83	0.83	0.78	0.73				

Crop residue

The cultivated area is approximately 1,106 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. Since 2012, the cultivated area has increased slightly. 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). In the 2016-submission the dry matter fraction (DRY) of harvested grass-clover was changed from former Danish DRY-factor 0.27 to the IPCC default DRY factor of 0.9.

Table 16.5.15 N-content in crop residues 2015.

	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	-	8.8	-	5.2	5	14.0	15 348
Total N from crop residue, kg							15 473

Reference: National data and IPCC 2006 (Table 11.2).

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 2015 (Table 16.5.16).

Table 16.5.16 Emission from crop residues 1990-2015.

Crop residue	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Potatoes, kg N	-	-	-	-	-	-	-	-	-	-
Grass-Clover, kg N	17 477	17 657	15 698	14 256	15 626	17 069	17 682	20 288	17 477	18 422
Crop residue total, kg N	17 477	17 657	15 698	14 256	15 626	17 069	17 682	20 288	17 477	18 422
N_2O emission, kg	275	277	247	224	246	268	278	319	275	289
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	17 929	17 885	16 633	16 889	17 875	18 694	18 670	19 034	18 486	17 661
Crop residue total, kg N	17 929	17 944	16 693	16 949	17 935	18 754	18 729	19 093	18 546	17 739
N_2O emission, kg	282	282	262	266	282	295	294	300	291	279
continued	2010	2011	2012	2013	2014	2015				
Potatoes, kg N	78	125	125	125	125	125				
Grass-Clover, kg N	18 179	17 743	17 633	17 534	16 432	15 348				
Crop residue total, kg N	18 256	17 868	17 759	17 659	16 558	15 473				
N_2O emission, kg	287	281	279	278	260	243				

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 2015. 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 2015 due an increase in the agricultural area.

Table 16.5.17 Activity data and emission from cultivation of histosols 1990-2015.

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	2014	2015				
Cultivated histosols, ha	268	270	268	270	272	277				
N_2O emission, kg	357	364	361	364	366	372				

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 and recently also sheep N_2O emission has decreased from 1990 to 2015.

Table 16.5.18 Emission from grassing animals 1990-2015.

	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	2014	2015				
N-excretion on grass, tonnes N	73	72	72	71	68	65				
NH_3-N emission, tonnes	5	5	5	5	5	5				
N deposited on grass, tonnes N	68	67	67	66	63	60				
N_2O emission, tonnes	1.07	1.05	1.05	1.04	0.99	0.94				

Indirect emissions

Atmospheric deposition

Atmospheric deposition includes ammonia emission from manure management, use of inorganic fertilizer and from grassing animals.

N_2O emission from atmospheric deposition has more than doubled from since 1990. Even though the number of reindeer and sheep has decreased, the increasing use of inorganic fertilizer has increased total N_2O emission from atmospheric deposition by 180.0 % from 1990 to 2015.

Table 16.5.19 Emission from atmospheric deposition 1990-2015.

	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	2014	2015				
NH_3-N manure management, tonnes	14	13	13	13	12	12				
NH_3-N inorganic fertlizer, tonnes	4	5	4	4	5	5				
NH_3-N pasture, tonnes	5	5	5	5	5	5				
NH_3-N total, tonnes	22	23	23	22	22	21				
N_2O emission, tonnes	0.06	0.08	0.07	0.08	0.08	0.08				

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).

N_2O emission from N-leaching and runoff more than doubled from 1990 to 2008. However, lately in 2009-2015 total N_2O emission has dropped to a 0.46-0.67 tonnes. In 2015, N_2O emission from N-leaching and runoff amounted to 0.58 tonnes, which is six times more than in 1990.

From 1990 to 2015 the total nitrogen content in manure has decreased due to a fall in the number of reindeer and sheep. 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 1990-2015.

	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	0.09	0.10	0.09	0.08	0.09	0.08	0.42	0.17	0.54	0.63
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	0.48	0.51	0.46	0.47	0.52	0.55	0.57	0.37	1.03	0.54
continued	2010	2011	2012	2013	2014	2015				
N-excretion total, tonnes N	142	139	138	137	130	122				
N in inorganic fertilizer, tonnes	120	163	141	136	172	148				
N_2O emission, tonnes	0.49	0.64	0.56	0.54	0.67	0.58				

Activity data

Table 16.5.21 provides an overview on activity data from 1990 to 2015 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 1990-2015, 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	17	18	16	14	16	17	18	20	17	18
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	8	8	7	7	7	7	36	14	46	53
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	18	18	17	17	18	19	19	19	19	18
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	40	43	39	40	44	46	49	32	88	45
continued	2010	2011	2012	2013	2014	2015				
A. Direct N_2O emissions from managed soils										
Inorganic fertilizer	120	163	141	136	172	148				
Animal manure applied to soils	55	53	53	53	49	46				
Urine and dung deposited by grazing animals	68	67	67	66	63	60				
Crop residue	18	18	18	18	17	15				
Cultivation of histosols	268	270	268	270	272	277				
B. Indirect N_2O emissions from managed soils										
Atmospheric deposition	4	5	4	4	5	5				
Nitrogen leaching and run-off	42	54	48	46	56	49				

Time-series consistency

N_2O emissions from agricultural soils have increased from 2.8 tonnes N_2O in 1990 to 5.3 tonnes N_2O in 2015. The increased is a consequence of a significant increase in use of nitrogen in inorganic fertilizer. However, lately in 2015 N_2O emissions from agricultural soils decreased slightly due to a drop in the use of inorganic fertilizer to the level in 2013.

Table 16.5.22 Emissions of N_2O from Agricultural Soils 1990–2015, tonnes N_2O.

CRF – Table 3.D	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Total N_2O emission	2.8	2.8	2.6	2.3	2.5	2.6	4.6	3.4	5.4	5.6
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	0.3	0.3	0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.3
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	0.4	0.2	0.5	0.6
continued	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Total N_2O emission	4.7	4.9	4.7	4.7	5.1	5.3	5.4	4.4	8.0	5.2
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	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
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	0.5	0.6	0.4	1.0	0.5
continued	2010	2011	2012	2013	2014	2015				
Total N_2O emission	5.0	5.8	5.4	5.3	5.8	5.3				
A. Direct N_2O emissions from managed soils										
Inorganic fertilizer	1.9	2.6	2.2	2.1	2.7	2.3				
Animal manure applied on soil	0.9	0.8	0.8	0.8	0.8	0.7				
Urine and dung deposited by grazing animals	1.1	1.1	1.0	1.0	1.0	0.9				
Crop residue	0.3	0.3	0.3	0.3	0.3	0.2				
Cultivation of histosols	0.4	0.4	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	0.1	0.1				
Nitrogen leaching and run-off	0.5	0.6	0.6	0.5	0.7	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 1990-2015 %	Trend uncertainty %
GHG	± 73	-10.2	± 13.7
CO_2	± 50	-50.0	± 3.5
CH_4	± 98	-20.1	± 11.1
N_2O	± 49	35.5	± 38.8

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

In this 2017 submission there has been no revisions in the agricultural sector.

Table 16.6.25 shows recalculations in the waste sector compared to the 2016 submission. No changes occur.

Table 16.6.25 Changes in GHG emission in the agricultural sector compared to the 2016 submission.

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Previous inventory, Gg CO_2 eqv.	9.5	9.6	8.6	7.6	8.3	8.9	9.7	10.2	10.3	9.6
Recalculated, Gg CO_2 eqv.	9.5	9.6	8.6	7.6	8.3	8.9	9.7	10.2	10.3	9.6
Change in Gg CO_2 eqv.	-	-	-	-	-	-	-	-	-	-
Change in pct.	-	-	-	-	-	-	-	-	-	-
continued	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Previous inventory, Gg CO_2 eqv.	9.1	9.3	8.9	9.0	9.5	9.9	9.7	9.6	10.5	9.5
Recalculated, Gg CO_2 eqv.	9.1	9.3	8.9	9.0	9.5	9.9	9.7	9.6	10.5	9.5
Change in Gg CO_2 eqv.	-	-	-	-	-	-	-	-	-	-
Change in pct.	-	-	-	-	-	-	-	-	-	-
continued	2010	2011	2012	2013	2014	2015				
Previous inventory, Gg CO_2 eqv.	9.6	9.7	9.5	9.4	9.1	-				
Recalculated, Gg CO_2 eqv.	9.6	9.7	9.5	9.4	9.1	8.5				
Change in Gg CO_2 eqv.	-	-	-	-	-	-				
Change in pct.	-	-	-	-	-	-				

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.

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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 2016 was 55 847 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 218.5 hectares and 10.5 hectares with Cropland. Grassland is divided into improved Grassland covering 1096 hectares and unimproved Grassland covering 240 894 hectares. Wetlands consist of man made water reservoirs – in total 1076 hectares. Settlements cover 5761 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 1.04 kt CO_2 equivalents in 2015 equivalent to 0.2 % of the total Greenlandic emission.

The overall land use change from 1990 to 2015 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 2015. GL has been estimated to be a net source too. The major emission from CL and GL in 2015 is due to cultivation of organic soils.

Table 16.6.1 Overall emission (kt CO_2-eq) from the LULUCF sector in Greenland, 1990-2015.

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
4. Land use, land-use change and forestry	0.21	0.38	0.52	0.63	1.42	1.21	1.32	1.12	1.13	1.04
A. Forest land	IE,NO	-0.02	-0.03	-0.05	-0.04	-0.04	-0.04	-0.05	-0.05	-0.05
B. Cropland	NO	NO	NO	0.02	0.03	0.05	0.05	0.05	0.05	0.05
C. Grassland	0.21	0.41	0.55	0.66	1.42	1.20	1.31	1.12	1.13	1.04
D. Wetlands	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
E. Settlements	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
F. Other land	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
G. Harvested wood products	NO	NO	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

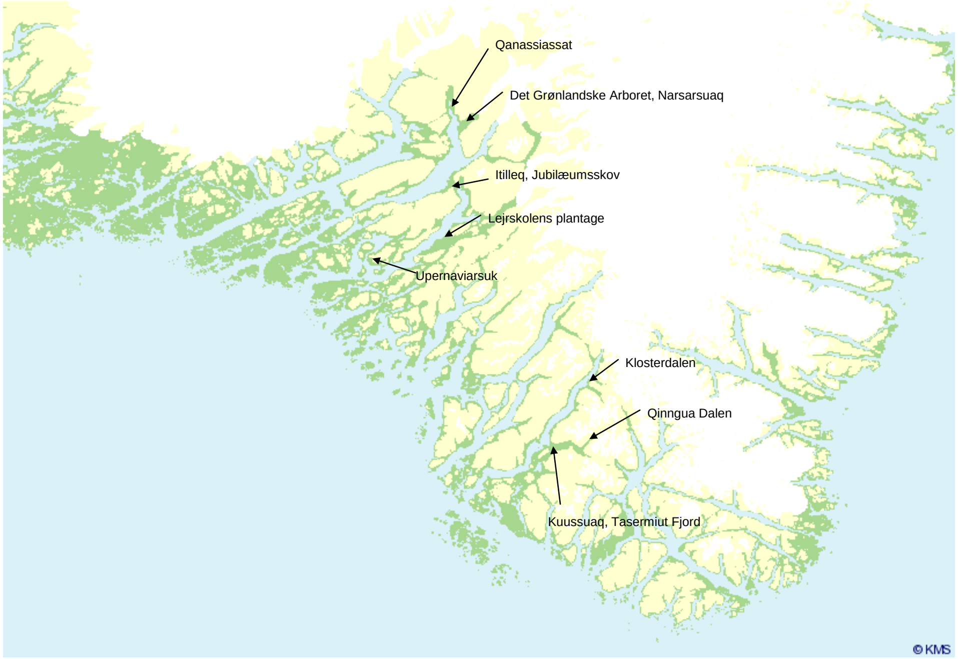

Figure 16.6.2 The position of the Greenlandic forests (Courtesy to Rasmus Enoksen Christensen).

Table 16.6.2 Forests in Greenland 1990 and 2015.

Location	Established	Dominant tree	Area,ha	1990 average tree height (m)	2014 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	12.06	1500	1000
Kuussuaq Forest	1962-64 -1982	Conifer	5	3	11.5	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			218.5				

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 presently 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 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.

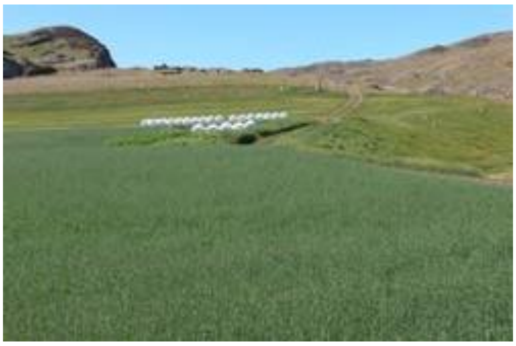

Figure 16.6.5 Cropland and Grassland in Greenland.
(Photos from: http://nunalerineq.gl/english/landbrug/landbrug/index-landbrug.htm).

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 241,990 hectares. Of these, only approximately 1,100 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 490 hectares to 1096 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	2015
Inhabitants	55 589	56 176	55 916
Settlements, total, ha	4801	4891	5761

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 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 Emission/sink, kt CO_2 eqv.	2015 Emission/sink, kt CO_2 eqv.	Activity data, %	Emission factor, %	Combined uncertainty	Total kt CO_2 eqv
5. LULUCF	0.206	1.041	5	50	50.2	± 50.49
5.A Forests	0	-0.051	5	50	50.2	± 2.45
5.B Cropland	0	0.048	5	50	50.2	± 2.32
5.C.Grassland	0.206	1.044	5	50	50.2	± 50.37

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 2.6 % of the overall greenhouse gas emission in 2015. This corresponds to an emission of 14.4 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	2014	2015				
5A Solid waste disposal	CH_4	4.7	4.6	4.6	4.6	4.6	4.6				
5B Incineration and open burning	CO_2	3.1	3.1	3.1	3.1	3.2	3.1				
5B Incineration and open burning	CH_4	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	0.6	0.6				
5C Wastewater treatment and discharge	N_2O	6.0	6.1	5.7	4.6	4.4	4.2				
5. Waste total		16.2	16.3	15.9	14.7	14.6	14.4				

The largest sources of greenhouse gas emission from the waste sector in 2015 are CH_4 emission from solid waste disposal (31.7 %) and N_2O emission from waste water treatment and discharge (29.5 %) followed by CO_2 from waste incineration and open burning (21.8 %).

Total greenhouse gas emission from the waste sector has decreased by 17.5 % since 1990. In 2015 emissions from all sources except wastewater treatment and discharge were more or less unchanged. However, N_2O from wastewater treatment and discharge decreased by 3.1 % 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	2014	2015				
5A1 Managed waste disposal sites	4 413	4 476	4 503	4 518	4 548	4 568				
5A2 Unmanaged waste disposal sites	722	692	658	631	602	579				
5C1 Incineration, with energy recovery	17 077	17 500	17 854	18 131	18 394	18 678				
5C1 Incineration, without energy rec.	3 486	3 488	3 501	3 523	3 550	3 548				
5C2 Open burning of waste	11 470	11 540	11 526	11 500	11 502	11 494				
5. Waste total	37 168	37 695	38 043	38 303	38 596	38 866				

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 1960-2015 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 burning) 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 1990-2015 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 (amount of waste in fractions), potential emission of CH_4, oxidized CH_4 and annual CH_4 emission 1990-2015.

	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
2014	348	266	225	1 200	501	891	491	335	291	4 548	176.4	187.4	18.7	168.7
2015	350	267	226	1 205	503	895	493	337	292	4 568	177.5	187.0	18.7	168.3

Table 16.7.7 Unmanaged disposal. AD for the FOD model (amount of waste in fractions), potential emission of CH_4, oxidized CH_4 and annual CH_4 emission 1990-2015.

	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
2014	46	35	30	159	66	118	65	44	39	602	9.9	14.6	0.0	14.6
2015	44	34	29	153	64	113	62	43	37	579	9.4	14.3	0.0	14.3

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	2014	2015				
Incinerated waste without energy recovery, Mg	3 486	3 488	3 501	3 523	3 550	3 548				

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	2014	2015				
Open burning of waste, Mg	11 470	11 540	11 526	11 500	11 502	11 494				

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.

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: IPCC Guidelines 2006, 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/EEA 2013 (Table 3-1).

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	2000	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	2014	2015				
CO_2, Gg	3.1	3.1	3.1	3.1	3.2	3.1				
CH_4, Mg	75.7	76.1	76.0	75.9	75.9	75.8				
N_2O, Mg	1.9	1.9	1.9	1.9	1.9	1.9				
CO_2 eqv., Gg	5.6	5.6	5.6	5.6	5.6	5.6				

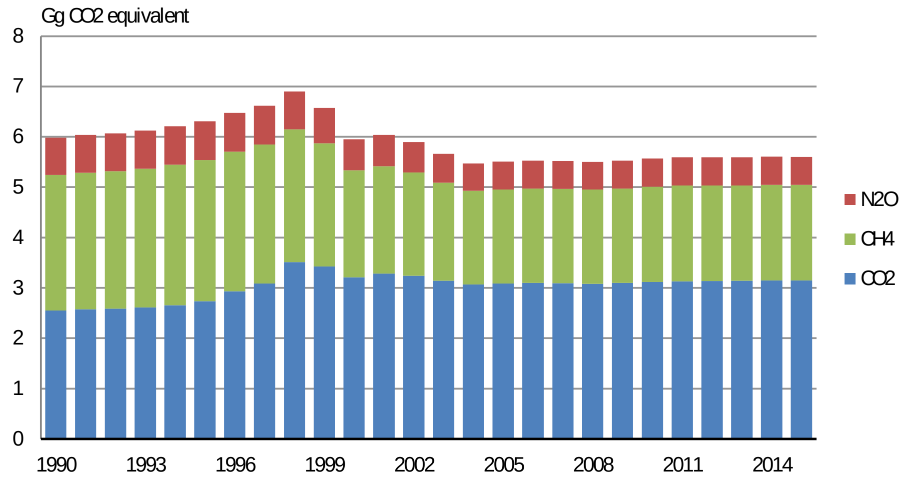

Figure 16.7.1 Emission of greenhouse gases from incineration and open burning.

The emissions of indirect greenhouse gases from incineration and open burning are shown in Table 16.7.15.

Table 16.7.15 Emission 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	2014	2015				
NO_x	41.4	41.6	41.6	41.5	41.6	41.5				
SO_2	6.3	6.3	6.3	6.4	6.4	6.4				
NMVOC	14.1	14.2	14.2	14.2	14.2	14.2				
CO	640.6	644.6	643.8	642.3	642.4	642.0				

16.7.4 Wastewater treatment and discharge

Source category description

In Greenland, no wastewater treatment occurs; although it should be mentioned that 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 1993-2015. 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 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. 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 2015 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 1990-2015.

	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	2014	2015				
N_2O emission, effluents households, Gg	0.005	0.005	0.005	0.005	0.005	0.005				
N_2O emission, effluents industries, Gg	0.015	0.016	0.014	0.010	0.010	0.009				
N_2O emission, effluents sum, Gg	0.020	0.020	0.019	0.015	0.015	0.014				

Total emission of N_2O increased slightly until 2008 due to an increase in the emission from industrial effluents. However, since 2009 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 and an overall economic recession.

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 1990-2015 %	Trend uncertainty %
GHG	± 45	-17.5	± 15.9
CO_2	± 27	23.4	± 17.5
CH_4	± 73	-8.0	± 13.6
N_2O	± 93	-39.1	± 22.9

16.7.6 Source specific QA/QC

The elaboration of a formal QA/QC plan is to be completed.

However, data on solid waste disposal, 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

In this 2017 submission there has been no revisions in the waste sector.

Table 16.8.19 shows recalculations in the waste sector compared to the 2016 submission. No changes occur.

Table 16.8.19 Changes in GHG emission in the waste sector compared to the 2016 submission.

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Previous inventory, Gg CO_2 eqv.	17.5	17.6	17.7	17.8	18.0	18.2	18.4	18.6	19.0	18.7
Recalculated, Gg CO_2 eqv.	17.5	17.6	17.7	17.8	18.0	18.2	18.4	18.6	19.0	18.7
Change in Gg CO_2 eqv.	-	-	-	-	-	-	-	-	-	-
Change in pct.	-	-	-	-	-	-	-	-	-	-
continued	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Previous inventory, Gg CO_2 eqv.	18.1	18.1	18.0	17.7	17.5	17.5	17.5	17.6	17.8	16.5
Recalculated, Gg CO_2 eqv.	18.1	18.1	18.0	17.7	17.5	17.5	17.5	17.6	17.8	16.5
Change in Gg CO_2 eqv.	-	-	-	-	-	-	-	-	-	-
Change in pct.	-	-	-	-	-	-	-	-	-	-
continued	2010	2011	2012	2013	2014	2015				
Previous inventory, Gg CO_2 eqv.	16.2	16.3	15.9	14.7	14.6	-				
Recalculated, Gg CO_2 eqv.	16.2	16.3	15.9	14.7	14.6	14.4				
Change in Gg CO_2 eqv.	-	-	-	-	-					
Change in pct.	-	-	-	-	-					

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 2017 submission is the seventh 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.

16.10 KP-LULUCF

Greenland does not have a commitment in the second commitment period and therefore is not accounting for KP-LULUCF activities. However, the reporting is still done as Greenland continues to be part of the Kyoto Protocol.

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.

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 - 2014 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 1078 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 0.2 % 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 2015 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 2015

The entries in the results of KCA in Tables 16.11.1 to 16.11.3 for the years 1990 and 2015 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 2015, 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 2015 is shown in Table 16.11.2. For the assessment, 7 categories were identified as key categories, refer Table 16.11.2.

The result of the Tier 1 KCA trend assessment for Greenland for 1990/1995-2015 is shown in Table 16.11.3. For the trend assessment, eight 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. 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 2015 and for trend for years 1990-2015. 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	523.866	0.803	0.803
Energy	Domestic aviation		CO_2	38.709	0.059	0.862
Energy	Road transportation		CO_2	36.423	0.056	0.918
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	1.339	0.002	0.992
Energy	Combustion excluding transport		CH_4	1.133	0.002	0.993
Agriculture	Manure management		N_2O	0.869	0.001	0.995
Agriculture	Agricultural soils		N_2O	0.841	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				652.748	1.000	

Table 16.11.2 Key Category Analysis year 2015, 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 2015 Estimate Ex,t Gg CO_2-eqv	Year 2015 Level Assessment Lx,t	Year 2015 Cumulative total of Col. E
Energy	Combustion excluding transport	Liquid fuels	CO_2	523.866	409.051	0.732	0.732
Energy	Domestic aviation		CO_2	38.709	40.017	0.072	0.804
Energy	Domestic navigation		CO_2	20.941	33.565	0.060	0.864
Energy	Road transportation		CO_2	36.423	30.504	0.055	0.919
Industry	Consumption of HFC's		HFCs	0.027	10.176	0.018	0.937
Energy	Combustion excluding transport	Other fuels	CO_2	1.674	7.256	0.013	0.950
Agriculture	Enteric fermentation		CH_4	7.627	6.091	0.011	0.961
Waste	Solid waste disposal		CH_4	4.328	4.564	0.008	0.969
Waste	Wastewater treatment and discharge		N_2O	7.154	4.246	0.008	0.977
Waste	Incineration and open burning of waste		CO_2	2.550	3.148	0.006	0.982
Waste	Incineration and open burning of waste		CH_4	2.692	1.896	0.003	0.986
Agriculture	Agricultural soils		N_2O	0.841	1.572	0.003	0.988
Energy	Combustion excluding transport		N_2O	1.339	1.235	0.002	0.991
LULUCF	Grassland remaining grassland		CO_2	0.206	1.044	0.002	0.992
Energy	Combustion excluding transport		CH_4	1.133	1.008	0.002	0.994
Agriculture	Manure management		N_2O	0.869	0.745	0.001	0.996
Energy	Road transportation		N_2O	0.627	0.712	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	0.334	0.001	0.999
Industry	Solvent use		CO_2	0.263	0.214	0.000	0.999
Energy	Road transportation		CH_4	0.068	0.135	0.000	0.999
Agriculture	Manure management		CH_4	0.167	0.133	0.000	0.999
Industry	Paraffin wax use		CO_2	0.043	0.101	0.000	1.000
Energy	Domestic navigation		N_2O	0.051	0.082	0.000	1.000
Energy	Domestic navigation		CH_4	0.036	0.057	0.000	1.000
LULUCF	Forest land remaining forest land		CO_2	0.000	-0.051	0.000	1.000
LULUCF	Land converted to cropland		CO_2	0.000	0.048	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				652.748	558.456	1.000	

Table 16.11.3 Key Category Analysis years 1990/1995-2015, 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 2015 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	523.866	409.051	0.060	0.458	0.458
Energy	Domestic navigation		CO_2	20.941	33.565	0.024	0.183	0.642
Industry	Consumption of HFC's		HFCs	0.027	10.176	0.016	0.119	0.761
Energy	Domestic aviation		CO_2	38.709	40.017	0.011	0.081	0.841
Energy	Combustion excluding transport	Other fuels	CO_2	1.674	7.256	0.009	0.068	0.910
Waste	Wastewater treatment and discharge		N_2O	7.154	4.246	0.003	0.022	0.932
Waste	Incineration and open burning of waste		CO_2	2.550	3.148	0.001	0.011	0.943
LULUCF	Grassland remaining grassland		CO_2	0.206	1.044	0.001	0.010	0.953
Waste	Solid waste disposal		CH_4	4.328	4.564	0.001	0.010	0.963
Agriculture	Agricultural soils		N_2O	0.841	1.572	0.001	0.010	0.973
Energy	Road transportation		CO_2	36.423	30.504	0.001	0.008	0.981
Agriculture	Enteric fermentation		CH_4	7.627	6.091	0.001	0.005	0.986
Waste	Incineration and open burning of waste		CH_4	2.692	1.896	0.001	0.005	0.991
Energy	Road transportation		N_2O	0.627	0.712	0.000	0.002	0.993
Energy	Combustion excluding transport		N_2O	1.339	1.235	0.000	0.001	0.994
Energy	Road transportation		CH_4	0.068	0.135	0.000	0.001	0.995
Waste	Incineration and open burning of waste		N_2O	0.741	0.558	0.000	0.001	0.996
Industry	Paraffin wax use		CO_2	0.043	0.101	0.000	0.001	0.996
Energy	Domestic aviation		N_2O	0.323	0.334	0.000	0.001	0.997
LULUCF	Forest land remaining forest land		CO_2	0.000	-0.051	0.000	0.001	0.998
LULUCF	Land converted to cropland		CO_2	0.000	0.048	0.000	0.001	0.998
Energy	Combustion excluding transport		CH_4	1.133	1.008	0.000	0.000	0.999
Energy	Domestic navigation		N_2O	0.051	0.082	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	0.057	0.000	0.000	1.000
Industry	Solvent use		CO_2	0.263	0.214	0.000	0.000	1.000
Agriculture	Manure management		CH_4	0.167	0.133	0.000	0.000	1.000
Agriculture	Liming		CO_2	0.008	0.004	0.000	0.000	1.000
Agriculture	Manure management		N_2O	0.869	0.745	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				652.748	558.456		1.000	

Table 16.11.4 Summary of Key Category Analysis for Greenland for level assessment for year 1990/95 and 2015 and for trend for years 1990-2015.

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 2015	Trend Tier1 1990-2015
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	7	
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			7
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			8

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 1990-2015 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 1990-2015. With regard to aerosol cans, we are aware that N_2O is found in the products. Since we cannot 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	620	513	3	2	3.606	10.976	0.026	0.786	0.052	3.335	11.126
1A Municipal waste	CO_2	2	7	3	25	25.179	0.107	0.009	0.011	0.223	0.047	0.052
1A Liquid fuels	CH_4	1	1	3	100	100.045	0.036	0.000	0.002	0.004	0.007	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	0.010	0.001	0.000
1A Liquid fuels	N_2O	2	2	3	500	500.009	3.635	0.000	0.003	0.133	0.014	0.018
1A Municipal waste	N_2O	0	0	3	500	500.009	0.009	0.000	0.000	0.065	0.001	0.004
1A Biomass	N_2O	0	0	3	200	200.022	0.002	0.000	0.000	0.032	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	0.000	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	10	10	50	50.990	0.863	0.016	0.016	0.778	0.220	0.653
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	6	10	100	100.499	1.202	0.001	0.009	0.066	0.132	0.022
3B Manure Management	CH_4	0	0	10	100	100.499	0.001	0.000	0.000	0.002	0.003	0.000
3B Manure Management	N_2O	1	1	10	100	100.499	0.018	0.000	0.001	0.000	0.016	0.000
3D Agricultural soils	N_2O	1	2	20	50	53.852	0.023	0.001	0.002	0.065	0.068	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 uncer-tainty	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	0.004	0.001	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	0.066	0.011	0.005
5A Solid Waste Disposal	CH_4	4	5	10	100	100.499	0.675	0.001	0.007	0.132	0.099	0.027
5C Incineration and open burning of waste	CO_2	3	3	10	25	26.926	0.023	0.001	0.005	0.037	0.068	0.006
5C Incineration and open burning of waste	CH_4	3	2	10	50	50.990	0.030	0.001	0.003	0.031	0.041	0.003
5C Incineration and open burning of waste	N_2O	1	1	10	100	100.499	0.010	0.000	0.001	0.012	0.012	0.000
5D Wastewater treatment and discharge	N_2O	7	4	30	100	104.403	0.630	0.003	0.007	0.287	0.276	0.159
Total		653	558				18,248					12,085
Total uncertainties				Overall uncertainty in the year (%):			4.272			Trend uncertainty (%):		3.476

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 CO_2 emission factor was revised in the 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 contains information on the aggregated submission for Denmark and Greenland submitted under the Kyoto Protocol. This chapter contains a trend discussion, a tier 1 uncertainty analysis, information on the aggregated reference approach, information relating to key categories and information on recalculations. Sector specific information is included for Denmark in Chapter 3-10 and for Greenland in Chapter 16.

The institutional arrangements and the overall QA/QC plan are described in Chapter 1. This description covers all the Danish submissions to the European Union, the UNFCCC and the Kyoto Protocol, and therefore information regarding the national system is not presented in this chapter. Information on the specific QA/QC activities concerning the aggregated submission is presented in Chapter 17.7.

In Chapter 17.6 a description of the aggregation process is provided. The chapter explains the technical issues in aggregating two CRF submissions, including the software used in the process and the handling of background data.

17.1 Trends in emissions

Due to the small emission originating from Greenland the trends for Denmark and Greenland are practically identical to the trends for Denmark presented in Chapter 2. Therefore they are not further described here.

17.2 The reference approach

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 2006 IPCC Guidelines. 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 national approach.

The reference approach for Denmark and Greenland is an aggregation of the individual reference approaches for the two. The reference approach for Denmark is described in Chapter 3.4 and the reference approach for Greenland is included in Chapter 16.

In 2015 the fuel consumption rates in the two approaches differ by -1.91 % and the CO_2 emission differs by -2.10 %. With the exception of 2015, both the fuel consumption and the CO_2 emission differ by less than 2.0% since 1990. The differences are below 1 % for all years except 1998, 2009, 2012 and 2014. This is almost identical to the reference approach for Denmark, due to the very small emission from Greenland compared to Denmark. According to the 2006 IPCC Guidelines the difference should be within 5 %. The explanation for the differences in the Danish inventory is explained in Chapter 3.4.

A comparison of the national approach and the reference approach is illustrated in Figure 17.1.

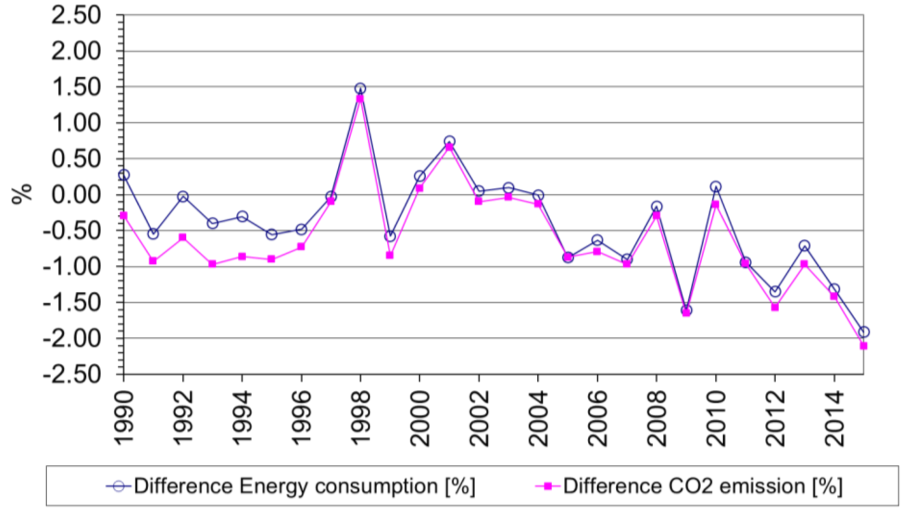

Figure 17.1 Comparison of the reference approach and the national approach.

17.3 Uncertainties

An uncertainty estimate has been calculated for Denmark and Greenland. The uncertainty estimate for Denmark is included in Chapter 1.7 and for Greenland in Chapter 16.

The uncertainty estimates are based on the Approach 1 methodology in the 2006 IPCC Guidelines. Uncertainty estimates cover 100 % of the total net greenhouse gas emissions and removals. The emissions from Greenland have been treated separately due to the uncertainties being different than the uncertainties in the Danish inventory. The uncertainty of the Greenlandic emissions has almost no effect on the overall uncertainty estimate, due to the low emissions originating from Greenland.

The estimated uncertainties for total GHG and for CO_2, CH_4, N_2O and F-gases are shown in Table 17.1. The base year for F-gases is 1995 and for all other sources the base year is 1990. The total net GHG emission from Denmark and Greenland is estimated with an uncertainty of ±5.6 % and the trend in net GHG emission since 1990/1995 has been estimated to be -29.4 % ± 2.0 %-age points. The GHG uncertainty estimates do not take into account the uncertainty of the GWP factors.

Table 17.1 Uncertainties 1990-2015.

	Uncertainty [%]	Trend [%]	Uncertainty in trend [%-age points]
GHG	5.6	-29.4	2.0
GHG ex. LULUCF	5.0	-30.8	1.9
CO_2	5.5	-43.0	1.8
CH_4	16.7	-8.2	12.3
N_2O	37	-35	10
F-gases	41	118	97

The uncertainties for the activity rates and emission factors are shown in Table 17.2.

Table 17.2 Uncertainties for activity rates and emission factors.

	IPCC Source category	Gas	Base year emission Input data Gg CO_2 eqv.	2015 emission Input data Gg CO_2 eqv.	Activity data uncer-tainty In-put data %	Emission factor un-certainty Input data %
Denmark	1A Stationary combustion, Coal, ETS data	CO_2	0.0	6096.7	0.5	0.3
Denmark	1A Stationary combustion, Coal, no ETS data	CO_2	23833.8	1072.7	0.9	1.0
Denmark	1A Stationary combustion, BKB	CO_2	11.3	0.0	2.9	5.0
Denmark	1A Stationary combustion, Coke oven coke	CO_2	136.5	68.7	1.8	5.0
Denmark	1A Stationary combustion, Fossil waste, ETS data	CO_2	0.0	0.0	2.0	5.0
Denmark	1A Stationary combustion, Fossil waste, no ETS data	CO_2	573.5	1699.5	5.0	10.0
Denmark	1A Stationary combustion, Petroleum coke, ETS data	CO_2	0.0	593.1	0.5	0.5
Denmark	1A Stationary combustion, Petroleum coke, no ETS data	CO_2	414.7	23.1	1.9	5.0
Denmark	1A Stationary combustion, Residual oil, ETS data	CO_2	0.0	0.0	0.5	0.5
Denmark	1A Stationary combustion, Residual oil, no ETS data	CO_2	2524.5	327.2	1.6	2.0
Denmark	1A Stationary combustion, Gas oil	CO_2	4721.8	699.1	2.6	1.5
Denmark	1A Stationary combustion, Kerosene	CO_2	367.6	2.3	1.7	3.0
Denmark	1A Stationary combustion, LPG	CO_2	186.8	87.2	2.6	4.0
Denmark	1A1b Stationary combustion, Petroleum refining, Refinery gas	CO_2	816.1	928.4	1.0	2.0
Denmark	1A Stationary combustion, Natural gas, onshore	CO_2	3790.5	5478.1	1.3	0.4
Denmark	1A1c_ii Stationary combustion, Oil and gas extraction, Off shore gas turbines, Natural gas	CO_2	544.9	1429.1	0.5	0.5
Denmark	1A1 Stationary Combustion, Solid fuels	CH_4	5.3	1.6	1.0	100.0
Denmark	1A1 Stationary Combustion, Liquid fuels	CH_4	0.7	0.5	1.0	100.0
Denmark	1A1 Stationary Combustion, not engines, gaseous fuels	CH_4	0.8	1.8	1.0	100.0
Denmark	1A1 Stationary Combustion, Waste	CH_4	0.2	0.3	3.0	100.0
Denmark	1A1 Stationary Combustion, not engines, Biomass	CH_4	3.6	10.7	3.0	100.0
Denmark	1A2 Stationary Combustion, solid fuels	CH_4	3.8	1.1	2.0	100.0
Denmark	1A2 Stationary Combustion, Liquid fuels	CH_4	0.9	0.6	2.0	100.0
Denmark	1A2 Stationary Combustion, not engines, gaseous fuels	CH_4	0.6	0.8	2.0	100.0
Denmark	1A2 Stationary Combustion, Waste	CH_4	0.0	1.9	3.0	100.0
Denmark	1A2 Stationary Combustion, not engines, Biomass	CH_4	1.6	1.4	10.0	100.0
Denmark	1A4 Stationary Combustion, Solid fuels	CH_4	6.2	0.2	3.0	100.0
Denmark	1A4 Stationary Combustion, Liquid fuels	CH_4	3.0	0.3	3.0	100.0
Denmark	1A4 Stationary Combustion, not engines, gaseous fuels	CH_4	0.6	0.9	3.0	100.0
Denmark	1A4 Stationary Combustion, Waste	CH_4	0.7	0.1	3.0	100.0
Denmark	1A4 Stationary Combustion, not engines, not residential wood and not residential/agricultural straw, Biomass	CH_4	0.1	0.4	10.0	100.0
Denmark	1A4b_i Stationary combustion, Residential wood combustion	CH_4	71.1	86.9	20.0	150.0
Denmark	1A4b_i/1A4c_i Stationary Combustion, Residential and agri-cultural straw combustion	CH_4	63.6	36.9	15.0	150.0
Denmark	1A Stationary combustion, Natural gas fuelled engines, gase-ous fuels	CH_4	5.5	51.5	1.0	2.0
Denmark	1A Stationary combustion, Biogas fuelled engines, Biomass	CH_4	2.2	45.9	3.0	10.0
Denmark	1A1 Stationary Combustion, Solid fuels	N_2O	57.4	17.1	1.0	400.0
Denmark	1A1 Stationary Combustion, Liquid fuels	N_2O	2.8	1.5	1.0	1000.0
Denmark	1A1 Stationary Combustion, Gaseous fuels	N_2O	11.8	16.2	1.0	750.0
Denmark	1A1 Stationary Combustion, Waste	N_2O	5.2	13.4	3.0	400.0
Denmark	1A1 Stationary Combustion, Biomass	N_2O	8.4	33.9	3.0	400.0
Denmark	1A2 Stationary Combustion, Solid fuels	N_2O	6.7	9.2	2.0	400.0
Denmark	1A2 Stationary Combustion, Liquid fuels	N_2O	28.7	6.6	2.0	1000.0
Denmark	1A2 Stationary Combustion, Gaseous fuels	N_2O	7.2	9.1	2.0	750.0
Denmark	1A2 Stationary Combustion, Waste	N_2O	0.0	3.0	3.0	400.0
Denmark	1A2 Stationary Combustion, Biomass	N_2O	6.9	6.0	10.0	400.0
Denmark	1A4 Stationary Combustion, Solid fuels	N_2O	1.5	0.3	3.0	400.0
Denmark	1A4 Stationary Combustion, Liquid fuels	N_2O	11.4	1.4	3.0	1000.0
Denmark	1A4 Stationary Combustion, Gaseous fuels	N_2O	7.7	10.2	3.0	750.0
Denmark	1A4 Stationary Combustion, Waste	N_2O	1.1	0.2	3.0	400.0
Denmark	1A4 Stationary Combustion, not residential wood and not resi-dential/agricultural straw, Biomass	N_2O	0.5	2.3	10.0	400.0

	IPCC Source category	Gas	Base year emission Input data Gg CO_2 eqv.	2015 emission Input data Gg CO_2 eqv.	Activity data uncertainty Input data %	Emission factor uncertainty Input data %
Denmark	1A4b_i Stationary Combustion, Residential wood combustion	N_2O	10.7	44.4	20.0	500.0
Denmark	1A4b_i/1A4c_i Stationary Combustion, Residential and agricultural straw combustion	N_2O	10.1	5.9	15.0	500.0
Denmark	1.A.2.g Industry (mobile)	CO_2	664.5	717.7	41.0	5.0
Denmark	1.A.3.a Civil aviation	CO_2	248.1	127.6	10.0	5.0
Denmark	1.A.3.b Road Transport	CO_2	9283.4	11442.3	2.0	5.0
Denmark	1.A.3.c Railways	CO_2	296.7	248.3	2.0	5.0
Denmark	1.A.3.d Navigation (large vessels)	CO_2	748.2	373.6	11.0	5.0
Denmark	1.A.4.a Commercial/Institutional (mobile)	CO_2	73.7	171.4	35.0	5.0
Denmark	1.A.4.b Residential (mobile)	CO_2	39.1	61.9	35.0	5.0
Denmark	1.A.4.c ii Agriculture (mobile)	CO_2	1272.3	1081.0	24.0	5.0
Denmark	1.A.4.c ii Forestry (mobile)	CO_2	35.7	15.5	30.0	5.0
Denmark	1.A.4.c iii Fisheries	CO_2	585.6	533.8	2.0	5.0
Denmark	1.A.5.b Other (military)	CO_2	47.9	98.1	41.0	5.0
Denmark	1.A.5.b Other (small boats)	CO_2	119.0	98.4	2.0	5.0
Denmark	1.A.2.g Industry (mobile)	CH_4	1.5	0.7	41.0	100.0
Denmark	1.A.3.a Civil aviation	CH_4	0.1	0.0	10.0	100.0
Denmark	1.A.3.b Road Transport	CH_4	56.0	10.4	2.0	40.0
Denmark	1.A.3.c Railways	CH_4	0.3	0.1	2.0	100.0
Denmark	1.A.3.d Navigation (large vessels)	CH_4	0.4	0.4	11.0	100.0
Denmark	1.A.4.a Commercial/Institutional (mobile)	CH_4	2.9	4.3	35.0	100.0
Denmark	1.A.4.b Residential (mobile)	CH_4	1.3	0.9	35.0	100.0
Denmark	1.A.4.c ii Agriculture (mobile)	CH_4	2.3	2.0	24.0	100.0
Denmark	1.A.4.c ii Forestry (mobile)	CH_4	4.0	0.4	30.0	100.0
Denmark	1.A.4.c iii Fisheries	CH_4	0.3	0.3	2.0	100.0
Denmark	1.A.5.b Other (military)	CH_4	1.9	0.2	41.0	100.0
Denmark	1.A.5.b Other (small boats)	CH_4	0.1	0.1	2.0	100.0
Denmark	1.A.2.g Industry (mobile)	N_2O	7.8	9.6	41.0	1000.0
Denmark	1.A.3.a Civil aviation	N_2O	3.0	2.1	10.0	1000.0
Denmark	1.A.3.b Road Transport	N_2O	89.2	126.5	2.0	50.0
Denmark	1.A.3.c Railways	N_2O	2.7	2.2	2.0	1000.0
Denmark	1.A.3.d Navigation (large vessels)	N_2O	5.6	2.8	11.0	1000.0
Denmark	1.A.4.a Commercial/Institutional (mobile)	N_2O	0.3	0.8	35.0	1000.0
Denmark	1.A.4.b Residential (mobile)	N_2O	0.2	0.3	35.0	1000.0
Denmark	1.A.4.c ii Agriculture (mobile)	N_2O	14.7	14.9	24.0	1000.0
Denmark	1.A.4.c ii Forestry (mobile)	N_2O	0.2	0.2	30.0	1000.0
Denmark	1.A.4.c iii Fisheries	N_2O	4.4	4.0	2.0	1000.0
Denmark	1.A.5.b Other (military)	N_2O	0.4	1.0	41.0	1000.0
Denmark	1.A.5.b Other (small boats)	N_2O	1.1	1.1	2.0	1000.0
Denmark	1.B.2.a.1 Exploration, oil	CO_2	4.7	0.8	2.0	10.0
Denmark	1.B.2.a.2 Production, oil	CO_2	0.0	0.0	2.0	100.0
Denmark	1.B.2.a.3 Transport, oil	CO_2	0.0	0.0	2.0	40.0
Denmark	1.B.2.b.1 Exploration, gas	CO_2	8.3	0.1	2.0	10.0
Denmark	1.B.2.b.2 Production, gas	CO_2	0.1	0.1	2.0	100.0
Denmark	1.B.2.b.4 Transmission and storage, gas	CO_2	0.0	0.0	15.0	2.0
Denmark	1.B.2.b.5 Distribution, gas	CO_2	0.0	0.0	25.0	10.0
Denmark	1.B.2.c.1.ii Venting, gas	CO_2	0.0	0.0	15.0	2.0
Denmark	1.B.2.c.2.i Flaring, oil	CO_2	22.9	12.8	11.0	2.0
Denmark	1.B.2.c.2.ii Flaring, gas	CO_2	304.7	233.3	7.5	2.0
Denmark	1.B.2.a.1 Exploration, oil	CH_4	0.0	0.0	2.0	125.0
Denmark	1.B.2.a.2 Production, oil	CH_4	0.1	0.1	2.0	100.0
Denmark	1.B.2.a.3 Transport, oil	CH_4	20.4	13.8	2.0	40.0

	IPCC Source category	Gas	Base year emission Input data Gg CO_2 eqv.	2015 emission Input data Gg CO_2 eqv.	Activity data uncertainty Input data %	Emission factor uncertainty Input data %
Denmark	1.B.2.a.4 Refining/storage	CH_4	10.9	15.4	1.0	200.0
Denmark	1.B.2.b.1 Exploration, gas	CH_4	0.8	0.0	2.0	125.0
Denmark	1.B.2.b.2 Production, gas	CH_4	48.8	43.0	2.0	100.0
Denmark	1.B.2.b.4 Transmission and storage, gas	CH_4	4.8	0.8	15.0	2.0
Denmark	1.B.2.b.5 Distribution, gas	CH_4	6.4	3.9	25.0	10.0
Denmark	1.B.2.c.1.ii Venting, gas	CH_4	1.5	0.8	15.0	2.0
Denmark	1.B.2.c.2.i Flaring, oil	CH_4	0.2	0.1	11.0	15.0
Denmark	1.B.2.c.2.ii Flaring, gas	CH_4	28.9	23.6	7.5	125.0
Denmark	1.B.2.a.1 Exploration, oil	N_2O	0.0	0.0	2.0	1000.0
Denmark	1.B.2.b.1 Exploration, gas	N_2O	1.4	0.0	2.0	1000.0
Denmark	1.B.2.c.2.i Flaring, oil	N_2O	0.1	0.0	11.0	1000.0
Denmark	1.B.2.c.2.ii Flaring, gas	N_2O	51.5	42.5	7.5	1000.0
Denmark	2A1 Cement production	CO_2	882.4	931.5	1.0	2.0
Denmark	2A2 Lime production	CO_2	105.4	50.6	5.0	4.0
Denmark	2A3 Glass production	CO_2	20.2	8.9	1.0	2.0
Denmark	2A4a Ceramics	CO_2	42.1	28.8	5.0	2.0
Denmark	2A4b Other uses of soda ash	CO_2	13.8	10.1	5.0	2.0
Denmark	2A4d Other process uses of carbonates	CO_2	17.5	21.8	30.0	2.0
Denmark	2B10 Production of catalysts	CO_2	0.9	1.6	5.0	5.0
Denmark	2C1a Steel	CO_2	30.3	0.0	5.0	10.0
Denmark	2C5 Lead production	CO_2	0.2	0.2	10.0	50.0
Denmark	2D1 Lubricant use	CO_2	49.7	31.7	10.0	20.0
Denmark	2D2 Paraffin wax use	CO_2	21.7	72.5	15.0	60.0
Denmark	Paint Application	CO_2	12.8	6.3	10.0	15.0
Denmark	Degreasing, dry cleaning and electronics	CO_2	0.0	0.0	10.0	15.0
Denmark	Chemical products manufacturing or processing	CO_2	19.4	11.8	10.0	15.0
Denmark	Other use of solvents and related activities	CO_2	61.4	42.5	10.0	20.0
Denmark	2D3 Road paving with asphalt	CO_2	0.1	0.1	20.0	75.0
Denmark	2D3 Asphalt roofing	CO_2	0.0	0.0	20.0	75.0
Denmark	2D3 Urea based catalysts	CO_2	0.0	7.2	5.0	10.0
Denmark	2G4 Fireworks	CO_2	0.1	0.3	10.0	50.0
Denmark	2D2 Paraffin wax use	CH_4	0.0	0.1	15.0	60.0
Denmark	2D3 Road paving with asphalt	CH_4	0.3	0.4	20.0	75.0
Denmark	2G4 Fireworks	CH_4	0.0	0.1	10.0	50.0
Denmark	2G4 Tobacco	CH_4	1.0	0.6	10.0	50.0
Denmark	2G4 Charcoal	CH_4	1.1	2.7	10.0	100.0
Denmark	2B2 Nitric acid production	N_2O	1002.5	0.0	2.0	25.0
Denmark	2D2 Paraffin wax use	N_2O	0.1	0.2	15.0	60.0
Denmark	2G3a Medical application of N_2O	N_2O	11.3	11.3	25.0	20.0
Denmark	2G3b N_2O as propellant for pressure and aerosol products	N_2O	5.6	4.7	100.0	150.0
Denmark	2G4 Fireworks	N_2O	0.7	3.3	10.0	50.0
Denmark	2G4 Tobacco	N_2O	0.2	0.1	10.0	50.0
Denmark	2G4 Charcoal	N_2O	0.1	0.2	10.0	100.0
Denmark	2E Electronics industry	HFCs	0.0	0.0	10.0	50.0
Denmark	2F1 Refrigeration and air conditioning	HFCs	41.9	590.9	10.0	50.0
Denmark	2F2 Foam blowing agents	HFCs	199.5	26.2	10.0	50.0
Denmark	2F4 Aerosols	HFCs	0.0	16.8	10.0	50.0
Denmark	2E Electronics industry	PFCs	0.0	0.0	10.0	50.0
Denmark	2F1 Refrigeration and air conditioning	PFCs	0.6	4.9	10.0	50.0
Denmark	2C4 Magnesium production	SF6	34.2	0.0	10.00	30.00
Denmark	2G1 Electrical equipment	SF6	3.7	12.2	10.00	50.00
Denmark	2G2 SF_6 and PFCs from other product use	SF6	64.5	90.9	10.00	50.00

	IPCC Source category	Gas	Base year emission Input data Gg CO_2 eqv.	2015 emission Input data Gg CO_2 eqv.	Activity data uncertainty Input data %	Emission factor uncertainty Input data %
Denmark	3A Enteric Fermentation	CH_4	4039.5	3667.2	2.00	20.00
Denmark	3B Manure Management	CH_4	1419.8	1854.1	5.00	20.00
Denmark	3F Field Burning of Agricultural Residues	CH_4	2.2	3.0	25.00	50.00
Denmark	3B Manure Management	N_2O	781.1	593.9	25.00	100.00
Denmark	3B5 Atmospheric deposition	N_2O	197.3	138.1	16.00	100.00
Denmark	3Da1 Inorganic N fertilizer	N_2O	1875.0	952.9	3.00	100.00
Denmark	3Da2a Animal manure applied to soils	N_2O	1002.7	978.8	25.00	100.00
Denmark	3Da2b Sewage sludge applied to soils	N_2O	14.6	13.0	15.00	100.00
Denmark	3Da2c Other organic fertilizer applied to soils	N_2O	7.2	20.9	20.00	100.00
Denmark	3Da3 Urine and dung deposited by grazing animals	N_2O	297.9	177.2	10.00	100.00
Denmark	3Da4 Crop Residues	N_2O	569.3	662.2	25.00	100.00
Denmark	3Da5 Mineralization	N_2O	68.2	4.4	50.00	100.00
Denmark	3Da6 Cultivation of organic soils	N_2O	831.9	619.3	20.00	100.00
Denmark	3Db1 Atmospheric deposition	N_2O	309.9	152.1	16.00	100.00
Denmark	3Db2 Leaching	N_2O	549.3	395.9	20.00	100.00
Denmark	3F Field Burning of Agricultural Residues	N_2O	0.7	0.9	25.00	50.00
Denmark	3G Liming	CO_2	565.5	165.6	5.00	100.00
Denmark	3H Urea applicaton	CO_2	14.7	1.4	3.00	100.00
Denmark	3I Other carbon-containing fertilizers	CO_2	38.4	10.5	3.00	100.00
Denmark	4.A.1 Forest land remaining forest land, Living biomass	CO_2	-737.9	-2470.7	5.00	2.00
Denmark	4.A.1 Forest land remaining forest land, Dead organic matter	CO_2	-5.8	2016.6	5.00	2.00
Denmark	4.A.1 Forest land remaining forest land, Mineral soils	CO_2	0.0	0.0	5.00	2.00
Denmark	4.A.1 Forest land remaining forest land, Organic soils	CO_2	189.9	136.3	10.00	50.00
Denmark	4.A.2 Land converted to forest land	CO_2	-30.9	493.6	10.00	8.74
Denmark	4.B.1 Cropland remaining cropland, Living biomass	CO_2	-84.9	387.9	2.50	15.00
Denmark	4.B.1 Cropland remaining cropland, Mineral soils	CO_2	-591.8	-1069.8	2.50	75.00
Denmark	4.B.1 Cropland remaining cropland, Organic soils	CO_2	3929.7	2703.5	3.30	50.00
Denmark	4.B.2 Forest land converted to cropland	CO_2	3.1	143.0	10.00	50.00
Denmark	4.B.2 Other land uses converted to cropland	CO_2	-8.7	-200.5	10.00	50.00
Denmark	4.C.1 Grassland remaining grassland, Living biomass	CO_2	64.7	406.5	2.50	7.00
Denmark	4.C.1 Grassland remaining grassland, Organic soils	CO_2	838.6	734.7	3.30	50.00
Denmark	4.C.2 Forest land converted to grassland	CO_2	2.0	94.0	10.00	50.00
Denmark	4.C.2 Other land uses converted to grassland	CO_2	12.6	114.3	10.00	50.00
Denmark	4.D.1.1 Peat extraction remaining peat extraction	CO_2	99.5	40.7	10.00	75.00
Denmark	4.D.1.2 Flooded land remaining flooded land	CO_2	0.0	0.0	10.00	75.00
Denmark	4.D.2 Land converted to wetlands	CO_2	1.0	0.0	10.00	75.00
Denmark	4.E.2 Forest land converted to settlements	CO_2	2.9	8.4	10.00	75.00
Denmark	4.E.2 Other land uses converted to settlements	CO_2	9.9	58.4	10.00	75.00
Denmark	4.G Harvested wood products	CO_2	-2.4	-171.5	25.00	75.00
Denmark	4(II) Grassland on organic soils	CH_4	13.5	12.0	10.00	90.00
Denmark	4(II) A. Forest land, organic soils	CH_4	4.0	29.1	10.00	90.00
Denmark	4(II) Land converted to wetlands	CH_4	0.6	14.3	10.00	90.00
Denmark	4(II) Peatland	CH_4	0.2	0.1	10.00	90.00
Denmark	4(V) Biomass Burning	CH_4	0.7	0.0	10.00	30.00
Denmark	4(III) Mineralization/immobilization, Forest land	N_2O	0.0	0.0	10.00	90.00
Denmark	4(III) Mineralization/immobilization, Cropland	N_2O	0.0	3.6	10.00	90.00
Denmark	4(III) Mineralization/immobilization, Grassland	N_2O	0.0	1.9	10.00	90.00
Denmark	4(III) Mineralization/immobilization, Land converted to Settlements	N_2O	0.1	4.5	10.00	90.00
Denmark	4(V) Biomass burning	N_2O	0.4	0.0	10.00	30.00
Denmark	4(II) Drainage and rewetting, Forest soils	N_2O	26.5	23.9	10.00	50.00
Denmark	4(II) Peat extraction remaining peat extraction	N_2O	0.2	0.1	10.00	50.00
Denmark	5.E Accidental fires	CO_2	17.5	21.3	10.00	300.00

	IPCC Source category	Gas	Base year emission Input data Gg CO_2 eqv.	2015 emission Input data Gg CO_2 eqv.	Activity data uncer-tainty In-put data %	Emission factor un-certainty Input data %
Denmark	5.A Solid waste disposal	CH_4	1536.3	655.4	10.00	117.90
Denmark	5.B.1 Composting	CH_4	34.7	116.3	40.00	100.00
Denmark	5.B.2. Anaerobic digestion at biogas facilities	CH_4	3.6	71.8	5.00	20.00
Denmark	5.C.1 Incineration of corpses	CH_4	0.0	0.0	1.00	150.00
Denmark	5.C.2 Incineration of carcasses	CH_4	0.0	0.0	40.00	150.00
Denmark	5.D Wastewater treatment and discharge	CH_4	95.7	109.3	23.97	31.62
Denmark	5.E Accidental fires	CH_4	1.9	2.4	10.00	500.00
Denmark	5.B.1 Composting	N_2O	12.1	113.1	40.00	100.00
Denmark	5.C.1 Incineration of corpses	N_2O	0.0	0.1	1.00	150.00
Denmark	5.C.2 Incineration of carcasses	N_2O	0.2	0.2	40.00	150.00
Denmark	5.D Wastewater treatment and discharge	N_2O	61.4	62.6	21.74	49.59
Green-land	1A Liquid fuels	CO_2	619.9	513.1	3.0	2.0
Green-land	1A Municipal waste	CO_2	1.7	7.3	3.0	25.0
Green-land	1A Liquid fuels	CH_4	1.2	1.1	3.0	100.0
Green-land	1A Municipal waste	CH_4	0.0	0.1	3.0	100.0
Green-land	1A Biomass	CH_4	0.0	0.1	3.0	100.0
Green-land	1A Liquid fuels	N_2O	2.3	2.1	3.0	500.0
Green-land	1A Municipal waste	N_2O	0.0	0.1	3.0	500.0
Green-land	1A Biomass	N_2O	0.0	0.1	3.0	200.0
Green-land	1B2 Oil exploration	CO_2	0.0	0.0	3.0	1000.0
Green-land	1B2 Oil exploration	CH_4	0.0	0.0	3.0	1000.0
Green-land	1B2 Oil exploration	N_2O	0.0	0.0	3.0	1000.0
Green-land	2A4 Limestone and dolomite use	CO_2	0.0	0.0	5.0	5.0
Green-land	2D2 Paraffin wax use	CO_2	0.0	0.1	5.0	25.0
Green-land	2D3 Solvent use	CO_2	0.3	0.2	5.0	25.0
Green-land	2D3 Road paving with asphalt	CO_2	0.0	0.0	5.0	25.0
Green-land	2D3 Asphalt roofing	CO_2	0.0	0.0	5.0	25.0
Green-land	2F Consumption of HFC	HFC	0.0	10.2	10.0	50.0
Green-land	2G Consumption of SF_6	SF6	0.0	0.0	10.0	50.0
Green-land	3A Enteric Fermentation	CH_4	7.6	6.1	10.0	100.0
Green-land	3B Manure Management	CH_4	0.2	0.1	10.0	100.0
Green-land	3B Manure Management	N_2O	0.9	0.7	10.0	100.0
Green-land	3D Agricultural soils	N_2O	0.8	1.6	20.0	50.0
Green-land	3G Liming	CO_2	0.0	0.0	5.0	50.0
Green-land	4A Forest	CO_2	0.0	-0.1	5.0	50.0
Green-land	4B Cropland	CO_2	0.0	0.0	5.0	50.0
Green-land	4C Grassland	CO_2	0.2	1.0	5.0	50.0
Green-land	5A Solid Waste Disposal	CH_4	4.3	4.6	10.0	100.0

	IPCC Source category	Gas	Base year emission Input data Gg CO_2 eqv.	2015 emission Input data Gg CO_2 eqv.	Activity data uncertainty Input data %	Emission factor uncertainty Input data %
Greenland	5C Incineration and open burning of waste	CO_2	2.6	3.1	10.0	25.0
Greenland	5C Incineration and open burning of waste	CH_4	2.7	1.9	10.0	50.0
Greenland	5C Incineration and open burning of waste	N_2O	0.7	0.6	10.0	100.0
Greenland	5D Wastewater treatment and discharge	N_2O	7.2	4.2	30.0	100.0

17.4 Key category analysis

A tier 1 key category analysis (KCA) has been carried out on emissions from Denmark and Greenland. The key category analysis for Denmark is included in Chapter 1.5 and Annex 1, and the key category analysis for Greenland is included in Chapter 16.

The KCA for 1990 and 2015 has been carried out in accordance with the IPCC Guidelines 2006. The KCA is based on data available in CRF and thus slightly more aggregated than the KCA carried out for Denmark. The categorisation used results in a total of 138 source categories of which 19 are LULUCF categories.

The KCA for Denmark and Greenland includes a total of six different analyses:

- Base year, reporting year and trend,
- Including and excluding LULUCF.

The six different KCA for Denmark and Greenland point out 19-27 key source categories each and a total of 31 different key source categories. The number of key categories in each of the main sectors is: Energy 15, Industrial processes and product use 4, Agriculture 5, LULUCF 6 and Waste 1.

The KCA for Denmark and Greenland are shown in Annex 8. An overview for all KCA is given in Table 17.3.

Table 17.3 Key Category Analysis for Denmark and Greenland, overview.

IPCC Source Categories		GHG	Level Tier 1 1990 Excl. LULUCF	Level Tier 1 2015 Excl. LULUCF	Trend Tier 1 1990/1995 - 2015 Excl. LULUCF	Level Tier 1 1990 Incl. LULUCF	Level Tier 1 2015 Incl. LULUCF	Trend Tier 1 1990/1995 - 2015 Incl. LULUCF
Energy	1A1 Energy industries, Liquid Fuels	CO_2	7	12	11	8	13	12
Energy	1A1 Energy industries, Solid Fuels	CO_2	1	2	1	1	2	1
Energy	1A1 Energy industries, Gaseous Fuels	CO_2	10	5	4	11	5	5
Energy	1A1 Energy industries, Other Fuels	CO_2	19	10	7	22	11	9
Energy	1A2 Manufacturing industries and construction, Liquid Fuels	CO_2	6	11	6	7	12	7
Energy	1A2 Manufacturing industries and construction, Solid Fuels	CO_2	12	17	8	13	20	8
Energy	1A2 Manufacturing industries and construction, Gaseous Fuels	CO_2	13	9	14	14	10	18
Energy	1A2 Manufacturing industries and construction, Other Fuels	CO_2						
Energy	1A4 Other sectors , Liquid Fuels	CO_2	3	6	2	3	6	2
Energy	1A4 Other sectors , Solid Fuels	CO_2			19			21
Energy	1A4 Other sectors , Gaseous Fuels	CO_2	11	7	13	12	8	15
Energy	1A4 Other sectors , Other Fuels	CO_2						
Energy	1A5 Non-specified, Mobile	CO_2		21			26	
Energy	1A1 Energy industries, Liquid Fuels	CH_4						
Energy	1A1 Energy industries, Solid Fuels	CH_4						
Energy	1A1 Energy industries, Gaseous Fuels	CH_4						
Energy	1A1 Energy industries, Other Fuels	CH_4						
Energy	1A1 Energy industries, Biomass	CH_4						
Energy	1A2 Manufacturing industries and construction, Liquid Fuels	CH_4						
Energy	1A2 Manufacturing industries and construction, Solid Fuels	CH_4						
Energy	1A2 Manufacturing industries and construction, Gaseous Fuels	CH_4						
Energy	1A2 Manufacturing industries and construction, Other Fuels	CH_4						
Energy	1A2 Manufacturing industries and construction, Biomass	CH_4						
Energy	1A4 Other sectors , Liquid Fuels	CH_4						
Energy	1A4 Other sectors , Solid Fuels	CH_4						
Energy	1A4 Other sectors , Gaseous Fuels	CH_4						
Energy	1A4 Other sectors , Other Fuels	CH_4						

IPCC Source Categories		GHG	Level Tier 1 1990 Excl. LULUCF	Level Tier 1 2015 Excl. LULUCF	Trend Tier 1 1990/1995 - 2015 Excl. LULUCF	Level Tier 1 1990 Incl. LULUCF	Level Tier 1 2015 Incl. LULUCF	Trend Tier 1 1990/1995 - 2015 Incl. LULUCF
Energy	1A4 Other sectors , Biomass	CH_4						
Energy	1A5 Non-specified, Mobile	CH_4						
Energy	1A1 Energy industries, Liquid Fuels	N_2O						
Energy	1A1 Energy industries, Solid Fuels	N_2O						
Energy	1A1 Energy industries, Gaseous Fuels	N_2O						
Energy	1A1 Energy industries, Other Fuels	N_2O						
Energy	1A1 Energy industries, Biomass	N_2O						
Energy	1A2 Manufacturing industries and construction, Liquid Fuels	N_2O						
Energy	1A2 Manufacturing industries and construction, Solid Fuels	N_2O						
Energy	1A2 Manufacturing industries and construction, Gaseous Fuels	N_2O						
Energy	1A2 Manufacturing industries and construction, Other Fuels	N_2O						
Energy	1A2 Manufacturing industries and construction, Biomass	N_2O						
Energy	1A4 Other sectors , Liquid Fuels	N_2O						
Energy	1A4 Other sectors , Solid Fuels	N_2O						
Energy	1A4 Other sectors , Gaseous Fuels	N_2O						
Energy	1A4 Other sectors , Other Fuels	N_2O						
Energy	1A4 Other sectors , Biomass	N_2O						
Energy	1A5 Non-specified, Mobile	N_2O						
Energy	1A3. Transport, a Domestic aviation	CO_2						
Energy	1A3. Transport, a Domestic aviation	CH_4						
Energy	1A3. Transport, a Domestic aviation	N_2O						
Energy	1A3. Transport, b Road transportation	CO_2	2	1	3	2	1	3
Energy	1A3. Transport, b Road transportation	CH_4						
Energy	1A3. Transport, b Road transportation	N_2O						
Energy	1A3. Transport, c Railways	CO_2		19			23	
Energy	1A3. Transport, c Railways	CH_4						
Energy	1A3. Transport, c Railways	N_2O						
Energy	1A3. Transport, d Domestic navigation	CO_2	17	18	17	19	21	19
Energy	1A3. Transport, d Domestic navigation	CH_4						
Energy	1A3. Transport, d Domestic navigation	N_2O						

IPCC Source Categories		GHG	Level Tier 1 1990 Excl. LULUCF	Level Tier 1 2015 Excl. LULUCF	Trend Tier 1 1990/1995 - 2015 Excl. LULUCF	Level Tier 1 1990 Incl. LULUCF	Level Tier 1 2015 Incl. LULUCF	Trend Tier 1 1990/1995 - 2015 Incl. LULUCF
Energy	1B Fugitive emissions from fuels, 2a Oil	CO_2						
Energy	1B Fugitive emissions from fuels, 2a Oil	CH_4						
Energy	1B Fugitive emissions from fuels, 2a Oil	N_2O						
Energy	1B Fugitive emissions from fuels, 2b Natural gas	CO_2						
Energy	1B Fugitive emissions from fuels, 2b Natural gas	CH_4						
Energy	1B Fugitive emissions from fuels, 2c Venting gas	CO_2						
Energy	1B Fugitive emissions from fuels, 2c Venting gas	CH_4						
Energy	1B Fugitive emissions from fuels, 2c, Flaring	CO_2		20			24	
Energy	1B Fugitive emissions from fuels, 2c, Flaring	CH_4						
Energy	1B Fugitive emissions from fuels, 2c, Flaring	N_2O						
Industrial processes	2A. Mineral industry, 1 Cement production	CO_2	16	13		18	15	
Industrial processes	2A. Mineral industry, 2 Lime production	CO_2						
Industrial processes	2A. Mineral industry, 3 Glass production	CO_2						
Industrial processes	2A. Mineral industry, 4 Other process uses of carbonates	CO_2						
Industrial processes	2B. Chemical Industry, 2 Nitric acid production	N_2O	14		9	15		10
Industrial processes	2B. Chemical Industry, 10 Other	CO_2						
Industrial processes	2C. Metal industry, 1 Iron and steel production	CO_2						
Industrial processes	2C. Metal industry, 1 Iron and steel production	CH_4						
Industrial processes	2C. Metal industry, 4 Magnesium production	SF_6						
Industrial processes	2C. Metal industry, 5 Lead production	CO_2						
Industrial processes	2D. Non-energy products from fuels and solvent use, 1 Lubricant use	CO_2						
Industrial processes	2D. Non-energy products from fuels and solvent use, 2 Paraffin wax use	CO_2						
Industrial processes	2D. Non-energy products from fuels and solvent use, 2 Paraffin wax use	CH_4						
Industrial processes	2D. Non-energy products from fuels and solvent use, 2 Paraffin wax use	N_2O						
Industrial processes	2D. Non-energy products from fuels and solvent use, 3 Other	CO_2						
Industrial processes	2D. Non-energy products from fuels and solvent use, 3 Other	CH_4						

IPCC Source Categories		GHG	Level Tier 1 1990 Excl. LULUCF	Level Tier 1 2015 Excl. LULUCF	Trend Tier 1 1990/1995 - 2015 Excl. LULUCF	Level Tier 1 1990 Incl. LULUCF	Level Tier 1 2015 Incl. LULUCF	Trend Tier 1 1990/1995 - 2015 Incl. LULUCF
Industrial processes	2E. Electronics industry, 5 Other	HFCs						
Industrial processes	2E. Electronics industry, 5 Other	PFCs						
Industrial processes	2F. Product uses as substitutes for ODS, 1 Refrigeration and air conditioning	HFCs		16	12		18	13
Industrial processes	2F. Product uses as substitutes for ODS, 1 Refrigeration and air conditioning	PFCs						
Industrial processes	2F. Product uses as substitutes for ODS, 2 Foam blowing agents	HFCs						26
Industrial processes	2F. Product uses as substitutes for ODS, 4 Aerosols	HFCs						
Industrial processes	2G. Other product manufacture and use, 1 Electrical equipment	SF_6						
Industrial processes	2G. Other product manufacture and use, 2 SF6 and PFCs from other product use	SF_6						
Industrial processes	2G. Other product manufacture and use, 3 N2O from product uses	N_2O						
Industrial processes	2G. Other product manufacture and use, 4 Other	CO_2						
Industrial processes	2G. Other product manufacture and use, 4 Other	CH_4						
Industrial processes	2G. Other product manufacture and use, 4 Other	N_2O						
Agriculture	3A. Enteric fermentation, -	CH_4	5	4	16	5	4	16
Agriculture	3B. Manure management, -	CH_4	8	8	18	9	9	20
Agriculture	3B. Manure management, -	N_2O	15	14	20	16	16	22
Agriculture	3D. Agricultural soils, -	N_2O	4	3	5	4	3	4
Agriculture	3F. Field burning of agricultural residues, -	CH_4						
Agriculture	3F. Field burning of agricultural residues, -	N_2O						
Agriculture	3G. Liming, -	CO_2	18		15	20		17
Agriculture	3H. Urea application, -	CO_2						
Agriculture	3I. Other carbon-containing fertilizers, -	CO_2						
Waste	5A. Solid waste disposal, -	CH_4	9	15	10	10	17	11
Waste	5B. Biological treatment of solid waste, 1. Composting	CH_4						
Waste	5B. Biological treatment of solid waste, 1. Composting	N_2O						
Waste	5B. Biological treatment of solid waste, 2. Anaerobic digestion at biogas facilities	CH_4						
Waste	5C. Incineration and open burning of waste, 1. Waste incineration	CO_2						

IPCC Source Categories		GHG	Level Tier 1 1990 Excl. LULUCF	Level Tier 1 2015 Excl. LULUCF	Trend Tier 1 1990/1995 - 2015 Excl. LULUCF	Level Tier 1 1990 Incl. LULUCF	Level Tier 1 2015 Incl. LULUCF	Trend Tier 1 1990/1995 - 2015 Incl. LULUCF
Waste	5C. Incineration and open burning of waste, 1. Waste incineration	CH_4						
Waste	5C. Incineration and open burning of waste, 1. Waste incineration	N_2O						
Waste	5C. Incineration and open burning of waste, 2. Open burning of waste	CO_2						
Waste	5C. Incineration and open burning of waste, 2. Open burning of waste	CH_4						
Waste	5C. Incineration and open burning of waste, 2. Open burning of waste	N_2O						
Waste	5D. Wastewater treatment and discharge, 1. Domestic wastewater	CH_4						
Waste	5D. Wastewater treatment and discharge, 1. Domestic wastewater	N_2O						
Waste	5D. Wastewater treatment and discharge, 2. Industrial wastewater	N_2O						
Waste	5E. Other (please specify), -	CO_2						
Waste	5E. Other (please specify), -	CH_4						
LULUCF	4A. Forest land, -	CH_4						
LULUCF	4A. Forest land, -	N_2O						
LULUCF	4A. Forest land, 1. Forest land remaining forest land	CO_2				21	22	23
LULUCF	4A. Forest land, 2. Land converted to forest land	CO_2					19	14
LULUCF	4B. Cropland, 1. Cropland remaining cropland	CO_2				6	7	6
LULUCF	4B. Cropland, 2. Land converted to cropland	CO_2						
LULUCF	4B. Cropland, 2. Land converted to cropland	N_2O						
LULUCF	4C. Grassland, -	CH_4						
LULUCF	4C. Grassland, 1. Grassland remaining grassland	CO_2				17	14	24
LULUCF	4C. Grassland, 1. Grassland remaining grassland	N_2O						
LULUCF	4C. Grassland, 2. Land converted to grassland	CO_2					25	25
LULUCF	4C. Grassland, 2. Land converted to grassland	N_2O						
LULUCF	4D. Wetlands, -	CH_4						
LULUCF	4D. Wetlands, -	N_2O						
LULUCF	4D. Wetlands, 1. Wetlands remaining wetlands	CO_2						

IPCC Source Categories		GHG	Level Tier 1 1990 Excl. LULUCF	Level Tier 1 2015 Excl. LULUCF	Trend Tier 1 1990/1995 - 2015 Excl. LULUCF	Level Tier 1 1990 Incl. LULUCF	Level Tier 1 2015 Incl. LULUCF	Trend Tier 1 1990/1995 - 2015 Incl. LULUCF
LULUCF	4D. Wetlands, 2. Land converted to wetlands	CO_2						
LULUCF	4E. Settlements, 2. Land converted to settlements	CO_2						
LULUCF	4E. Settlements, 2. Land converted to settlements	N_2O						
LULUCF	4G. Harvested wood products, -	CO_2					27	

17.4.1 Key category analysis for KP-LULUCF

The contribution from Greenland to the KP-LULUCF inventory is miniscule the same categories are therefore identified as key as for the submission from Denmark, see Chapter 11.9 for more information.

17.5 Recalculations

17.5.1 Implications for emission levels

The impact of recalculations in the Greenlandic inventory is insignificant compared to the recalculations in the Danish inventory. Therefore the explanations and justifications are not repeated in this Chapter. Detailed information on the recalculations in the Danish inventory is provided in Chapter 9 and in the sectoral Chapters 3-7. The recalculations carried out for the Greenlandic inventory are described in Chapter 16.

17.6 Technical description of the aggregation of the emission inventories of Denmark and Greenland

In order to accommodate the request of the ERT of full inclusion of the Greenlandic emission data in the full CRF format, Denmark operates separate installations for Denmark and Greenland (and the Faroe Islands). The country identification codes provided by the UNFCCC secretariat are DNM for Denmark and GRL for Greenland (FRO for the Faroe Islands). Two additional installations are necessary to enable the submission of aggregated submissions under the Kyoto Protocol (Denmark and Greenland) and under UNFCCC (Denmark, Greenland and the Faroe Islands). The country identification codes provided by the UNFCCC secretariat are DKE for the aggregated submission for Denmark and Greenland and DNK for the UNFCCC submission (Denmark, Greenland and the Faroe Islands).

For the aggregation of the submissions three IT tools are used.

- EU CRF Aggregator developed by the European Environment Agency – Aggregation of global CRF variables
- NERI CRF Aggregator developed by NERI (Now DCE) – Aggregation of local CRF variables
- MS Excel

The three main work processes in connection with the aggregation of the submissions are:

- In the EU CRF Aggregator the following work processes take place:
    - Aggregation of global variables; sum of emissions and activity data, notation keys and comments.
    - As input data the xml submission files from the CRF Reporter installations for DNM (Denmark), GRL (Greenland) and FRO (Faroe Islands) are used.
    - As output file a CRF Reporter xml import file is generated. This file is then imported in the installation for the aggregated submission, DKE (KP) or DNK (UNFCCC).

- In NERI CRF Aggregator the following work processes take place:

  - Aggregation of local variables; sum of emissions and activity data, notation keys and comments. Aggregation of additional information variables either as sums or uniform values.
  - As input data the simple CRF Reporter xml files from the CRF Reporter installations for DNM (Denmark), GRL (Greenland) and FRO (Faroe Islands) are used.
  - As output file a CRF Reporter simple xml import file is generated. This file is then imported in the installation for the aggregated submission, DKE (KP) or DNK (UNFCCC).

- In MS Excel the following work processes take place:
  - Aggregation of additional information variables where average values or weighted average values are used.
  - Aggregation of KP-LULUCF/NIR-1 and KP-LULUCF/NIR-2.
  - The aggregated data is at the moment copy/pasted from the CRF Reporter installations of Denmark and Greenland to Excel aggregated and copy/pasted back to the CRF Reporter installations of the KP submission (DKE).

Efforts are ongoing to ensure the highest possible degree of automation to avoid the risk of errors during the manual work processes.

17.7 QA/QC of the aggregated submission for Denmark and Greenland

The QA/QC procedures for the Danish inventory are described in Chapter 1.6 and the sectoral chapters. Please refer to Chapter 1.6 for a general description of the QA/QC system, and the structural setup of the Danish QA/QC system for the greenhouse gas inventory. The QA/QC procedures carried out by Greenlandic authorities for the Greenlandic inventory are described in Chapter 16. The following focuses on the specific QA/QC measures carried out at DCE both on the data (CRF tables and documentation) received from Greenland and the QC checks carried out for the aggregated versions of the inventory for reporting to the Kyoto Protocol and the UNFCCC. The PM's relevant for this are listed in Table 17.5.

Table 17.5 PM's specific to the handling of Greenlandic emission data and the aggregated submissions.

Data Storage level 4	3.Completeness	DS.4.3.3	Check that no sources where methodology exists in the IPCC guidelines are reported as NE by Greenland.
	4.Consistency	DS.4.4.2	Check time series consistency of the reporting by Greenland prior to aggregating the final submissions.
	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.
		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.
	7.Transparency	DS.4.7.2	Perform QA on the documentation report provided by the Government of Greenland.

Data Storage level 4	3.Completeness	DS.4.3.3	Check that no sources where a methodology exists in the IPCC guidelines or good practice guidance are reported as NE by Greenland

A check is made to filter any NE's from the CRF tables. If any greenhouse gas emissions are reported as NE, it is checked whether methodologies exist in the IPCC guidelines or the IPCC good practice guidance. If methodologies do exist efforts are made to quickly estimate and report emissions. No categories where methodology exists were identified for the submission of Denmark and Greenland.

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.

The check has, since the 2012 submission, been extended to also cover area information reported in the KP-LULUCF tables (NIR-2).

Data Storage level 4	5.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 CRF submission for Denmark and Greenland is checked to see if the additional information has been aggregated correctly. The additional information is mainly related to the agricultural and waste sectors.

Data Storage level 4	7.Transparency	DS.4.7.2	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. NERI 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

Annexes

Annex 1 – Key category analysis

Annex 2 – Assessment of uncertainty

Annex 3 – Other detailed methodological descriptions for individu7al source or sink categories (where relevant)

Annex 3A – Stationary combustion

Annex 3B – Transport and other mobile sources

Annex 3C – Industrial processes and product use

Annex 3D - Agriculture

Annex 3E – LULUCF

Annex 3F - Waste

Annex 4 – Information on the energy statistics

Annex 5 – Assessment of completeness and (potential) sources and sinks of greenhouse gas emissions and removals excluded

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

Annex 7 – Methodology applied for the greenhouse gas inventory for the Faroe Islands

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 2015 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 1990-2015 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, 2015 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 2015, and for the trend 1990-2015.

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 217 emission source categories including 33 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 26-53 key source categories each and a total of 75 different key source categories. The number of key categories in each of the main sectors is: energy 38, IPPU 5, agriculture 13, LULUCF 15 and waste 4.

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 2015 excl. LULUCF, approach 1.
Table A1-7 KCA for Denmark, level assessment 2015 incl. LULUCF, approach 1.
Table A1-8 KCA for Denmark, trend assessment 1990-2015 excl. LULUCF, approach 1.
Table A1-9 KCA for Denmark, trend assessment 1990-2015 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 2015 excl. LULUCF, approach 2.
Table A1-13 KCA for Denmark, level assessment 2015 incl. LULUCF, approach 2.
Table A1-14 KCA for Denmark, trend assessment 1990-2015 excl. LULUCF, approach 2.
Table A1-15 KCA for Denmark, trend assessment 1990-2015 incl. LULUCF, approach 2.

[1] Including and excluding LULUCF.

Table A1-1 Summary of KCA for Denmark, level and trend for 1990-2015, 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 2015**	**Trend Approach 1 1990-2015**	**Level Approach 2 1990**	**Level Approach 2 2015**	**Trend Approach 2 1990-2015**
Energy	1A Stationary combustion, Coal, ETS data	CO_2		2	2			38
Energy	1A Stationary combustion, Coal, no ETS data	CO_2	1	9	1	14		8
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		7	7		36	25
Energy	1A Stationary combustion, Fossil waste, no ETS data	CO_2	20	18	25	33	31	
Energy	1A Stationary combustion, Petroleum coke, ETS data	CO_2		20	12			
Energy	1A Stationary combustion, Petroleum coke, no ETS data	CO_2	25		21			
Energy	1A Stationary combustion, Residual oil, ETS data	CO_2		26	18			
Energy	1A Stationary combustion, Residual oil, no ETS data	CO_2	6		6	32		31
Energy	1A Stationary combustion, Gas oil	CO_2	3	15	5	24		19
Energy	1A Stationary combustion, Kerosene	CO_2	26		23			
Energy	1A Stationary combustion, LPG	CO_2						
Energy	1A1b Stationary combustion, Petroleum refining, Refinery gas	CO_2	14	13	15			
Energy	1A Stationary combustion, Natural gas, onshore	CO_2	5	3	4		28	35
Energy	1A1c_ii Stationary combustion, Oil and gas extraction, Off shore gas turbines, Natural gas	CO_2	24	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	CH_4						

IPCC Source Categories (LULUCF excluded)		GHG	Key categories with number according to ranking in analysis Identification criteria					
			Level Approach 1 1990	Level Approach 1 2015	Trend Approach 1 1990-2015	Level Approach 2 1990	Level Approach 2 2015	Trend Approach 2 1990-2015
	wood and not residential/agricultural straw, Biomass							
Energy	1A4b_i Stationary combustion, Residential wood combustion	CH_4				26	22	26
Energy	1A4b_i/1A4c_i Stationary Combustion, Residential and agricultural straw combustion	CH_4				28	37	
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	29	18
Energy	1A1 Stationary Combustion, Liquid fuels	N_2O						
Energy	1A1 Stationary Combustion, Gaseous fuels	N_2O				30	25	24
Energy	1A1 Stationary Combustion, Waste	N_2O					38	34
Energy	1A1 Stationary Combustion, Biomass	N_2O					21	15
Energy	1A2 Stationary Combustion, Solid fuels	N_2O						
Energy	1A2 Stationary Combustion, Liquid fuels	N_2O				17	32	13
Energy	1A2 Stationary Combustion, Gaseous fuels	N_2O					30	40
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				25		23
Energy	1A4 Stationary Combustion, Gaseous fuels	N_2O					27	36
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					15	9
Energy	1A4b_i/1A4c_i Stationary Combustion, Residential and agricultural straw combustion	N_2O						
Energy	1.A.2.g Industry (mobile)	CO_2	18	14	22	18	13	16
Energy	1.A.3.a Civil aviation	CO_2		34				
Energy	1.A.3.b Road Transport	CO_2	2	1	3	11	6	6
Energy	1.A.3.c Railways	CO_2		27				
Energy	1.A.3.d Navigation (large vessels)	CO_2	16	25		29		

IPCC Source Categories (LULUCF excluded)		GHG	Key categories with number according to ranking in analysis Identification criteria					
			Level Approach 1 1990	Level Approach 1 2015	Trend Approach 1 1990-2015	Level Approach 2 1990	Level Approach 2 2015	Trend Approach 2 1990-2015
Energy	1.A.4.a Commercial/Institutional (mobile)	CO_2		30			35	32
Energy	1.A.4.b Residential (mobile)	CO_2						
Energy	1.A.4.c ii Agriculture (mobile)	CO_2	10	8	26	15	14	29
Energy	1.A.4.c ii Forestry (mobile)	CO_2						
Energy	1.A.4.c iii Fisheries	CO_2	19	22				
Energy	1.A.5.b Other (military)	CO_2						43
Energy	1.A.5.b Other (small boats)	CO_2						
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				31	26	33
Energy	1.A.3.a Civil aviation	N_2O						
Energy	1.A.3.b Road Transport	N_2O					34	39
Energy	1.A.3.c Railways	N_2O						
Energy	1.A.3.d Navigation (large vessels)	N_2O						
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	19	30
Energy	1.A.4.c ii Forestry (mobile)	N_2O						
Energy	1.A.4.c iii Fisheries	N_2O						
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						

IPCC Source Categories (LULUCF excluded)		GHG	Key categories with number according to ranking in analysis Identification criteria					
			Level Approach 1 1990	**Level Approach 1 2015**	**Trend Approach 1 1990-2015**	**Level Approach 2 1990**	**Level Approach 2 2015**	**Trend Approach 2 1990-2015**
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	28				
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	21
IPPU	2A1 Cement production	CO_2	13	12	17			
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						37
IPPU	Paint Application	CO_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 2015**	**Trend Approach 1 1990-2015**	**Level Approach 2 1990**	**Level Approach 2 2015**	**Trend Approach 2 1990-2015**
IPPU	Degreasing, dry cleaning and electronics	CO_2						
IPPU	Chemical products manufacturing or processing	CO_2						
IPPU	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	12		11	19		11
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	2E Electronics industry	HFCs						
IPPU	2F1 Refrigeration and air conditioning	HFCs		21	13		12	4
IPPU	2F2 Foam blowing agents	HFCs				27		27
IPPU	2F4 Aerosols	HFCs						
IPPU	2E Electronics industry	PFCs						
IPPU	2F1 Refrigeration and air conditioning	PFCs						
IPPU	2C4 Magnesium production	SF6						
IPPU	2G1 Electrical equipment	SF6						
IPPU	2G2 SF6 and PFCs from other product use	SF6						
Agriculture	3A Enteric Fermentation	CH_4	4	4	9	4	4	10
Agriculture	3B Manure Management	CH_4	8	5	10	12	11	12
Agriculture	3F Field Burning of Agricultural Residues	CH_4						
Agriculture	3B Manure Management	N_2O	15	19		5	7	28
Agriculture	3B5 Atmospheric deposition	N_2O		33		21	20	
Agriculture	3Da1 Inorganic N fertilizer	N_2O	7	11	16	1	2	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 2015**	**Trend Approach 1 1990-2015**	**Level Approach 2 1990**	**Level Approach 2 2015**	**Trend Approach 2 1990-2015**
Agriculture	3Da2a Animal manure applied to soils	N_2O	11	10	19	3	1	3
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	29		16	16	41
Agriculture	3Da4 Crop Residues	N_2O	21	16	20	7	5	5
Agriculture	3Da5 Mineralization	N_2O				22		20
Agriculture	3Da6 Cultivation of organic soils	N_2O	17	23		6	8	
Agriculture	3Db1 Atmospheric deposition	N_2O	27	32		13	18	22
Agriculture	3Db2 Leaching	N_2O	23	24		9	10	
Agriculture	3F Field Burning of Agricultural Residues	N_2O						
Agriculture	3G Liming	CO_2	22	31	24	8	17	7
Agriculture	3H Urea applicaton	CO_2						
Agriculture	3I Other carbon-containing fertilizers	CO_2						
Waste	5.E Accidental fires	CO_2					33	42
Waste	5.A Solid waste disposal	CH_4	9	17	14	2	3	1
Waste	5.B.1 Composting	CH_4					23	17
Waste	5.B.2. Anaerobic digestion at biogas facilities	CH_4						
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					24	14
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 1990-2015, 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 2015	Trend Approach 1 1990-2015	Level Approach 2 1990	Level Approach 2 2015	Trend Approach 2 1990-2015
Energy	1A Stationary combustion, Coal, ETS data	CO_2		2	2			49
Energy	1A Stationary combustion, Coal, no ETS data	CO_2	1	12	1	17		9
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	9		46	34
Energy	1A Stationary combustion, Fossil waste, no ETS data	CO_2	23	22	31		40	
Energy	1A Stationary combustion, Petroleum coke, ETS data	CO_2		24	15			
Energy	1A Stationary combustion, Petroleum coke, no ETS data	CO_2	29		26			
Energy	1A Stationary combustion, Residual oil, ETS data	CO_2		34	24			
Energy	1A Stationary combustion, Residual oil, no ETS data	CO_2	7		7			42
Energy	1A Stationary combustion, Gas oil	CO_2	3	19	5	27		24
Energy	1A Stationary combustion, Kerosene	CO_2	30		28			
Energy	1A Stationary combustion, LPG	CO_2						
Energy	1A1b Stationary combustion, Petroleum refining, Refinery gas	CO_2	16	16	22			
Energy	1A Stationary combustion, Natural gas, onshore	CO_2	6	3	4		35	47
Energy	1A1c_ii Stationary combustion, Oil and gas extraction, Off shore gas turbines, Natural gas	CO_2	28	9	10			
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						

IPCC Source Categories (LULUCF included)		GHG	Key categories with number according to ranking in analysis Identification criteria					
			Level Approach 1 1990	Level Approach 1 2015	Trend Approach 1 1990-2015	Level Approach 2 1990	Level Approach 2 2015	Trend Approach 2 1990-2015
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				29	27	36
Energy	1A4b_i/1A4c_i Stationary Combustion, Residential and agricultural straw combustion	CH_4				32	49	
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	38	22
Energy	1A1 Stationary Combustion, Liquid fuels	N_2O						
Energy	1A1 Stationary Combustion, Gaseous fuels	N_2O				34	30	33
Energy	1A1 Stationary Combustion, Waste	N_2O						45
Energy	1A1 Stationary Combustion, Biomass	N_2O					24	17
Energy	1A2 Stationary Combustion, Solid fuels	N_2O						
Energy	1A2 Stationary Combustion, Liquid fuels	N_2O				20	41	14
Energy	1A2 Stationary Combustion, Gaseous fuels	N_2O					39	53
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				28		31
Energy	1A4 Stationary Combustion, Gaseous fuels	N_2O					34	48
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					18	10
Energy	1A4b_i/1A4c_i Stationary Combustion, Residential and agricultural straw combustion	N_2O						
Energy	1.A.2.g Industry (mobile)	CO_2	21	18	29	21	16	19
Energy	1.A.3.a Civil aviation	CO_2						
Energy	1.A.3.b Road Transport	CO_2	2	1	3	12	7	7
Energy	1.A.3.c Railways	CO_2	34	35				

IPCC Source Categories (LULUCF included)		GHG	Key categories with number according to ranking in analysis Identification criteria					
			Level Approach 1 1990	Level Approach 1 2015	Trend Approach 1 1990-2015	Level Approach 2 1990	Level Approach 2 2015	Trend Approach 2 1990-2015
Energy	1.A.3.d Navigation (large vessels)	CO_2	18	33	35	33		
Energy	1.A.4.a Commercial/Institutional (mobile)	CO_2		40			45	43
Energy	1.A.4.b Residential (mobile)	CO_2						
Energy	1.A.4.c ii Agriculture (mobile)	CO_2	11	11	32	18	17	41
Energy	1.A.4.c ii Forestry (mobile)	CO_2						
Energy	1.A.4.c iii Fisheries	CO_2	22	26				
Energy	1.A.5.b Other (military)	CO_2						
Energy	1.A.5.b Other (small boats)	CO_2						
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				35	33	44
Energy	1.A.3.a Civil aviation	N_2O						
Energy	1.A.3.b Road Transport	N_2O					44	51
Energy	1.A.3.c Railways	N_2O						
Energy	1.A.3.d Navigation (large vessels)	N_2O						
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	22	40
Energy	1.A.4.c ii Forestry (mobile)	N_2O						
Energy	1.A.4.c iii Fisheries	N_2O						
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						

IPCC Source Categories (LULUCF included)		GHG	Key categories with number according to ranking in analysis Identification criteria					
			Level Approach 1 1990	Level Approach 1 2015	Trend Approach 1 1990-2015	Level Approach 2 1990	Level Approach 2 2015	Trend Approach 2 1990-2015
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	32	36				
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				11	10	32
IPPU	2A1 Cement production	CO_2	14	15	23			
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						50
IPPU	Paint Application	CO_2						
IPPU	Degreasing, dry cleaning and electronics	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 2015	Trend Approach 1 1990-2015	Level Approach 2 1990	Level Approach 2 2015	Trend Approach 2 1990-2015
IPPU	Chemical products manufacturing or processing	CO_2						
IPPU	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		14	22		11
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	2E Electronics industry	HFCs						
IPPU	2F1 Refrigeration and air conditioning	HFCs		25	16		15	4
IPPU	2F2 Foam blowing agents	HFCs				30		35
IPPU	2F4 Aerosols	HFCs						
IPPU	2E Electronics industry	PFCs						
IPPU	2F1 Refrigeration and air conditioning	PFCs						
IPPU	2C4 Magnesium production	SF6						
IPPU	2G1 Electrical equipment	SF6						
IPPU	2G2 SF6 and PFCs from other product use	SF6						
Agriculture	3A Enteric Fermentation	CH_4	4	4	12	5	5	12
Agriculture	3B Manure Management	CH_4	9	8	13	15	12	13
Agriculture	3F Field Burning of Agricultural Residues	CH_4						
Agriculture	3B Manure Management	N_2O	17	23		6	8	38
Agriculture	3B5 Atmospheric deposition	N_2O		44		24	23	
Agriculture	3Da1 Inorganic N fertilizer	N_2O	8	14	21	2	3	3
Agriculture	3Da2a Animal manure applied to soils	N_2O	12	13	25	4	2	5
Agriculture	3Da2b Sewage sludge applied to soils	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 2015	Trend Approach 1 1990-2015	Level Approach 2 1990	Level Approach 2 2015	Trend Approach 2 1990-2015
Agriculture	3Da2c Other organic fertilizer applied to soils	N_2O						
Agriculture	3Da3 Urine and dung deposited by grazing animals	N_2O	33	38		19	19	52
Agriculture	3Da4 Crop Residues	N_2O	25	20	27	8	6	6
Agriculture	3Da5 Mineralization	N_2O				25		25
Agriculture	3Da6 Cultivation of organic soils	N_2O	20	28		7	9	
Agriculture	3Db1 Atmospheric deposition	N_2O	31	42		16	21	30
Agriculture	3Db2 Leaching	N_2O	27	31		10	11	
Agriculture	3F Field Burning of Agricultural Residues	N_2O						
Agriculture	3G Liming	CO_2	26	41	30	9	20	8
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	19	6	8		26	23
LULUCF	4.A.1 Forest land remaining forest land, Dead organic matter	CO_2		7	6		31	18
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		45		31	37	
LULUCF	4.A.2 Land converted to forest land	CO_2		27	17		42	29
LULUCF	4.B.1 Cropland remaining cropland, Living biomass	CO_2		32	18		47	26
LULUCF	4.B.1 Cropland remaining cropland, Mineral soils	CO_2	24	29	11	13	14	1
LULUCF	4.B.1 Cropland remaining cropland, Organic soils	CO_2	5	5		1	1	
LULUCF	4.B.2 Forest land converted to cropland	CO_2		43			36	28
LULUCF	4.B.2 Other land uses converted to cropland	CO_2		37	33		32	21
LULUCF	4.C.1 Grassland remaining grassland, Living biomass	CO_2		30	20			
LULUCF	4.C.1 Grassland remaining grassland, Organic soils	CO_2	15	17	36	14	13	27
LULUCF	4.C.2 Forest land converted to grassland	CO_2						39
LULUCF	4.C.2 Other land uses converted to grassland	CO_2					48	37
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.D.2. Land converted to wetlands	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						46
LULUCF	4.G Harvested wood products	CO_2		39	34		25	15
LULUCF	4(II) Cropland on organic soils	CH_4						
LULUCF	4(II) Grassland on organic soils	CH_4						
LULUCF	4(II) A. Forest land, organic soils	CH_4						

IPCC Source Categories (LULUCF included)		GHG	Key categories with number according to ranking in analysis Identification criteria					
			Level Approach 1 1990	Level Approach 1 2015	Trend Approach 1 1990-2015	Level Approach 2 1990	Level Approach 2 2015	Trend Approach 2 1990-2015
LULUCF	4(II) Land converted to wetlands	CH_4						
LULUCF	4(II) Peatland	CH_4						
LULUCF	4(V) Biomass Burning	CH_4						
LULUCF	4(III) Mineralization/immobilization, Forest land	N_2O						
LULUCF	4(III) Mineralization/immobilization, Cropland	N_2O						
LULUCF	4(III) Mineralization/immobilization, Grassland	N_2O						
LULUCF	4(III) Mineralization/immobilization, Land converted to Settlements	N_2O						
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					43	
Waste	5.A Solid waste disposal	CH_4	10	21	19	3	4	2
Waste	5.B.1 Composting	CH_4					28	20
Waste	5.B.2. Anaerobic digestion at biogas facilities	CH_4						
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	16
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 1990	Level Approach 1 2015	Trend Approach 1 1990-2015	Level Approach 2 1990	Level Approach 2 2015	Trend Approach 2 1990-2015
Excluding LULUCF	29	34	26	33	38	43
Including LULUCF	34	45	36	35	49	53

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/greenhouse-gases-nir/

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/greenhouse-gases-nir/

Table A1-6 KCA for Denmark, level assessment 2015 excl. LULUCF, approach 1.
This table is available at:
http://envs.au.dk/videnudveksling/luft/emissioner/supporting_documentation/greenhouse-gases-nir/

Table A1-7 KCA for Denmark, level assessment 2015 incl. LULUCF, approach 1.
This table is available at:
http://envs.au.dk/videnudveksling/luft/emissioner/supporting_documentation/greenhouse-gases-nir/

Table A1-8 KCA for Denmark, trend assessment 1990-2015 excl. LULUCF, approach 1.
This table is available at:
http://envs.au.dk/videnudveksling/luft/emissioner/supporting_documentation/greenhouse-gases-nir/

Table A1-9 KCA for Denmark, trend assessment 1990-2015 incl. LULUCF, approach 1.
This table is available at:
http://envs.au.dk/videnudveksling/luft/emissioner/supporting_documentation/greenhouse-gases-nir/

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/greenhouse-gases-nir/

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/greenhouse-gases-nir/

Table A1-12 KCA for Denmark, level assessment 2015 excl. LULUCF, approach 2.
This table is available at:
http://envs.au.dk/videnudveksling/luft/emissioner/supporting_documentation/greenhouse-gases-nir/

Table A1-13 KCA for Denmark, level assessment 2015 incl. LULUCF, approach 2.
This table is available at:

http://envs.au.dk/videnudveksling/luft/emissioner/supporting_documentation/greenhouse-gases-nir/

Table A1-14 KCA for Denmark, trend assessment 1990-2015 excl. LULUCF, approach 2. This table is available at:
http://envs.au.dk/videnudveksling/luft/emissioner/supporting_documentation/greenhouse-gases-nir/

Table A1-15 KCA for Denmark, trend assessment 1990-2015 incl. LULUCF, approach 2. This table is available at:
http://envs.au.dk/videnudveksling/luft/emissioner/supporting_documentation/greenhouse-gases-nir/

Annex 2 - Assessment of uncertainty

Description of methodology used for identifying uncertainties

For the inventory of Denmark, the uncertainties are estimated using Approach 1 of the 2006 IPCC Guidelines.

More information and the results are provided in Chapter 1.7.

The underlying table corresponding to Table 3.3 of volume 1 of the 2006 IPCC Guidelines is very large and not suitable for incorporation in a text document. The table in Excel format can be found at http://envs.au.dk/videnudveksling/luft/emissioner/supporting-documentation/greenhouse-gases-nir/.

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
Annex 3A-2:	Fuel rate
Annex 3A-3:	Default Lower Calorific Value (LCV) of fuels and fuel correspondence list
Annex 3A-4:	Emission factors
Annex 3A-5:	Large point sources
Annex 3A-6:	Adjustment of CO_2 emission
Annex 3A-7:	Uncertainty estimates
Annex 3A-8:	Emission inventory 2015 based on SNAP sectors
Annex 3A-9:	EU ETS data

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 1990-2015, 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	SUB-BITUMINOUS										
	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	63.8	67.4	58.6	64.6	56.5	56.3	60.8	53.9	51.3	50.4
	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	2.8	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	BIO OIL	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	2.0	2.4	2.7	2.7
	310A	BIO GASIF GAS					0.1	0.0	0.0	0.0	0.0	0.0
	315A	BIONATGAS										
Total			**501.3**	**612.1**	**552.4**	**583.2**	**625.6**	**602.9**	**759.6**	**655.5**	**618.1**	**589.4**

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	SUB-BITUMINOUS										
	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	44.1	46.3	41.2	41.4	38.2	34.2	29.5	25.3	25.0	27.4
	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	14.1	15.0
GAS	301A	NATURAL GAS	186.1	193.8	193.6	195.9	195.1	187.4	191.1	171.0	173.0	165.7
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	BIO OIL	0.0	0.2	0.1	0.4	0.6	0.8	1.1	1.2	1.8	1.7
	309A	BIOGAS	2.9	3.0	3.4	3.6	3.7	3.8	3.9	3.9	3.9	4.2
	310A	BIO GASIF GAS	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.3
	315A	BIONATGAS										
Total			**547.1**	**573.4**	**571.7**	**631.2**	**571.6**	**535.1**	**621.0**	**562.4**	**535.1**	**527.7**

Continued								
Sum of Fuel_rate_PJ			Year					
fuel_type	**fuel_id**	**fuel_gr_abbr**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**
SOLID	101A	ANODIC CARBON	0.0	0.0	0.0	0.0		
	102A	COAL	163.0	135.5	105.6	135.0	107.0	75.9
	103A	SUB-BITUMINOUS		0.0	0.1	0.1	0.0	0.0
	106A	BROWN COAL BRI.	0.0	0.0	0.0	0.0	0.0	
	107A	COKE OVEN COKE	0.7	0.7	0.6	0.6	0.6	0.5
LIQUID	110A	PETROLEUM COKE	5.1	6.5	6.7	6.1	6.6	6.6
	203A	RESIDUAL OIL	13.0	8.0	7.3	5.7	4.5	4.1
	204A	GAS OIL	27.0	20.9	17.3	15.4	8.2	9.4
	206A	KEROSENE	0.1	0.0	0.0	0.0	0.0	0.0
	225A	ORIMULSION						
	303A	LPG	1.5	1.4	1.5	1.3	0.9	1.4
	308A	REFINERY GAS	14.3	13.7	14.8	14.8	15.4	16.2
GAS	301A	NATURAL GAS	186.0	157.5	147.3	139.5	119.5	120.8
WASTE	114A	WASTE	36.8	36.7	35.9	35.7	36.9	37.7
	115A	INDUSTR. WASTES	1.4	1.7	1.5	1.8	1.8	2.5
BIOMASS	111A	WOOD	81.3	78.8	81.8	81.3	80.2	85.7
	117A	STRAW	23.3	20.2	18.3	20.3	18.4	19.2
	215A	BIO OIL	2.0	0.8	1.1	0.9	0.7	0.6
	309A	BIOGAS	4.3	4.1	4.4	4.6	5.1	5.2
	310A	BIO GASIF GAS	0.2	0.3	0.4	0.4	0.4	0.5
	315A	BIONATGAS					0.3	1.0
Total			**560.0**	**486.9**	**444.6**	**463.3**	**406.7**	**387.4**

Table 3A-2.2 Detailed fuel consumption data for stationary combustion plants, 1990-2015, 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 2016a).

		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Crude Oil, Average	GJ pr tonne	42.40	42.40	42.40	42.70	42.70	42.70	42.70	43.00	43.00	43.00
Crude Oil, Golf	GJ pr 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 pr tonne	42.70	42.70	42.70	42.70	42.70	42.70	42.70	43.00	43.00	43.00
Refinery Feedstocks	GJ pr tonne	41.60	41.60	41.60	41.60	41.60	41.60	41.60	42.70	42.70	42.70
Refinery Gas	GJ pr tonne	52.00	52.00	52.00	52.00	52.00	52.00	52.00	52.00	52.00	52.00
LPG	GJ pr tonne	46.00	46.00	46.00	46.00	46.00	46.00	46.00	46.00	46.00	46.00
Naphtha (LVN)	GJ pr tonne	44.50	44.50	44.50	44.50	44.50	44.50	44.50	44.50	44.50	44.50
Motor Gasoline	GJ pr tonne	43.80	43.80	43.80	43.80	43.80	43.80	43.80	43.80	43.80	43.80
Aviation Gasoline	GJ pr tonne	43.80	43.80	43.80	43.80	43.80	43.80	43.80	43.80	43.80	43.80
JP4	GJ pr tonne	43.80	43.80	43.80	43.80	43.80	43.80	43.80	43.80	43.80	43.80
Other Kerosene	GJ pr tonne	43.50	43.50	43.50	43.50	43.50	43.50	43.50	43.50	43.50	43.50
JP1	GJ pr 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 pr tonne	42.70	42.70	42.70	42.70	42.70	42.70	42.70	42.70	42.70	42.70
Fuel Oil	GJ pr tonne	40.40	40.40	40.40	40.40	40.40	40.40	40.70	40.65	40.65	40.65
Orimulsion	GJ pr tonne	27.60	27.60	27.60	27.60	27.60	28.13	28.02	27.72	27.84	27.58
Petroleum Coke	GJ pr tonne	31.40	31.40	31.40	31.40	31.40	31.40	31.40	31.40	31.40	31.40
Waste Oil	GJ pr tonne	41.90	41.90	41.90	41.90	41.90	41.90	41.90	41.90	41.90	41.90
White Spirit	GJ pr tonne	43.50	43.50	43.50	43.50	43.50	43.50	43.50	43.50	43.50	43.50
Bitumen	GJ pr tonne	39.80	39.80	39.80	39.80	39.80	39.80	39.80	39.80	39.80	39.80
Lubricants	GJ pr tonne	41.90	41.90	41.90	41.90	41.90	41.90	41.90	41.90	41.90	41.90
Natural Gas	GJ pr 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 pr 1000 m^3							17.00	17.00	17.00	17.00
Electricity Plant Coal	GJ pr 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 pr tonne	26.10	26.50	26.50	26.50	26.50	26.50	26.50	26.50	26.50	26.50
Coke	GJ pr 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 pr tonne	18.30	18.30	18.30	18.30	18.30	18.30	18.30	18.30	18.30	18.30
Straw	GJ pr tonne	14.50	14.50	14.50	14.50	14.50	14.50	14.50	14.50	14.50	14.50
Wood Chips	GJ pr 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 pr m^3	9.30	9.30	9.30	9.30	9.30	9.30	9.30	9.30	9.30	9.30
Firewood, Hardwood	GJ pr 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 pr tonne	7.60	7.60	7.60	7.60	7.60	7.60	7.60	7.60	7.60	7.60
Wood Pellets	GJ pr tonne	17.50	17.50	17.50	17.50	17.50	17.50	17.50	17.50	17.50	17.50
Wood Waste	GJ pr Cubic metre	14.70	14.70	14.70	14.70	14.70	14.70	14.70	14.70	14.70	14.70
Wood Waste	GJ pr 1000 m^3	3.20	3.20	3.20	3.20	3.20	3.20	3.20	3.20	3.20	3.20
Biogas	GJ pr tonne								23.00	23.00	23.00
Wastes	GJ pr tonne	8.20	8.20	9.00	9.40	9.40	10.00	10.50	10.50	10.50	10.50
Bioethanol	GJ pr tonne	26.70	26.70	26.70	26.70	26.70	26.70	26.70	26.70	26.70	26.70
Liquid Biofuels	GJ pr tonne	37.60	37.60	37.60	37.60	37.60	37.60	37.60	37.60	37.60	37.60
Bio Oil	GJ pr 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 pr 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 pr 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 pr tonne	43.00	43.00	43.00	43.00	43.00	43.00	43.00	43.00	43.00	43.00
Refinery Feedstocks	GJ pr tonne	42.70	42.70	42.70	42.70	42.70	42.70	42.70	42.70	42.70	42.70
Refinery Gas	GJ pr tonne	52.00	52.00	52.00	52.00	52.00	52.00	52.00	52.00	52.00	52.00
LPG	GJ pr tonne	46.00	46.00	46.00	46.00	46.00	46.00	46.00	46.00	46.00	46.00
Naphtha (LVN)	GJ pr tonne	44.50	44.50	44.50	44.50	44.50	44.50	44.50	44.50	44.50	44.50
Motor Gasoline	GJ pr tonne	43.80	43.80	43.80	43.80	43.80	43.80	43.80	43.80	43.80	43.80
Aviation Gasoline	GJ pr tonne	43.80	43.80	43.80	43.80	43.80	43.80	43.80	43.80	43.80	43.80
JP4	GJ pr tonne	43.80	43.80	43.80	43.80	43.80	43.80	43.80	43.80	43.80	43.80
Other Kerosene	GJ pr tonne	43.50	43.50	43.50	43.50	43.50	43.50	43.50	43.50	43.50	43.50
JP1	GJ pr 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 pr tonne	42.70	42.70	42.70	42.70	42.70	42.70	42.70	42.70	42.70	42.70
Fuel Oil	GJ pr tonne	40.65	40.65	40.65	40.65	40.65	40.65	40.65	40.65	40.65	40.65
Orimulsion	GJ pr tonne	27.62	27.64	27.71	27.65	27.65	27.65	27.65	27.65	27.65	27.65
Petroleum Coke	GJ pr tonne	31.40	31.40	31.40	31.40	31.40	31.40	31.40	31.40	31.40	31.40
Waste Oil	GJ pr tonne	41.90	41.90	41.90	41.90	41.90	41.90	41.90	41.90	41.90	41.90
White Spirit	GJ pr tonne	43.50	43.50	43.50	43.50	43.50	43.50	43.50	43.50	43.50	43.50
Bitumen	GJ pr tonne	39.80	39.80	39.80	39.80	39.80	39.80	39.80	39.80	39.80	39.80
Lubricants	GJ pr tonne	41.90	41.90	41.90	41.90	41.90	41.90	41.90	41.90	41.90	41.90
Natural Gas	GJ pr 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 pr 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 pr 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 pr tonne	26.50	26.50	26.50	26.50	26.50	26.50	26.50	26.50	25.81	25.13
Coke	GJ pr 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 pr tonne	18.30	18.30	18.30	18.30	18.30	18.30	18.30	18.30	18.30	18.30
Straw	GJ pr tonne	14.50	14.50	14.50	14.50	14.50	14.50	14.50	14.50	14.50	14.50
Wood Chips	GJ pr 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 pr m^3	9.30	9.30	9.30	9.30	9.30	9.30	9.30	9.30	9.30	9.30
Firewood, Hardwood	GJ pr 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 pr tonne	7.60	7.60	7.60	7.60	7.60	7.60	7.60	7.60	7.60	7.60
Wood Pellets	GJ pr tonne	17.50	17.50	17.50	17.50	17.50	17.50	17.50	17.50	17.50	17.50
Wood Waste	GJ pr Cubic metre	14.70	14.70	14.70	14.70	14.70	14.70	14.70	14.70	14.70	14.70
Wood Waste	GJ pr 1000 m^3	3.20	3.20	3.20	3.20	3.20	3.20	3.20	3.20	3.20	3.20
Biogas	GJ pr tonne	23.00	23.00	23.00	23.00	23.00	23.00	23.00	23.00	23.00	23.00
Wastes	GJ pr tonne	10.50	10.50	10.50	10.50	10.50	10.50	10.50	10.50	10.50	10.50
Bioethanol	GJ pr tonne	26.70	26.70	26.70	26.70	26.70	26.70	26.70	26.70	26.70	26.70
Liquid Biofuels	GJ pr tonne	37.60	37.60	37.60	37.60	37.60	37.60	37.60	37.60	37.50	37.50
Bio Oil	GJ pr 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	2014	2015
Crude Oil, Average	GJ pr tonne	43.00	43.00	43.00	43.00	43.00	43.00
Crude Oil, Golf	GJ pr tonne	41.80	41.80	41.80	41.80	41.80	41.80
Crude Oil, North Sea	GJ pr tonne	43.00	43.00	43.00	43.00	43.00	43.00
Refinery Feedstocks	GJ pr tonne	42.70	42.70	42.70	42.70	42.70	42.70
Refinery Gas	GJ pr tonne	52.00	52.00	52.00	52.00	52.00	52.00
LPG	GJ pr tonne	46.00	46.00	46.00	46.00	46.00	46.00
Naphtha (LVN)	GJ pr tonne	44.50	44.50	44.50	44.50	44.50	44.50
Motor Gasoline	GJ pr tonne	43.80	43.80	43.80	43.80	43.80	43.80
Aviation Gasoline	GJ pr tonne	43.80	43.80	43.80	43.80	43.80	43.80
JP4	GJ pr tonne	43.80	43.80	43.80	43.80	43.80	43.80
Other Kerosene	GJ pr tonne	43.50	43.50	43.50	43.50	43.50	43.50
JP1	GJ pr tonne	43.50	43.50	43.50	43.50	43.50	43.50
Gas/Diesel Oil	GJ pr tonne	42.70	42.70	42.70	42.70	42.70	42.70
Fuel Oil	GJ pr tonne	40.65	40.65	40.65	40.65	40.65	40.65
Orimulsion	GJ pr tonne	27.65	27.65	27.65	27.65	27.65	27.65
Petroleum Coke	GJ pr tonne	31.40	31.40	31.40	31.40	31.40	31.40
Waste Oil	GJ pr tonne	41.90	41.90	41.90	41.90	41.90	41.90
White Spirit	GJ pr tonne	43.50	43.50	43.50	43.50	43.50	43.50
Bitumen	GJ pr tonne	39.80	39.80	39.80	39.80	39.80	39.80
Lubricants	GJ pr tonne	41.90	41.90	41.90	41.90	41.90	41.90
Natural Gas	GJ pr 1000 Nm3	39.46	39.51	39.55	38.99	39.53	39.64
Town Gas	GJ pr 1000 m3	21.35	21.37	19.30	19.31	20.10	20.31
Electricity Plant Coal	GJ pr tonne	24.44	24.38	24.23	24.49	24.70	24.10
Other Hard Coal	GJ pr tonne	24.44	24.38	24.23	24.49	24.70	24.10
Coke	GJ pr tonne	29.30	29.30	29.30	29.30	29.30	29.30
Brown Coal Briquettes	GJ pr tonne	18.30	18.30	18.30	18.30	18.30	18.30
Straw	GJ pr tonne	14.50	14.50	14.50	14.50	14.50	14.50
Wood Chips	GJ pr Cubic metre	2.80	2.80	2.80	2.80	2.80	2.80
Wood Chips	GJ pr m3	9.30	9.30	9.30	9.30	9.30	9.30
Firewood, Hardwood	GJ pr m3	10.40	10.40	10.40	10.40	10.40	10.40
Firewood, Conifer	GJ pr tonne	7.60	7.60	7.60	7.60	7.60	7.60
Wood Pellets	GJ pr tonne	17.50	17.50	17.50	17.50	17.50	17.50
Wood Waste	GJ pr Cubic metre	14.70	14.70	14.70	14.70	14.70	14.70
Wood Waste	GJ pr 1000 m3	3.20	3.20	3.20	3.20	3.20	3.20
Biogas	GJ pr tonne	23.00	23.00	23.00	23.00	23.00	23.00
Wastes	GJ pr tonne	10.50	10.50	10.50	10.60	10.60	10.60
Bioethanol	GJ pr tonne	26.70	26.70	26.70	26.70	26.70	26.70
Liquid Biofuels	GJ pr tonne	37.50	37.50	37.50	37.50	37.50	37.50
Bio Oil	GJ pr tonne	37.20	37.20	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 simil.	Biomass
Wood Pellets	Wood and simil.	Biomass
Wood Chips	Wood and simil.	Biomass
Firewood, Hardwood & Conifer	Wood and simil.	Biomass
Waste Combustion (biomass)	Municip. 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 gasif. gas	Biomass
Biogas upgraded for distribution in the natural gas grid	Bio-natural gas	Biomass
Waste Combustion (fossil)	Fossil waste	Other fuel

Annex 3A-4 Emission factors

Table 3A-4.1 CO_2 emission factors, 2015.

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		94.46 1)	Country specific	Solid
Coal, Other source categories		94.6 3)	IPCC (2006)	Solid
Brown coal briquettes		97.5	IPCC (2006)	Solid
Coke oven coke		107 3)	IPCC (2006)	Solid
Other solid fossil fuels 6)		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		79.17 1)	Country-specific	Liquid
Residual oil, other source categories		78.6 3)	Country-specific	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		57.508	Country-specific	Liquid
Natural gas, off shore gas turbines		57.615	Country-specific	Gas
Natural gas, other		56.06	Country-specific	Gas
Waste	75.1 3)4)	+ 37 3)4)	Country-specific	Biomass and Other fuels
Straw	100		IPCC (2006)	Biomass
Wood	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
Bio-natural gas	55.55		Country-specific	Biomass

1) Plant specific data from EU ETS incorporated for individual plants.
2) Not applied in 2015. 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 corresponding IEF for CO_2, Other fuels is 82.22 kg CO_2 per GJ fossil waste (not including plant specific data).
5) Includes a high content of CO_2 in the gas.
6) Anodic carbon. Not applied in Denmark in 2015.

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 1990-2015.

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	78.6	57.6	57.469	56.9	86.7
1991	94	78.6	57.6	57.469	56.9	86.7
1992	94	78.6	57.6	57.469	56.9	84.2
1993	94	78.6	57.6	57.469	56.9	83.0
1994	94	78.6	57.6	57.469	56.9	83.0
1995	94	78.6	57.6	57.469	56.9	81.1
1996	94	78.6	57.6	57.469	56.9	79.6
1997	94	78.6	57.6	57.469	56.9	79.6
1998	94	78.6	57.6	57.469	56.9	79.6
1999	94	78.6	57.6	57.469	56.9	79.6
2000	94	78.6	57.6	57.469	57.1	79.6
2001	94	78.6	57.6	57.469	57.25	79.6
2002	94	78.6	57.6	57.469	57.28	79.6
2003	94	78.6	57.6	57.469	57.19	79.6
2004	94	78.6	57.6	57.469	57.12	79.6
2005	94	78.6	57.6	57.469	56.96	79.6
2006	94.4	78.6	57.812	57.879	56.78	79.6
2007	94.3	78.5	57.848	57.784	56.78	79.6
2008	94.0	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
2014	94.17	79.49	57.620	57.381	56.95	79.6
2015	94.46	79.17	57.508	57.615	57.06	79.6

Table 3A-4.3 CH_4 emission factors and references, 2015.

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-g	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-g	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	1A2 a-g	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	1A2 a-g	Industry	03	3	IPCC (2006), Tier 1, Table 2-3, Industry, petroleum coke.
		1A4a	Commercial/Institutional	0201	10	IPCC (2006), Tier 1, Table 2-4, Commercial, Petroleum coke.
		1A4b	Residential	0202	10	IPCC (2006), Tier 1, Table 2-5, Residential / agricultural, Petroleum coke.
		1A4c	Agriculture/Forestry	0203	10	IPCC (2006), Tier 1, Table 2-5, Residential / agricultural, Petroleum coke.
	RESIDUAL OIL	1A1a	Public electricity and heat production	010101	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.
				010105	4	IPCC (2006), Tier 3, Table 2-6, Utility, Large diesel engines
				010203	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-g	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-g	Industry	03	0.2	IPCC (2006), Tier 3, Table 2-7, Industry, gas oil, boilers.
				Turbines	3	IPCC (2006), Tier 1, Table 2-3, Industry, gas oil.
				Engines	24	Nielsen et al. (2010)

Fuel group	Fuel	CRF source category	CRF source category	SNAP	Emission factor, g per GJ	Reference
		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].
				020304	24	Nielsen et al. (2010)
	KEROSENE	1A2 a-g	Industry	all	3	IPCC (2006), Tier 1, Table 2-3, Industry, other kerosene.
		1A4a	Commercial/Institutional	0201	10	IPCC (2006), Tier 1, Table 2-4, Commercial, other kerosene.
		1A4b i	Residential	0202	10	IPCC (2006), Tier 1, Table 2-5, Residential/agricultural, other kerosene.
		1A4c i	Agriculture/	0203	10	IPCC (2006), Tier 1, Table 2-5, Residential/agricultural, other kerosene.
	LPG	1A1a	Public electricity and heat production	0101 0102	1	IPCC (2006), Tier 1, Table 2-2, Energy Industries, LPG.
		1A1b	Petroleum refining	0103	1	IPCC (2006), Tier 1, Table 2-2, Energy Industries, LPG.
		1A2 a-g	Industry	03	1	IPCC (2006), Tier 1, Table 2-3, Industry, LPG
		1A4a	Commercial/Institutional	0201	5	IPCC (2006), Tier 1, Table 2-4, Commercial, LPG.
		1A4b i	Residential	0202	5	IPCC (2006), Tier 1, Table 2-5, Residential / agricultural, LPG.
		1A4c i	Agriculture/Forestry	0203	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	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	1	IPCC (2006), Tier 3, Table 2-6, Utility, natural gas, boilers.
		1A1b	Petroleum refining	010306	1	Assumed equal to industrial boilers.
		1A1c	Oil and gas extraction	010503	1	Assumed equal to industrial boilers.
				010504	1.7	Nielsen et al. (2010)
		1A2 a-g	Industry	Other	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	1	IPCC (2006), Tier 3, Table 2-10, Commercial, natural gas boilers.
				020105	481	Nielsen et al. (2010)
		1A4b i	Residential	0202	1	IPCC (2006), Tier 3, Table 2-9. Residential, natural gas boilers.
				020204	481	Nielsen et al. (2010)
		1A4c i	Agriculture/Forestry	0203	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)
		1A2 a-g	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	11	IPCC (2006), Tier 3, Table 2-6,

Fuel group	Fuel	CRF source category	CRF source category	SNAP	Emission factor, g per GJ	Reference
						Utility boilers, wood
		1A2 a-g	Industry	03	11	IPCC (2006), Tier 3, Table 2-7, Industry, wood, boilers.
		1A4a	Commercial/Institutional	0201	11	IPCC (2006), Tier 3, Table 2-10, Commercial, wood.
		1A4b i	Residential	0202	93.19	DCE estimate based on technology distribution [3]
		1A4c i	Agriculture/Forestry	0203	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	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	3	IPCC (2006), Tier 1, Table 2-2, Energy industries, biodiesels.
		1A2 a-g	Industry	03	3	IPCC (2006), Tier 1, Table 2-3, Industry, biodiesels.
				030902	0.2	-
		1A4b i	Residential	0202	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-g	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)
		1A4b	Residential	0202	1	Assumed equal to natural gas.
		1A4c i	Agriculture/ Forestry	0203	5	IPCC (2006), Tier 1, Table 2-5, Agriculture, other biogas.
				020304	434	Nielsen et al. (2010)
	BIO GASIF GAS	1A1a	Public electricity and heat production	010101	1	Assumed equal to biogas.
				010105	13	Nielsen et al. (2010)
		1A4a	Commercial/Institutional	020105	13	Nielsen et al. (2010)
	BIONATGAS	1A1a	Public electricity and heat production	0101	1	Assumed equal to natural gas.
		1A2 a-g	Industry	03	1	Assumed equal to natural gas.
		1A4a	Commercial/Institutional	0201	1	Assumed equal to natural gas.
		1A4b	Residential	0202	1	Assumed equal to natural gas.
		1A4c	Agriculture/Forestry	0203	1	Assumed equal to natural gas.

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 below the IPCC (2006) interval for residential wood combustion (100-900 g/GJ).

The CH_4 emission factors applied for 2015 are presented in Table 3.2.25. In general, the same emission factors have been applied for 1990-2015. However, time series have been estimated for both natural gas fuelled engines and biogas fuelled engines, residential wood combustion, natural gas fuelled gas turbines[1] and waste incineration plants[1].

Table 3A-4.4 CH4 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	318	0.59	1.5
1991	309	251	312	0.59	1.5
1992	359	264	306	0.59	1.5
1993	562	276	300	0.59	1.5
1994	623	289	293	0.59	1.5
1995	632	301	286	0.59	1.5
1996	616	305	276	0.59	1.5
1997	551	310	267	0.59	1.5
1998	542	314	257	0.59	1.5
1999	541	318	237	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	111	0.34	1.7
2014	481	434	95	0.34	1.7
2015	481	434	93	0.34	1.7

[1] A minor emission source.

Table 3A-4.5 N_2O emission factors and references, 2015.

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-g	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-g	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-g	Industry	03	1.5	IPCC (2006), Tier 1, Table 2-3, manufacturing industries, other bituminous coal
	FOSSIL FLY ASH	1A1a	Public electricity and heat production	0101	0.8	Assumed equal to coal.
LIQUID	PETROLEUM COKE	1A2 a-g	Industry – other	03	0.6	IPCC (2006), Tier 1, Table 2-3, Industry, petroleum coke
		1A4a	Commercial/Institutional	0201	0.6	IPCC (2006), Tier 1, Table 2-4, Commercial, petroleum coke
		1A4b i	Residential	0202	0.6	IPCC (2006), Tier 1, Table 2-5, Residential, petroleum coke
		1A4c i	Agriculture/Forestry	0203	0.6	IPCC (2006), Tier 1, Table 2-5, Residential/Agricultural, 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-g	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
		1A1c	Oil and gas extraction	010504	0.6	IPCC (2006), Tier 1, Table 2-2, Energy industries, gas oil
		1A2 a-g	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)

Fuel group	Fuel	CRF source category	CRF source category	SNAP	Emission factor, g per GJ	Reference
		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)]
				020304	2.1	Nielsen et al. (2010)
	KEROSENE	1A2 a-g	Industry	03	0.6	IPCC (2006), Tier 1, Table 2-3, Industry, other kerosene
		1A4a	Commercial/Institutional	0201	0.6	IPCC (2006), Tier 1, Table 2-4, Commercial, other kerosene
		1A4b i	Residential	0202	0.6	IPCC (2006), Tier 1, Table 2-5, Residential, other kerosene
		1A4c i	Agriculture/Forestry	0203	0.6	IPCC (2006), Tier 1, Table 2-4, Commercial, other kerosene [1)]
	LPG	1A1a	Public electricity and heat production	0101 0102	0.1	IPCC (2006), Tier 1, Table 2-2, Energy industries, LPG
		1A1b	Petroleum refining	010306	0.1	IPCC (2006), Tier 1, Table 2-2, Energy industries, LPG
		1A2 a-g	Industry	03	0.1	IPCC (2006), Tier 1, Table 2-3, Industry, LPG
		1A4a	Commercial/Institutional	0201	0.1	IPCC (2006), Tier 1, Table 2-4, Commercial, LPG
		1A4b i	Residential	0202	0.1	IPCC (2006), Tier 1, Table 2-5, Residential, LPG
		1A4c i	Agriculture/Forestry	0203	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	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	1	IPCC (2006), Tier 3, Table 2-6, Natural gas, Utility, boiler
		1A4b	Petroleum refining	010306	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-g	Industry	03	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	1	IPCC (2006), Tier 3, Table 2-10, Commercial, natural gas boilers
				Engines	0.58	Nielsen et al. (2010)
		1A4b i	Residential	0202	1	IPCC (2006), Tier 3, Table 2-9, Residential, natural gas boilers
				Engines	0.58	Nielsen et al. (2010)
		1A4c i	Agriculture/ Forestry	0203	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-g	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	1A2 a-g	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,

Fuel group	Fuel	CRF source category	CRF source category	SNAP	Emission factor, g per GJ	Reference
						Energy industries, wood
		1A2 a-g	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	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-g	Industry	03	0.6	IPCC (2006), Tier 1, Table 2-3, Industry, biodiesels
				030902	0.4	-
		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-g	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)
		1A4b	Residential	0202	1	Assumed equal to natural gas.
		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 GASIF GAS	1A1a	Public electricity and heat production	010101	0.1	Assumed equal to biogas.
				010105	2.7	Nielsen et al. (2010)
		1A4a	Commercial/Institutional	020105	2.7	Nielsen et al. (2010)
	BIONATGAS	1A1a	Public electricity and heat production	0101 or 0102	1	Assumed equal to natural gas.
		1A2 a-g	Industry	03	1	Assumed equal to natural gas.
		1A4a	Commercial/Institutional	0201	1	Assumed equal to natural gas.
		1A4b	Residential	0202	1	Assumed equal to natural gas.
		1A4c	Agriculture/Forestry	020,3	1	Assumed equal to natural gas.

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 1990-2015.

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
2014	1.0	1.0
2015	1.0	1.0

Table 3A-4.15 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.
Modern stove (2008-2015)	125	Estimated based on the emission factor for new stoves and the emission factors for NMVOC.
Modern stove (2015-2017)	125	Same as modern stove (2008-2015).
Modern stove (2017-)	125	Same as modern stove (2008-2015).
Eco labelled stove / new advanced stove (-2015)	2	Low emissions from wood burning in an eco-labelled resi-dential boiler. Olsson & Kjällstrand (2005).
Eco labelled stove / new advanced stove (2015-)	2	Same as advanced / eco-labelled stoves.
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).

Annex 3A-5 Large point sources

Table 3A-5.1 Large point sources, 2015 (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
DanSteel
DTU
Esbjergvaerket
Faxe Kalk
Fjernvarme Fyn, Centrum Varmecentral
Frederikshavn Affaldskraftvarmevaerk
Frederikshavn Kraftvarmevaerk
Fynsvaerket
Grenaa Forbraending
Grenaa Kraftvarmevaerk
H.C.Oerstedsvaerket
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

Large point sources
Continued
Skaerbaekvaerket
Skagen Forbraending
Soenderborg Kraftvarmevaerk
Special Waste System
Statoil Raffinaderi
Studstrupvaerket
Svanemoellevaerket
Svendborg Kraftvarmevaerk
Viborg Kraftvarme
Vordingborg Kraftvarme
Aalborg Portland
AarhusKarlshamn Denmark A/S
Danisco Grindsted Dupont
Randersvaerket Verdo
Dalum Kraftvarmevaerk
Duferco Danish Steel

Table 3A-5.2 Large point sources, aggregated fuel consumption in 2015.

nfr_id_EA	fuel_id	fuel_gr_abbr	Sum of Fuel_TJ
1A1a	102A	COAL	71487
	103A	SUB-BITUMINOUS	49
	111A	WOOD	30136
	114A	WASTE	37522
	117A	STRAW	7419
	203A	RESIDUAL OIL	1029
	204A	GAS OIL	433
	215A	BIO OIL	21
	301A	NATURAL GAS	14959
	303A	LPG	10
	309A	BIOGAS	116
	310A	BIO GASIF GAS	0
1A1a Total			163180
1A1b	203A	RESIDUAL OIL	624
	204A	GAS OIL	7
	301A	NATURAL GAS	0
	303A	LPG	0
	308A	REFINERY GAS	16166
1A1b Total			16797
1A1c	204A	GAS OIL	0
	301A	NATURAL GAS	116
1A1c Total			117
1A2a	204A	GAS OIL	0
	301A	NATURAL GAS	1539
	303A	LPG	9
1A2a Total			1548
1A2c	203A	RESIDUAL OIL	204
	204A	GAS OIL	22
	301A	NATURAL GAS	1479
	303A	LPG	0
1A2c Total			1706
1A2e	102A	COAL	880
	107A	COKE OVEN COKE	97
	111A	WOOD	22
	203A	RESIDUAL OIL	2152
	204A	GAS OIL	13
	215A	BIO OIL	157
	301A	NATURAL GAS	79
	309A	BIOGAS	95
1A2e Total			3495
1A2f	102A	COAL	1466
	110A	PETROLEUM COKE	6331
	115A	INDUSTR. WASTES	2488
	203A	RESIDUAL OIL	94
	204A	GAS OIL	99
	215A	BIO OIL	0
	301A	NATURAL GAS	4
1A2f Total			10482
1A2g viii	101A	ANODIC CARBON	0
	102A	COAL	184
	107A	COKE OVEN COKE	376
	204A	GAS OIL	1
	301A	NATURAL GAS	1266
	303A	LPG	1
1A2g viii Total			1828
1A4a i	114A	WASTE	153
	309A	BIOGAS	0
1A4a i Total			153
Grand Total			199305

Annex 3A-6 Adjustment of CO_2 emission

Table 3A-6.1 Adjustment of CO_2 emission (DEA, 2016a).

		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	38.3	48.0	42.2	44.4	48.0	44.9	58.2	48.3	44.5	41.3
Adjusted CO_2 emission	1 000 000 tonnes	44.5	46.4	45.1	45.5	44.3	44.3	45.2	42.4	40.9	39.4
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	3289.4	3273.2	3271.3	3260.9	3224.2	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	37.4	39.0	38.5	43.3	37.2	33.5	41.2	35.7	32.9	32.0
Adjusted CO_2 emission	1 000 000 tonnes	38.0	38.6	36.9	36.5	35.0	34.6	35.6	34.9	34.0	32.3
Continued		**2010**	**2011**	**2012**	**2013**	**2014**	**2015**				
Actual Degree Days	Degree days	3742	2970	3234	3207	2664	2921				
Normal Degree Days	Degree days	3171	3156	3166	3155	3131	3112				
Net electricity import	PJ	-4.1	4.7	18.8	3.9	10.3	21.3				
Actual CO2 emission	1 000 000 tonnes	32.5	27.6	23.8	25.8	21.5	18.9				
Adjusted CO2 emission	1 000 000 tonnes	31.6	28.7	28.0	26.5	23.2	22.5				

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/

Annex 3A-8 Emission inventory 2015 based on SNAP sectors

Table 3A-8.1 Emission inventory 2015 based on SNAP sectors.

db	2015			
Sum of Emission		**pol_id**	**pol_abbr**	**uni_abbr**
		CO2	**CH4**	**N2O**
nfr_id_EA	**snap_id**	**Gg**	**Mg**	**Mg**
1A1a	010100	0.000	0.162	0.162
	010101	7310.694	90.915	71.891
	010102	996.755	42.955	39.963
	010103	468.218	7.495	15.245
	010104	434.747	50.840	21.120
	010105	188.324	2819.730	7.870
	010200	0.000	0.163	0.163
	010201	0.000	0.000	0.000
	010202	45.821	1.174	0.773
	010203	809.549	338.101	89.502
	010205	0.000	0.000	0.000
1A1a Total		**10254.108**	**3351.536**	**246.689**
1A1b	010304	115.138	3.442	2.025
	010306	862.960	16.033	1.792
1A1b Total		**978.098**	**19.475**	**3.817**
1A1c	010503	6.633	0.116	0.116
	010504	1429.141	42.169	24.805
	010505	0.000	0.000	0.000
1A1c Total		**1435.774**	**42.285**	**24.921**
1A2a	030400	0.286	0.005	0.018
	030402	88.405	1.548	1.540
1A2a Total		**88.691**	**1.554**	**1.558**
1A2b	030500	0.000	0.000	0.000
1A2b Total		**0.000**	**0.000**	**0.000**
1A2c	030600	286.505	12.261	5.067
	030602	41.182	0.699	0.703
	030603	20.280	0.344	1.100
	030604	40.384	1.205	0.706
	030605	0.000	43.525	0.160
1A2c Total		**388.351**	**58.034**	**7.737**
1A2d	031100	57.696	3.260	1.827
	031102	0.000	0.000	0.000
	031103	0.000	0.224	0.081
	031104	10.195	0.304	0.179
1A2d Total		**67.891**	**3.787**	**2.087**
1A2e	030900	632.768	14.300	11.030
	030902	171.713	9.540	7.452
	030903	118.713	3.852	5.396
	030904	71.109	2.119	1.246
	030905	14.489	122.135	0.147
1A2e Total		**1008.791**	**151.947**	**25.272**
1A2f	030700	288.286	6.602	5.082
	030703	23.924	2.510	0.380
	030705	0.436	3.679	0.004
	031600	849.062	105.924	21.780
	031604	0.000	0.000	0.000
	031605	0.000	0.000	0.000
1A2f Total		**1161.708**	**118.714**	**27.246**
1A2g viii	030104	0.000	0.000	0.000
	030105	0.000	0.000	0.000
	030106	6.360	0.111	0.111
	030800	36.799	10.920	4.375
	031000	15.887	0.444	0.344
	031005	0.009	0.076	0.000
	031200	13.238	0.482	0.329
	031205	0.000	0.000	0.000
	031300	144.791	6.167	3.809
	031305	7.626	64.287	0.078
	031400	8.608	20.197	7.530
	031403	0.000	3.707	1.348
	031405	0.058	0.492	0.001
	031500	28.454	0.496	0.433
	032000	59.207	13.261	5.660
	032002	73.748	5.863	25.740

db	2015			
Sum of Emission		**pol_id** **CO2**	**pol_abbr** **CH4**	**uni_abbr** **N2O**
nfr_id_EA	**snap_id**	**Gg**	**Mg**	**Mg**
Continued				
	032004	0.029	0.001	0.001
	032005	2.360	33.235	0.080
1A2g viii Total		**397.177**	**159.739**	**49.838**
1A4a i	020100	618.305	24.632	13.179
	020103	1.704	5.064	0.650
	020105	11.866	370.985	1.166
1A4a i Total		**631.875**	**400.681**	**14.995**
1A4b i	020200	1915.523	4391.971	189.715
	020202	9.688	0.533	0.185
	020204	8.363	70.510	0.085
1A4b i Total		**1933.575**	**4463.014**	**189.985**
1A4c i	020300	143.807	600.264	11.102
	020302	0.015	0.625	0.083
	020303	0.000	0.000	0.000
	020304	15.353	375.318	1.065
1A4c i Total		**159.175**	**976.207**	**12.251**
Grand Total		**18505.214**	**9746.973**	**606.398**

Annex 3A-9 EU ETS data for coal

EU ETS data are available for the years 2006-2015. Corresponding values for lower calorific value (LCV) and implied emission factor (IEF) for CO_2 for 2006-2009 are shown in Figure 3A-10.1. The IEF factors include the oxidation factors.

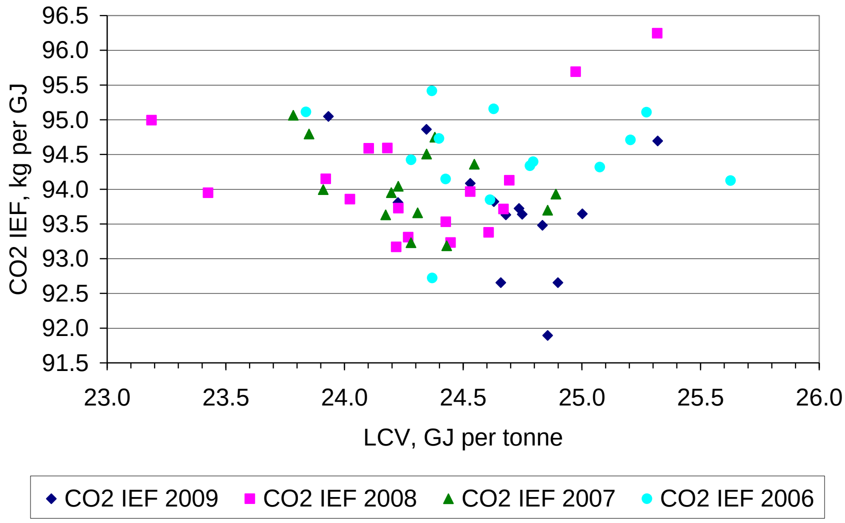

Figure 3A-9.1 EU ETS data for LCV and CO_2 IEF (including oxidation factor) for coal. Data for the years 2006-2009.

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All annexes are availalbe at:
http://envs.au.dk/videnudveksling/luft/emissioner/supporting-documentation/air-pollution-iir/

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All annexes are available at:
http://envs.au.dk/videnudveksling/luft/emissioner/supporting-documentation/greenhouse-gases-nir/

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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 1990-2015, 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, 2015.
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	slatted floor	-	16	-	-
with beds	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**

	Housing type	Floor or manure type	Urine TAN	Slurry TAN	Solid manure Total N	Deep litter Total N
			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**

	Housing type	Floor or manure type	Solid manure Total N	Deep litter Total N
			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, 2015.

			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 1990-2015, Dairy cattle; kg DM per cow per year, Others; FU per animal per year. http://envs.au.dk/videnudveksling/luft/emissioner/supporting-documentation/greenhouse-gases-nir/

Table 3D-9 Grazing animals 1990 – 2015, number of days on grass per year. http://envs.au.dk/videnudveksling/luft/emissioner/supporting-documentation/greenhouse-gases-nir/

Table 3D-10 Gross energy per kg DM for dairy cattle, 1990-2015, MJ per kg DM. http://envs.au.dk/videnudveksling/luft/emissioner/supporting-documentation/greenhouse-gases-nir/

Table 3D-11 Average gross energy intake (GE) 1990 – 2015, MJ per head per day. http://envs.au.dk/videnudveksling/luft/emissioner/supporting-documentation/greenhouse-gases-nir/

Table 3D-12 VS daily excretion 1990 – 2015, kg DM per head per day. http://envs.au.dk/videnudveksling/luft/emissioner/supporting-documentation/greenhouse-gases-nir/

Table 3D-13 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-14 MCF for liquid manure, 1990 – 2015. http://envs.au.dk/videnudveksling/luft/emissioner/supporting-documentation/greenhouse-gases-nir/

Table 3D-15 Area of agricultural land, 1990 – 2015, ha. http://envs.au.dk/videnudveksling/luft/emissioner/supporting-documentation/greenhouse-gases-nir/

Table 3D-16 Above-ground residue dry matter $AG_{DM(T)}$ 1990-2015, 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.

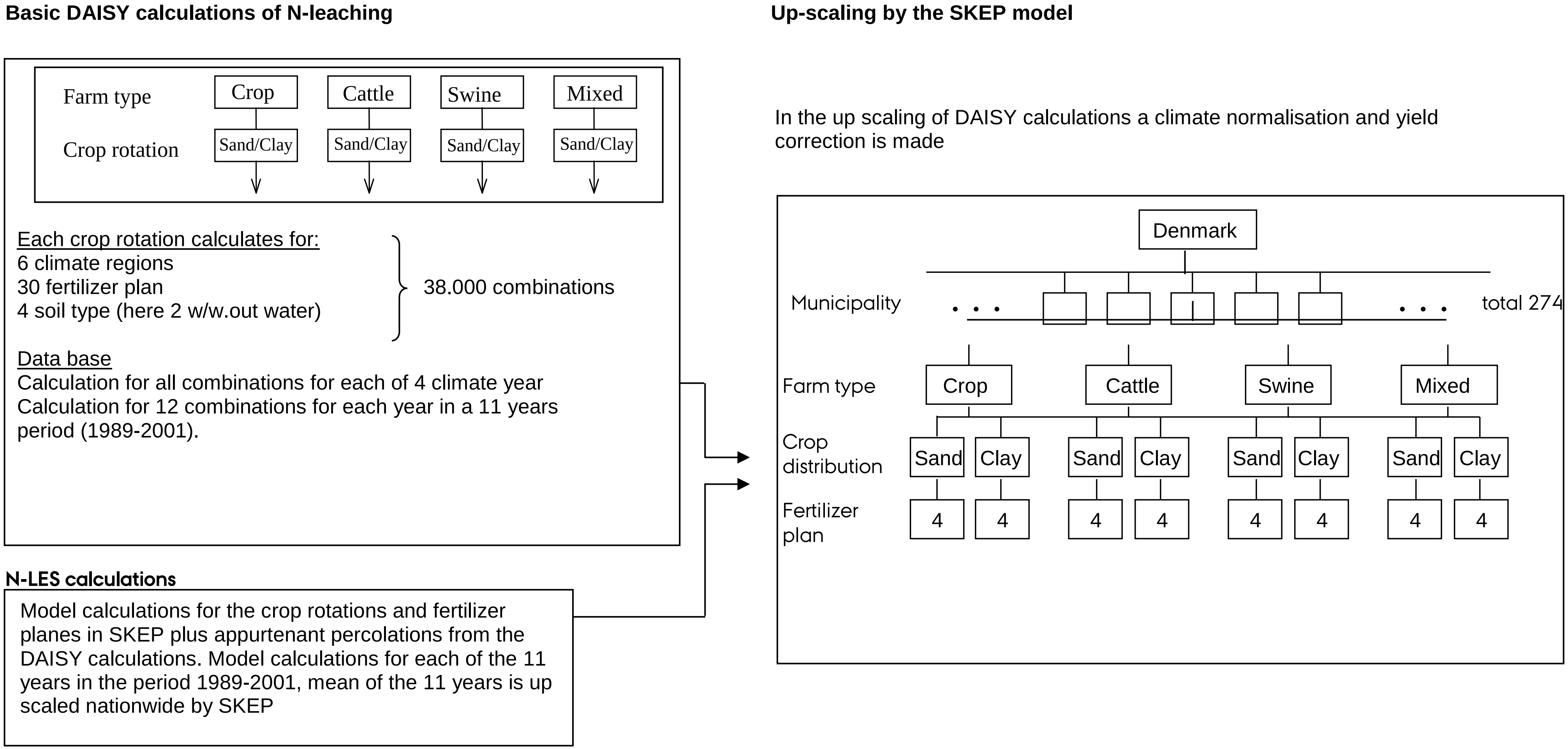


Table 3D-17 QA/QC procedure, stage I – III.

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)

Chapter 3D-1 Biogas treatment of manure

Introduction

A significant and growing part of the Danish animal slurry is being used for production of biogas. The production uses anaerobic digestion of animal manure in combination with other biodegradable products, e.g. agricultural waste and slaughterhouse waste. Biogas treatment is important to include in the inventory, because the anaerobic digested slurry produces lower CH_4 emission from storage and from applied slurry on cultivated soils.

The 2006 IPCC Guidelines Tier 2 approach recommends a MCF at 10 % for covered and a MCF at 17% for uncovered manure- cool climate – for swine and cattle. In relation to anaerobic digested slurry IPPC Guidelines mentioned 0-100 %, which is too large a range to use in calculation practice. Several studies have therefore been carried out to support both the improvements of activity data and the calculation of a MCF for Danish slurry treated in anaerobic digestion as an animal waste management system.

Focus has been on cattle and swine slurry, which cover 96 % of the total CH_4 emission from manure management in the 2015 submission.

Initially is given an overview of the biogas production in Denmark and the data foundation due to the estimate for biogas treated slurry amount, followed by a description of the estimation of MCF for digested cattle and swine slurry.

Biogas production in Denmark

The interest of biogas production was stimulated due to high energy prices as a consequence of the energy crises in 1973 and in combination with increasing amount of animal manure due to the growth of the livestock production. However, due to several technical problems and economic challenges, the biogas production based on animal manure did not reach a substantial level before the beginning of 1990'ies.

Biogas plants are divided in five facility types; wastewater, industrial, landfills, large-scale plants (common plants) and farm-level plants. Large-scale biogas plants are larger facilities where slurry is received from several farms and farm-level plants are characterized by receiving manure from one or few farms. In 2015, the total biogas production is estimated by the Danish Energy Agency to 6 348 PJ (DEA, 2016a) and the manure based biogas plants account for approximately 82 % of the total biogas production produced at 26 large-scale plants and 51 farm-level plants.

The livestock production mainly takes place in the western parts of Denmark in Jutland and consequently the majority of manure based biogas plants are located here.

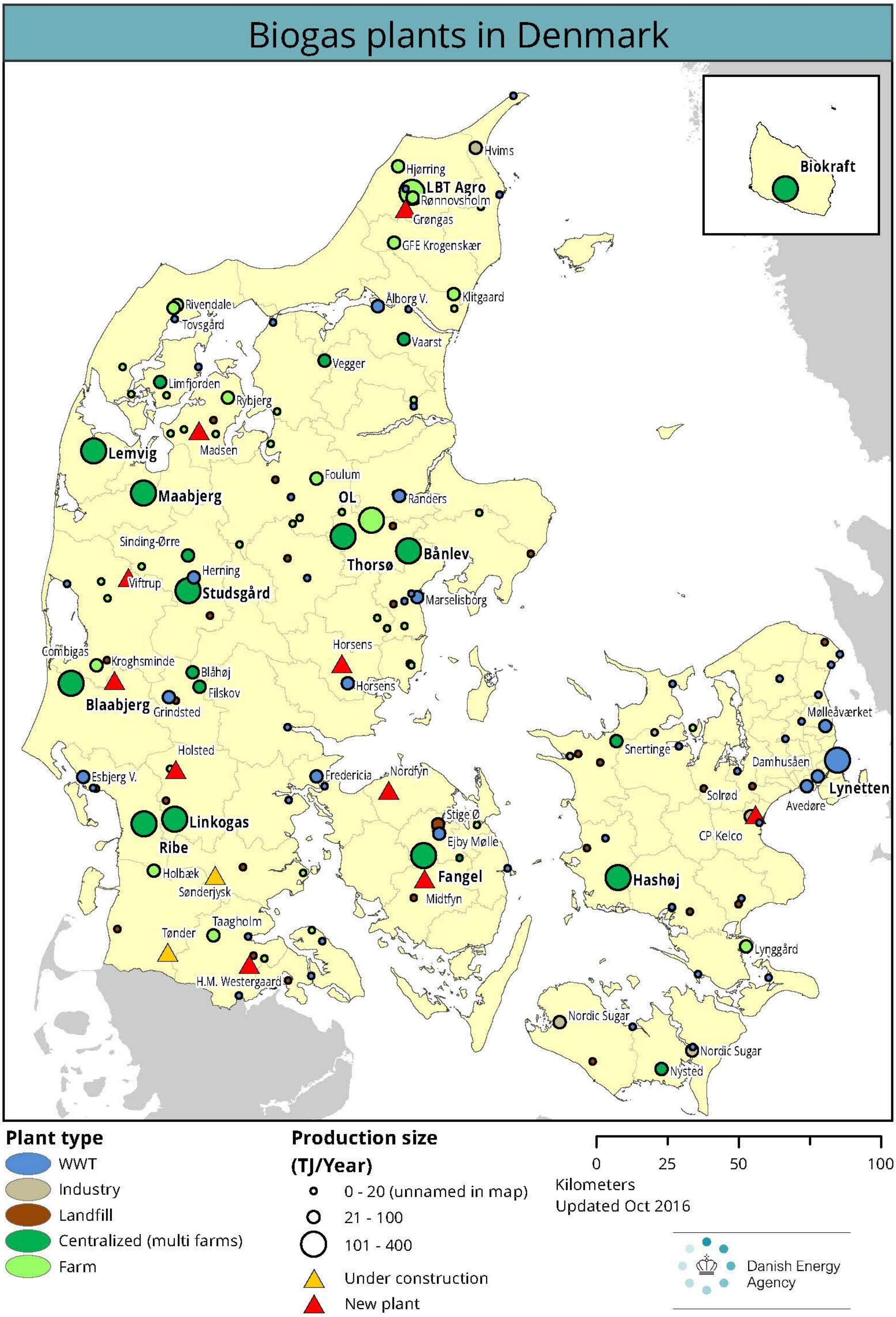


Figure 3D-2 Biogas producers in Denmark, 2016 (DEA, 2016c).

Activity data

It is important to estimate the amount of manure, which is delivered to the biogas plants.

Data collected by the Danish Energy Agency (DEA) based on reporting from each biogas plant gives for the first time an overview of the actual amount and different types of biomass used in biogas production. In the following, these data are referenced as; register of Biomass Input to Biogas production (BIB). The BIB register reflects the situation in 2015 (DEA, 2016b). The data given in the BIB register is used to find the relation between the biogas production and the amount of slurry delivered to biogas plants. This relation will be used to estimate the amount of biomass input for previous years 1990 – 2014.

The anaerobic digestion process is complicated and sensitive to several factors, such as different biomass types and different combination of biomass input, nutrients concentration, species and concentration of bacteria, operational conditions for each biogas plants, etc. Uses of current data from the BIB register will to some extend take these variations from biogas plant to biogas plant into account, because the data is based on existing production.

BIB register

The BIB register does not fully cover all biogas plants, however it includes the most important biogas producers, and thus it covers 93 % of the total biogas production. Animal manure for biogas production mainly takes place at the large-scale- or the farm-scaled biogas plants and only 1 % is delivered to industrial biogas plants.

Data covering the large-scale plants and farm-level biogas plants show that manure accounts for 79 % of the total biomass input. The remaining biomass input is from sewage sludge, residues from the meat production and biomass from crops. The BIB register shows that the majority of manure sent to anaerobic digestion is slurry, 96 %. Deep litter to biogas treatment accounts for 2% of the total amount of manure.

The emission inventory only includes biogas treated slurry from cattle- and swine slurry, which account for 88 % of the total amount of slurry delivered to biogas plants. The BIB register allows to include biogas treated slurry from mink- and poultry production, deep litter and other manure types, which is planned to be implemented in the emission inventory.

In 2015, large-scale and farm-level biogas plants produces 4 161 TJ, which correspond to 80 % of the total biogas production. The total biomass input to all facilities is estimated to 8 535 kt and the amount used in large-scale and farm-level biogas plants accounts for 3 289 kt (49 %).

Table 3D-18 Biomass input and biogas production, 2015

Facility type	Biomass input, kt	%	Biogas production, TJ*	%
Wastewater treatment	2 522	30	776	13
Industrial	1 871	22	927	16
Landfill	-	-	70	1
Large-scale	3 289	39	3 085	52
Farm-scale	854	10	1 086	18
Total	8 535	100	5 944	100

*Used a conversion factor of 35.8 MJ/m3 and CH_4 content of 65 %.

Biogas treated slurry 1990 – 2015

The biogas production 1990 – 2015 is specified in the Danish Energy Statistics (DEA, 2016d). Assuming that the relation between biogas production and input of slurry given in BIB register for 2015 is roughly similar in recent years 1990-2015, the biogas treated slurry can be estimated based on the energy production.

In 1990, the biogas production at the large-scale, farm-level and industrial biogas plants is 752 TJ which correspond to slurry input of 194 kt, increasing to 5 259 TJ and 3 832 kt slurry in 2015.

In 2015, around 10 % of total amount of slurry is delivered to biogas production, 14 % of the total amount of cattle slurry and 8 % for swine slurry.

Table 3D-19 Biogas production, 1990-2015 (DEA, 2016b and DEA, 2016d).

	1990	1995	2000	2005	2010	2015
Biogas production, TJ						
Total	752	1758	2912	3830	4337	6348
Large-scale, farm-level and industrial biogas plants	266	746	1442	2375	3184	5259
Slurry delivered to biogas plants, kt						
Cattle, swine and mixed	194	543	1050	1731	2320	3832
Percent of total produced slurry	<1	2	4	5	7	10

Result – a national estimated MCF for slurry

To estimate the emission from the biogas treated slurry in Denmark a methane conversion factor (MCF) for the biogas treated slurry has been estimated. This is based on studies and measures of emissions of CH_4 from anaerobic digested cattle and swine slurry.

National studies were initiated covering:

- Manure storage time in Danish barns
- Emissions from anaerobically digested material

During the work with estimating the CH_4 emission from anaerobic digested cattle and swine slurry, it became apparent that the currently used MCF for cattle and swine slurry (the default value from the 2006 IPCC Guidelines) were not properly reflecting the Danish conditions. The outcome of the analysis based on new measurements showed that the emission from not digested swine slurry was underestimated. It was therefore decided to also estimate a country specific MCF for not digested cattle and swine slurry.

The estimates are based on temperature dependent degradation functions, which take into account the different temperature conditions inside the barns and during outdoor storage. The emissions are estimated separately from the barns and pre-tanks at the farm. After manure has left the barn the manure is split in two fractions. The major fraction of 90% is left on the farm as untreated raw liquid manure and currently 10 % is brought to anaerobic digestion either on the farm or at large-scale biogas plants. The digested material is returned for storage on the farm until field application.

In the estimation of MCF are storage time and the related CH_4 emission inside the barns, outdoor storage and storage of anaerobic digested biomass taken into account. The approach use temperature dependent functions adapted to Danish conditions. The approach lowers the CH_4 emission from cattle slurry compared to the previous inventory submission and increases the emission from swine slurry. The change in MCF values is shown in Table 3D-20.

Table 3D-20 MCF values previously used and from the current study.

MCF in 2015, %	Previously used	New – liquid system	New - anaerobic digesters
Untreated cattle slurry	10	4.82	
Untreated swine slurry	10	13.92	
Biogas treated cattle slurry	10		2.62
Biogas treated swine slurry	10		10.25

A lower MCF for cattle than the 2006 IPCC Guidelines default has also been found in Swedish studies (Rodhe et al. 2009, 2012 and 2015). This is furthermore supported by studies by Møller (2013), who investigated the CH_4 emission from cattle and swine manure under different temperatures. This study indicates a low CH_4 emissions from dairy cattle slurry stored below 15 °C. Probably due to the fact, that the methanogens in the slurry are not very active at these relatively low temperatures. When the temperatures were higher than 20 °C, the CH_4 emission from cattle slurry increases, although not comparable to the emissions from swine slurry.

The national estimated MCF for swine slurry is higher than 2006 IPCC Guidelines default. The national investigation shows an unexpected very fast turnover of VS in the swine slurry, and especially inside the barns the temperatures are high all year around. This is also found by Møller (2013). The fast turnover also means that the CH_4 emission rate per kg VS quickly reduces to substrate depletion and leaving only small amounts of VSd (degradable VS) in the manure.

Table 3D-21 shows the national estimated MCF for cattle and swine slurry both digested and not digested 1990 - 2015. The national estimated MCF for cattle slurry is changing slightly over time, form 4.85 in 1990 and 4.82 in 2015. The MCF for swine slurry is reduced from 13.92 in 1990 to 10.25 in 2015 due to changes in housing system. The MCF depends on storage time in housing, which differ from system to system. The development from housing systems with fully slatted floor towards systems with partly slatted floor, shorter than storage time for slurry and thus reduces the MCF.

The MCF for undigested cattle slurry 2015 is estimated to 4.82 and the MCF for digested cattle manure is 2.62, which corresponds to a 46 % reduction of CH_4 emission. The MCF for undigested swine slurry 2015 is estimated to 13.92 and the digestion slurry reduces the MCF to 10.25 which mean a 26 % reduction.

Table 3D-21 Estimated MCF for digested and undigested cattle and swine slurry from 1990 to 2015.

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
Cattle										
MCF for digested cattle slurry	2.68	2.61	2.88	2.77	2.75	2.77	2.85	2.93	2.78	2.62
MCF for undigested cattle slurry	4.85	4.76	5.03	4.92	4.88	4.90	4.91	5.00	4.88	4.82
Swine										
MCF for digested swine slurry	11.94	11.79	11.55	10.70	10.66	10.59	10.52	10.46	10.39	10.25
MCF for undigested swine slurry	15.19	15.12	14.94	14.18	14.14	14.07	14.00	13.95	13.93	13.92

The calculation is not taken into account a likely reduction in the CH_4 emission due to crust covering of the manure stores. A more scientific literature search on this is needed before implementation in the current model. The 2006 IPCC Guidelines assumes a 40 % reduction in the CH_4 emission due to crust covering. It must be assumed that a crust cover inside the barns is not likely to occur and hence it should only be related to the outdoor storage. The 40 % reduction is mainly based on one study (Husted, 1994) and has been questioned by other authors (Duan et al. 2013).

Calculation method for the national MCF

MCF is estimated by using the Tier 2 equation for estimating CH_4 emission factor from manure management from IPCC 2006:

$$\mathrm{MCF}_{not\ digested} = \left(\frac{E_{barns} + E_{storage,not\ digested}}{VS_{barns}}\right) / (0.67 \cdot B_0) \quad \text{(Eq. 3D-1)}$$

Where:

$MCF_{not\ digested}$ = methane conversion factor for not digested slurry, %

E_{barns} = emission of CH_4 from barns, kg CH_4, see Equation 3D-3

$E_{storage,\ not\ digested}$ = emission of CH_4 from storage of not digested slurry, kg CH_4, see Equation 3D-4

VS_{barns} = amount of volatile solids, kg VS, based on VS excreted, see Table 3D-23

B_0 = maximum methane producing capacity, m^3 CH_4 per VS

0.67 = conversion factor, CH_4 per m^3 CH_4

$$\mathrm{MCF}_{digested} = \left(\frac{E_{barns} + E_{storage,digested}}{VS_{barns}}\right) / (0.67 \cdot B_0) \quad \text{(Eq. 3D-2)}$$

Where:

$MCF_{digested}$	= methane conversion factor for digested slurry, %
E_{barns}	= emission of CH_4 from barns, kg CH_4, see Equation 3D-3
$E_{storage, digested}$	= emission of CH_4 from storage of not digested slurry, kg CH_4, see Equation 3D-4
VS_{barns}	= amount of volatile solids, kg VS, based on VS excreted, see Table 3D-23
B_0	= maximum methane producing capacity, m^3 CH_4 per VS
0.67	= conversion factor, CH_4 per m^3 CH_4

Estimation of methane emission from raw cattle and swine slurry and anaerobic digested animal manure

The CH_4 emission from liquid cattle and swine manure is based on CH_4 emission from barns, from outdoor stored raw cattle and swine slurry, from anaerobic digesters and from anaerobically digested biomass/primarily animal manure.

Emission of CH_4 from barns

$$E_{barns} = VS_{barns} \cdot EF_{barns} \cdot HRT/365 \qquad \text{(Eq. 3D-3)}$$

Where:

E_{barns}	= emission of CH_4 from barns, kg CH_4
VS_{barns}	= amount of volatile solids, kg VS, based on VS excreted, see Table 3D-23
EF_{barns}	= emission factor for CH_4, based on measurements see Table 3D-22
HRT	= Hydraulic Retention Time, days, see Table 3D-23

Emission of CH_4 from storage of not digested slurry

CH_4 emission from storage of slurry is estimated as VS multiplied by EF where VS is divided in VS degradable (VSd) and VS non-degradable (VSnd).

$$E_{Storage,not\ digested} = VSd_{storage,not\ digested} \cdot EFd_{storage,not\ digested} + VSnd_{storage,not\ digested} \cdot EFnd_{storage,not\ digested} \qquad \text{(Eq. 3D-4)}$$

Where:

$E_{storage, not\ digested}$	= emission of CH_4 from storage of not digested slurry, kg CH_4
$VSd_{storage, not\ digested}$	= amount of degradable volatile solids in the slurry not digested, see Table 3D-23
$EFd_{storage, not\ digested}$	= emission factor for CH_4 for degradable VS, see Table 3D-22
$VSnd_{storage, not\ digested}$	= amount of non-degradable volatile solids in the slurry not digested, see Table 3D-23
$EFnd_{storage, not\ digested}$	= emission factor for CH_4 for degradable VS, see Table 3D-22

Emission of CH_4 from storage of digested slurry

$$E_{Storage,digested} = VSd_{storage,digested} \cdot EFd_{storage,digested} + VSnd_{storage,digested} \cdot EFnd_{storage,digested} \qquad \text{(Eq. 3D-5)}$$

Where:

$E_{storage, digested}$	= emission of CH_4 from storage of digested slurry, kg CH_4
$VSd_{storage, digested}$	= amount of degradable volatile solids in the slurry digested, see Table 3D-23
$EFd_{storage, digested}$	= emission factor for CH_4 for degradable VS, see Table 3D-22
$VSnd_{storage, digested}$	= amount of non-degradable volatile solids in the slurry digested, see Table 3D-23
$EFnd_{storage, digested}$	= emission factor for CH_4 for degradable VS, see Table 3D-22

Table 3D-22 Estimated emission factors.

Cattle	
EF_{barns}, g CH_4 per kg VS per year	66.92
$EFd_{storage, not digested}$, g CH_4 per kg VSd per year	12.02
$EFnd_{storage, not digested}$, g CH_4 per kg VSnd per year	0.16
$EFd_{storage, digested}$, g CH_4 per kg VSd per year	10.13
$EFnd_{storage, digested}$, g CH_4 per kg VSnd per year	0.19
Swine	
EF_{barns}, g CH_4 per kg VS per year	569.50
$EFd_{storage, not digested}$, g CH_4 per kg VSd per year	29.64
$EFnd_{storage, not digested}$, g CH_4 per kg VSnd per year	0.63
$EFd_{storage, digested}$, g CH_4 per kg VSd per year	10.13
$EFnd_{storage, digested}$, g CH_4 per kg VSnd per year	0.19

Solid animal manure and deep litter are in the inventory estimated according to the 2006 IPCC Guidelines although part of it are utilized in anaerobic digesters because it is assumed that the major part of the CH_4 emission is taking during its storage on the farm. In Table 3D-23a-c is shown the estimated CH_4 emission from liquid cattle and swine slurry for the years 1990-2015. Table 3D-23a-c shows the total amount of liquid VS excreted by cattle and swine, the average HRT, the estimated g CH_4 per kg VS and the total emission of CH_4 from that category. For cattle slurry has the total emission in barns in 1990 been estimated to 3.64 kt CH_4 increasing to 4.48 kt CH_4 in 2015. To this comes an emission from outdoor storage. This has been estimated to 4.25 kt CH_4 in 1990 and kept almost constant to 2015. To this comes a small amount from digested manure.

For swine slurry has the total emission inside the barns in 1990 been estimated to 16.26 kt CH_4 in 1990 increasing to 27.44 kt CH_4 in 2015 due to a growing swine production. To this comes an emission from outdoor storage. This has been estimated to 5.75 kt CH_4 in 1990 and an increase to 10.65 kt CH_4 in 2015. In addition, a small amount is realised from the digested manure.

Table 3D-23a Emission estimates for cattle slurry inside the barns and undigested stored liquid manure.

Cattle	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
Barns										
Slurry, tonnes VS per year	1 081 908	998 008	989 831	1 149 864	1 193 926	1 200 212	1 274 389	1 278 969	1 277 397	1 275 456
EF, g CH_4 per kg VS per year	66.92	66.92	66.92	66.92	66.92	66.92	66.92	66.92	66.92	66.92
Average HRT, days	18.33	18.12	20.81	20.14	19.64	19.77	19.94	20.58	19.63	19.15
EF, g CH_4 per kg VS per year	3.36	3.32	3.82	3.69	3.60	3.62	3.66	3.77	3.60	3.51
Emission, kt CH_4 per year	3.64	3.31	3.78	4.25	4.30	4.35	4.66	4.83	4.60	4.48
Storage, not digested										
Slurry, not digested, tonnes VSd ab barn	343 702	311 113	298 667	337 274	344 740	347 694	373 843	373 288	363 712	353 552
Slurry, not digested, tonnes VSnd ab barn	722 043	653 443	628 941	709 778	725 139	731 445	786 584	785 905	765 042	743 325
EF, g CH_4 per kg VSd per year	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0
EF, g CH_4 per kg VSnd per year	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Emission, kt CH_4 per year	4.25	3.85	3.69	4.17	4.26	4.30	4.62	4.62	4.50	4.37

Table 3D-23b Emission estimates for swine slurry inside the barns and undigested stored liquid manure.

Swine	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
Barns										
Slurry, tonnes VS per year	481 523	678 185	800 154	931 488	947 759	963 417	914 097	900 361	930 935	929 047
EF, g CH_4 per kg VS per year	569.50	569.50	569.50	569.50	569.50	569.50	569.50	569.50	569.50	569.50
Average HRT, days	21.64	21.49	21.10	19.47	19.39	19.23	19.10	18.98	18.94	18.93
EF, g CH_4 per kg VS per year	33.77	33.53	32.93	30.38	30.26	30.01	29.80	29.62	29.55	29.54
Emission, kt CH_4 per year	16.26	22.74	26.35	28.29	28.68	28.91	27.24	26.67	27.51	27.44
Storage, not digested										
Slurry, not digested, tons VSd ab barn	189 073	264.662	310 420	365 040	367 433	375 360	354 815	348 580	356 235	350 390
Slurry, not digested, tons VSnd ab barn	234 480	327.562.	382 251	440 107	442 561	451 201	425 762	417 669	426 599	419 553
EF, g CH_4 per kg VSd per year	29.64	29.64	29.64	29.64	29.64	29.64	29.64	29.64	29.64	29.64
EF, g CH_4 per kg VSnd per year	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63
Emission, kt CH_4 per year	5.75	8.05	9.44	11.10	11.17	11.41	10.78	10.59	10.83	10.65

Table 3D-23a Emission estimates for digested biomass.

Digested biomass	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
VSd, tonne	1 215	3 403	6 578	10 837	14 528	14 018	14 938	15 737	18 322	17 113
VSnd, tonne	7 529	21 079	40 745	67 129	89 990	86 834	92 531	97 479	113 493	106 004
EF, g CH_4 per kg VSd per year	10.13	10.13	10.13	10.13	10.13	10.13	10.13	10.13	10.13	10.13
EF, g CH_4 per kg VSnd per year	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19
Emission, kt CH_4 per year	0.01	0.04	0.07	0.12	0.16	0.16	0.17	0.18	0.21	0.19

Documentation

CH_4 formation in manure is mainly formed by microorganisms that produce methane as a metabolic by-product in anoxic conditions. They are classified as archaea, a domain distinct from bacteria. The metabolism is temperature dependent, and actual temperatures are therefore the main driver for the methanogenesis. The overall methodology for estimating the CH_4 emission from liquid animal manure and anaerobically digested biomass is based on the available amount of volatile substance (VS) in the biomass and the temperature dependent CH_4 formation functions (Van't-Hoof/Arrhenius equation) (Sommer et al. 2004). The model by Sommer et al. (2004) uses a 2-pooled concept for estimating the CH_4 emission from degradable VS (VSd) and from non-degradable VS (VSnd). The emission from VSnd has been set to 1 % of VS (Sommer et al. 2001, 2004). During storage inside the barns, in outdoor storages and in the anaerobic digesters VS is degraded. To take into account a "decreasing" emission due to depletion of the VS in the manure in up to 8-9 months a degradation model has been developed.

For the purpose of documenting the emission estimate in the inventory the following tasks have been performed:

- a thorough literature search
- estimation of temperature functions for animal manure stored
  - inside the barns for swine and cattle barns
  - outdoor storage for untreated liquid manure
  - anaerobically digested manure
- estimation of storage time, HRT (Hydraulic Retention Time) in the barns (Kai et al, 2015)
- temperature dependent CH_4 formation from 27 samples of different types of liquid swine manure and 12 samples of different type of liquid dairy cattle manure (Petersen et al. 2016)
- developing a model to estimate the storage time in outdoor liquid manure stores
- compilation of data from BIB. The BIB include information on suppliers, amount and types of manure and other biomass used in the Danish anaerobic digesters
- developing an emission model based on time steps of 10 days

Dry matter excretion and VS, VSd and VSnd

The amount of excreted dry matter is taken from the Danish Normative System for animal manure (data included in IDA). The share of VS of dry matter is set as a default to 80 % as used in the agricultural inventory (Chapter 5).

In the model for estimating the CH_4 emission a 2-pooled model is used, dividing the VS in VSd and VSnd (Tong et al. 1990, Sommer et al. 2004). The share of VSd and VSnd has for the purpose of the inventory been estimated by Petersen et al. (2016) for swine (sow, weaners and fattening pigs) and cattle slurry (mainly dairy cattle slurry). The manure samples were taken in barns in full production and can thus be seen as normal farming practise. Petersen et al. (2016) estimated the average age of the swine slurry to 13-15 days and the cattle slurry to around 20-30 days. The slurry samples can therefore be seen as quite fresh manure with only little degradation.

Petersen et al. (2016) sampled 27 swine slurry samples and 12 dairy cattle slurry samples and estimated the VSd. For swine manure they found an average VSd of 50.87 (95 % Confidence Interval: 44.49 - 57.26) and for slurry for dairy cattle a VSd of 32.63 (95 % Confidence Interval: 28.65 – 36.62).

Møller and Moset (2015) has measured dry matter and VS in digested manure from eight biogas plants. They found an average dry matter in the digested manure of 4.88 % were VS of dry matter in average were 3.32 %. The main part 86.1 % of VS in the digested manure were non-degradable VS (VSnd). Based on the model, which take storage time and temperature into account, the emission factor for $VSnd_{digested}$ and $VSd_{digested}$ were estimated to 0.19 g CH_4 per kg VS per year and 10.13 g CH_4 per kg VS per year, respectively.

Parameters for Arrhenius function

Estimation of the parameters for Arrhenius function is based on Petersen et al. (2016) combined on data from Elsgaard et al. (2016).

The determination of methane production rates largely followed the description of Elsgaard et al. (2016). Two temperatures were selected at approximately 10 and 20°C (Petersen et al., 2016). To estimate the parameters 20 samples from swine slurry and 11 samples from cattle slurry were used. In effect cattle slurry was always incubated at around 10 °C, and swine slurry around 20 °C.

Methane production rates observed, corrected to the ambient temperature in slurry pits and channels at sampling time, were compared with predictions based on the model presented by Sommer et al. (2001):

$$F(T) = VS_d * b_1 * \exp\left(lnA - E * \left(\frac{1}{RT}\right)\right) + VS_{nd} * b_2 * \exp(lnA - E * \left(\frac{1}{RT}\right)) \quad \text{(Eq. 3D-6)}$$

Where:

F	= CH_4 kg-1 VS
b1 and b2	= scaling factors, 1 for VSd and 0.01 for VSnd (dimension-less)
A	= Arrhenius parameter, g CH_4 per kg VS per h
E	= the apparent activation energy, J per mol–1
R	= the gas constant, J per K per mol
T	= temperature, K

An activation energy, Ea, of 80.9 kJ per mol was recently proposed by Elsgaard et al. (2016) which represented the temperature response of a cattle slurry, a swine slurry, fresh digestate and stored digestate (no significant differences).

In Table 3D-24 is shown the used parameters.

Table 3D-24 CH_4 emission estimate parameters.

	Ea, J mol-1	Ln(A), g CH4 kg–1 VS h–1	VSd, %	VSnd, %	Source
Liquid cattle manure	80.900	29.96	32.63	67.37	Petersen et al. (2016)
Liquid swine manure	80.900	31.30	50.87	49.13	Petersen et al. (2016)
Digestate	80.900	30.10	13.9	86.1	Elsgard et al. (2016)

Degradation function

To take into account long time storage of the slurry, the loss of VSd during storage and the actual amount of VSd and VSnd has to be determined.

Based on literature data and unpublished research data it was estimated that the C loss from manure stores constitutes roughly of 20 % CH_4-C and 80 % CO_2-C (Dinuccion et al. 2008). In the emission estimate is used a conservative figure of 25 %. Beside this Patni and Jui (1987) found 10-25 % losses of dry matter during storage of dairy cattle slurry supporting that a high share of loss of VS is taken place as CO_2 as this is not lost as CH_4. For effluent from digested animal manure, Wang et al. (2016) found very low CH_4/CO_2 ratios at around 3-4 % (unpublished data received from Yue Wang). For the digestate is used an estimate for CH_4-C/CO_2-C fraction of 10 % (Dong, 2013).

The CH_4/degradation model was built in an excel spreadsheet with a time step of 10 days.

Danish animal housing systems and Hydraulic Retention Time (HRT)

The most common housing systems for swine in Denmark are partly plug-systems with slatted floors and a depth of the slurry channels of 40-60 cm. The storage capacity inside the barns in these systems is around 40 days. After 40 days the farmers pull the plugs and the slurry under the slats are flushed to the outdoor storage tanks. During the production cycle of weaners and fattening pigs it is normally only needed to flush once during the production, and once after the pig has been moved and the barn is washed and cleaned. In these systems the average storage time is therefore app. 40 days/2 = 20 days. The average storage time is named the Hydraulic Retention Time (HRT).

For the purpose of the Danish inventory Kai et al. (2015) have investigated/measured the storage capacity in swine and cattle barns and estimated the HRT for all barn types mentioned in the Danish Normative System for animal manure (see Chapter 5 for a more thorough description).

Animal housing systems change over time. To take into account changes in the HRT inside the barns over time since 1990 has the shares of the different barn types been multiplied with the HRT for each barn type and summed for swine and cattle slurry to get the average HRT for swine and cattle slurry (Table 3D-25). The HRT for liquid cattle manure has increased since 1990. This is mainly because in the 1990'ies there was a high share of tied-up dairy cows with liquid handling and frequent removal of the slurry. These were later replaced by cubicles combined with slats. In recent years cubicles with scrapers are becoming more common so a decrease in the HRT for cattle is expected in the future. The most common housing system for swine has until recently been fully slatted floors. A ban on fully slatted floors forced the farmers to build partly slatted floors/drained floors. This has reduced the storage capacity below the slats and thus reduced the average HRT for swine slurry.

Table 3D-25 Average Hydraulic Retention Time (HRT) in cattle and swine barns from 1990 to 2015.

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
Cattle	18.33	18.12	20.81	20.14	19.64	19.77	19.94	20.58	19.63	19.15
Swine	21.64	21.49	21.10	19.47	19.39	19.23	19.10	18.98	18.94	18.93

In the emission estimate, it is assumed that all manure regardless of whether it is used for anaerobic digestion or not is having the same HRT. The data collected by Kai et al. (2015) do not prove that farms delivering manure to anaerobic digestion are empting their slurry channels more frequently than farmers who are not.

Temperatures

Based on average air temperature for the period 2001-2010, measured temperatures and literature data temperature functions have been developed.

Insulated swine barns

Only few measured slurry temperatures inside the barns can be found in the literature. Some measurements have been made by SEGES (Holm, 2015). Besides this has Petersen et al. (2016) measured slurry temperatures in 27 different swine barns in November and December 2014 in connection with the CH_4 emission parameterization. Holm (2015) has made 48 measurements in barns with fattening pigs at different times of the year and found an average slurry temperature of 18.6 °C (16.0-21.8 °C) with a standard deviation of 1.29. The highest temperatures were measured in summer. When the average outdoor temperature was 16-17 °C the slurry temperature tended to be around 19 °C. In winter when the average outdoor temperature was around 2-5 °C the slurry temperature was 17-18 °C (Figure 3D-5). The dots represent different combinations of slurry height and temperatures. Petersen et al. (2016) found an average temperature of 18.7 °C in their measurements in November and December. In the inventory is used the average data of 18.6 °C from SEGES throughout as the data are not sufficient qualified to distinguish between winter and summer. Figure 3D-3 shows the measured data by SEGES.

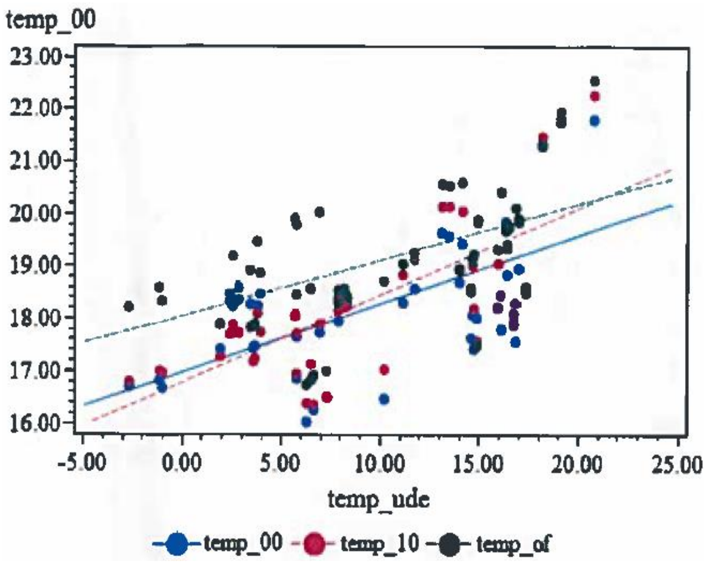


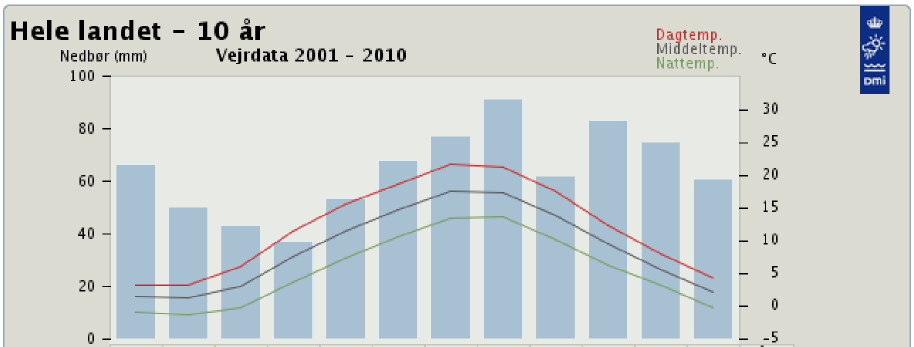
Figure 3D-3 Measured slurry temperature in fattening pig slurry channel in different times during the production cycle. The different colours indicate different slurry heights in the slurry channel (Holm, 2015).

Open cattle barns

Most cattle barns in Denmark are naturally ventilated. Inside the barns the air temperature is generally 5-6 °C higher than the outdoor temperature. Only a few measurements of the slurry temperatures can be found in the literature. Furthermore, Petersen et al. (2016) made 12 measurements in different dairy barns in November and December 2014. They measured an average air temperature of 5.2 °C and an average slurry temperature of 9.8 °C, thus a 4.6 °C higher slurry temperature than the air temperature. Because of the lack of data the temperature of liquid manure in naturally ventilated barns is conservatively set to outdoor air temperature plus 5 °C. More measurements are needed on this.

Air temperature

As temperature input annual monthly mean temperatures are used from the Danish Meteorological Institute (DMI) from 2001 to 2010 (Wang, 2012, DMI report 12-24) (Figure 3D-4). The monthly average mean has been converted to a sinus function (y=a+ bsin(2πx/d+c)) to estimate daily average temperatures.



	JAN	FEB	MAR	APR	MAJ	JUN	JUL	AUG	SEP	OKT	NOV	DEC	ÅR
Nedbør (mm)	66	50	43	37	53	68	77	91	62	83	75	61	765
Nedbørdage	18	15	13	11	13	13	14	16	14	17	20	17	179
Dagtemp.	3.3	3.3	6.1	11.5	15.5	18.5	21.6	21.2	17.5	12.3	7.9	4.2	11.9
Middeltemp.	1.5	1.2	3.0	7.5	11.4	14.6	17.4	17.2	13.8	9.4	5.7	2.2	8.8
Nattemp.	-0.8	-1.3	-0.2	3.6	7.4	10.6	13.4	13.5	10.2	6.2	3.2	-0.3	5.5
Solskinstimer	47	71	146	198	235	239	232	196	162	111	58	45	1739

Figure 3D-4 Average daily mean temperature in Denmark 2001-2010 (Wang, 2012).

In Table 3D-26 is given the parameters for the Sine-function which estimates the daily average air temperatures.

Table 3D-26 Parameters for the Sine-function for air temperature.

R^2 = 0.994					
Parameter	Value	Std Error	t-value	95% confidence limits	
a	8.697	0.167	81.49	8.47	8.92
b	8.234	0.141	58.38	7.94	8.52
c	4.253	0.028	110.00	4.17	4.25
d	363.134	1.878	193.31	359.21	367.05

Outdoor storage temperatures

The temperature in outdoor slurry tanks is expected to follow the outdoor temperature to a great extent. As with indoor storage only few data can be found in the literature. The temperature is a function of the loading with slurry, the actual amount stored and the solar radiation. If data from other climatic conditions is used they therefore have to be converted to Danish conditions. E.g. Park et al. (2006) found a linear relation between air temperature and slurry temperature in Canada with the following model parameters: Slurry_temperature = Air_temperature * 0.879 + 4.24 (Figure 3D-5). However, the locations used for this study is far more southern than Denmark and are thus not suited for Danish conditions, especially not during summer where a higher solar radiation is occurring. Hansen et al. (2006) measured the slurry temperatures in slurry tanks throughout a year on three farms receiving digestate from anaerobic digesters. They found also a linear relation similar to Park et al. (2006) with the parameters Slurry_temperature = Air_temperature * 0.75 + 6.23 (Figure 3D-5). The measurements by Hansen et al. (2006) cannot be seen as representative for raw liquid manure as the digestate as a starting point is having a higher temperature than raw undigested slurry due to the exothermic process in the anaerobic digesters. The model by Hansen et al. (2006) is used for anaerobic digested manure as this is likely a normal temperature profile for digestate returned to the farms for continued storage.

For raw undigested slurry a linear model has been constructed with data from Husted (1994) and Rodhe et al. (2009, 2012, 2015) with the following parameters Slurry_temperature = Air_temperature * 0.5011 + 5.1886 (r^2 = 0.75).

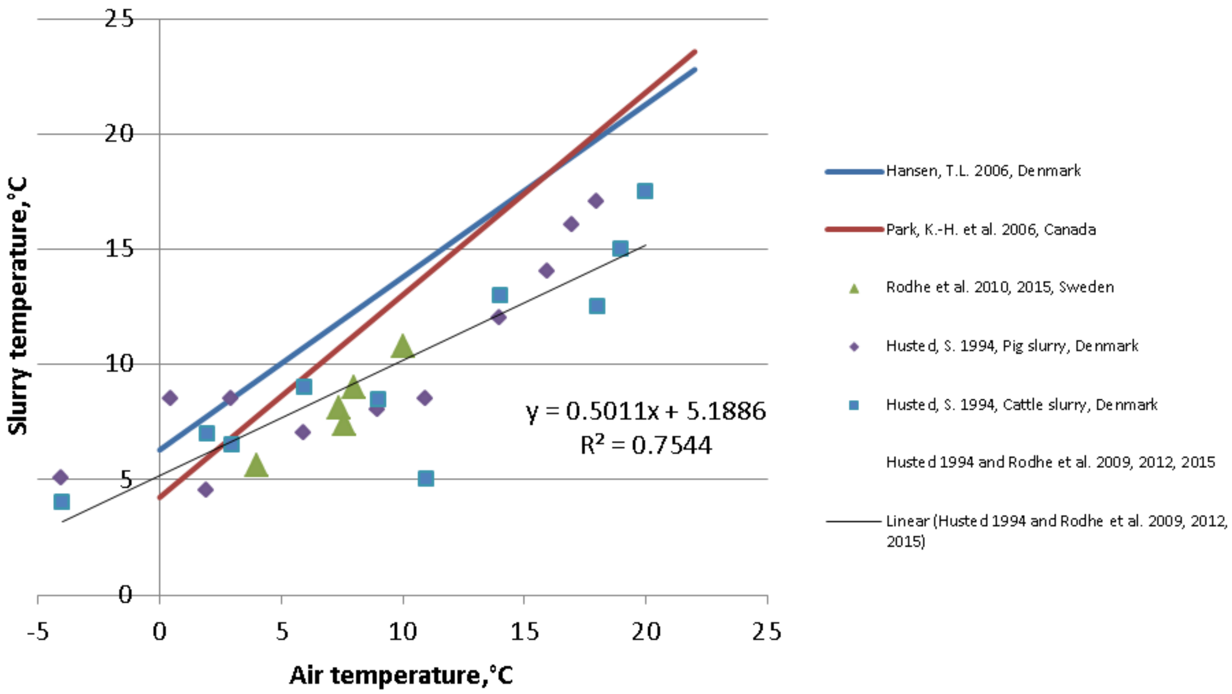


Figure 3D-5 Measured and modelled slurry temperatures in outdoor storage tanks.

Manure storage and application to fields

The Ministry of Food, Agriculture and Fisheries regulate the storage time and the secondary field application of raw undigested and digested biomass. The general rule is that manure is only allowed to be applied to crops, which have a nitrogen norm and is harvested the same calendar year. Only crops with an official nitrogen norm are allowed to be fertilised (Ministry of Environment and Food, 2015).

It means that autumn application is not allowed as these crops are not harvested within the calendar year. The storage manure capacity is therefore 8-10 months including eventually storage capacity inside the barns.

Field application of manure is not allowed before 1. February and not on frozen or snow covered areas. Because of difficulties for driving in the fields the optimum application time is March and April, plus some application to grass cuttings during summer. Based on discussions with the Danish Agricultural Advisory Centre (SEGES), the general storage profile for animal manure storages has been developed, Figure 3D-6. The figure shows that the maximum storage is in February and the minimum in end April. Slurry is generally stored in four meter deep concrete tanks where two meters are above ground and two meters below ground. As it is not possible to empty the tanks completely (crust cover) it is assumed that 10 % of the annual production is the minimum amount stored by end of April.

No reduction in the CH_4 emission due to microbial degradation in the crust cover (IPCC 2006) has been implemented in the emission estimate so far.

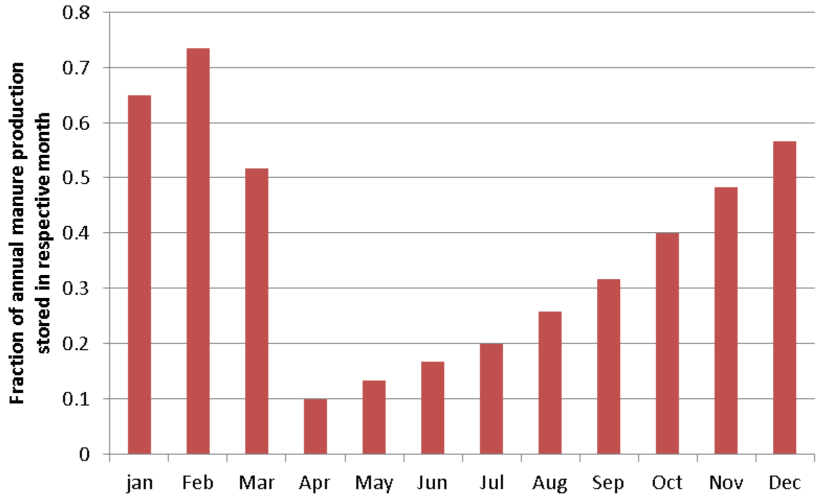


Figure 3D-6 The fraction of animal manure stored during different month of the year. The fraction is the share of the total annual manure production corrected for grazing. Small amounts are applied to grass during summer giving a lower increase in the summer months than in the winter period.

The model

The model estimates methane emission for slurry from cattle and swine. Estimations of CH_4, VSd and VSnd is based on measurements (Petersen et al., 2016). The measurements are not made on the exact time for excretion of the manure and the CH_4 emission is therefore calculated as a constant emission per day, even though some degrading of VS in the barn will take place. The CH_4 emission in barns for swine at 18.6 °C is estimated to 569.5 g CH_4 per kg VS per year, corresponding to 1.56 g CH_4 per kg VS per day. VS from barns are not divided in VSd and VSnd because the measured emission relate to the total amount of VS. The total CH_4 emission from barns is calculated as excreted VS multiplied by 1.56 g CH_4 per kg VS per day and average storage time (HRT) in the barn.

For cattle barns the temperature varies through the year. The emission factor of 66.92 g CH_4 per kg VS per year given in Table 3D-22 is an average for a year. For cattle total CH_4 emission from barns is also calculated as VS multiplied with average store time (HRT). It is assumed that excretion of VS in barns is constant. Time the cattle is on grass gives less manure in the barns, but this is not taken in to account. It is assumed that the effect of grazing is very small because the majority of dairy cattle in Denmark spend most of the time in the barns.

Methane emission from outdoor storage of undigested slurry is estimated in a matrix, where slurry is supplied and taken away with a time step of 10 days. The matrix sums the total methane emission until the decomposition of VS is almost null (around 2 years). The amount of VS supplied the storage is the total VS excretion from the animals and the straw used for bedding, subtracted VS-loss from barns. Removal of VSd and VSnd from storage is estimated for every time step and a new methane emission is calculated. For cattle slurry the estimation gives an emission of 12.02 g CH_4 per kg VSd and 0.16 g CH_4 per kg VSnd (Table 3D-22). For swine slurry the estimation gives 29.64 g CH_4 per kg VSd and 0.63 g CH_4 per kg VSnd (Table 3D-22).

For estimation of methane emission from outdoor storage of digested slurry are used the amount of digested slurry delivered to the biogas plants based on the BIB register. Same model as used for undigested slurry is used for digested slurry, though with a higher temperature in the storage after biogas treatment. The stored digested slurry has a high content of VSnd and the emission of methane is there for low. Due to the low activity of the decomposition a lower CH_4:CO_2-ratio (of 0.1) is assumed for digested slurry compared to undigested slurry (Dong, 2013).

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Annex 3E - LULUCF

List of tables

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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.
$\bar{\bar{X}} = \frac{1}{n}\left(\sum_{j=1}^{n} X_j R_j + N_{21}\bar{X}_1 + N_{22}\bar{X}_2\right)$	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 in 2015.

	Denmark	Copenha-gen area	Bornholm	Zealand	Funen	Southern Jutland	Eastern Jutland	Western Jutland	Northern Jutland
Winter wheat	608733	16543	12175	147728	77269	87802	101554	59744	105918
Spring wheat	12641	306	370	2758	374	2079	2010	2113	2630
Rye	125540	5975	567	7135	6627	27096	16130	30604	31405
Winter barley	114178	1262	1828	11462	12007	23989	26542	16831	20255
Spring barley	524952	9295	5597	126732	34963	113389	51116	111889	71972
Oats	37797	1009	206	1754	1940	11221	3445	8029	10194
Triticale etc.	30054	367	77	3821	2237	6597	4740	6128	6085
Pulses	12229	57	368	2018	1041	2300	1855	2110	2480
Seed potatoes	5851	9	0	589	53	1357	239	2846	757
Potatoes for manufacturing	22012	102	0	49	31	6597	759	10365	4109
Potatoes for human consump-tion	13716	238	5	1371	604	3982	858	5006	1653
Potatoes	41579	349	5	2010	688	11936	1856	18217	6519
Sugar beets	25004	53	0	24491	452	0	0	7	0
Fodder beets	5188	45	18	205	44	1348	614	943	1971
Winter rape	192535	7337	3554	47503	25926	27053	33003	15629	32531
Spring rape, total	699	34	0	212	7	237	139	58	12
Rape, total	193234	7371	3554	47715	25932	27290	33142	15687	32543
Flax	6	0	0	0	0	0	0	6	0
Other seeds for industrial use	401	16	13	280	4	32	23	19	14
Seeds for sowing	74512	899	1563	28271	15488	6323	9313	6730	5926
Lucerne	2579	88	45	512	367	752	271	403	143
Maize for green fodder	177908	907	2266	5926	11067	73861	12095	38255	33532
Cereals and pulses for green fodder	56621	201	313	1159	1157	17040	3549	14496	18706
Pulses, fodder cabbage etc.	0	0	0	0	0	0	0	0	0
Grass and clover in rotation	255623	5995	2434	12630	10338	78943	20529	61049	63705
Grass and green fodder in rotation, total	492732	7191	5057	20226	22930	170596	36445	114202	116086
Vegetables grown in the open, excl peas for canning	8331	434	8	1748	1716	182	1640	1713	891
Peas for canning	2749	16	0	2001	653	3	16	30	29
Vegetables grown in the open, total	11080	451	8	3749	2369	185	1656	1743	920
Bulbs and flowers	39	1	0	21	7	7	0	3	0
Apples	1501	62	6	438	724	57	138	36	40
Pears	317	18	0	104	152	8	21	7	7
Strawberries	1227	74	0	453	231	115	147	99	108
Sour cherries	0	0	0	0	0	0	0	0	0
Sweet cherries	0	0	0	0	0	0	0	0	0
Cherries, total	1059	26	0	601	416	2	3	10	2
Black current	1121	9	0	165	230	651	44	8	14
Other fruits and berries	1124	30	3	257	542	111	131	15	36
Fruits and berries, total	6348	220	9	2018	2294	944	483	174	207
Nursery area	2270	141	1	142	405	1119	115	318	29
Horticultural crops, total	19737	812	17	5929	5075	2255	2255	2237	1156
Permanent grass land out of rotation	254770	14634	2176	29552	19017	53843	30746	42757	62046
Set aside with grass	4501	39	31	2006	194	381	468	625	757
Christmas trees	22101	514	32	2464	2602	3596	5018	3732	4142
Other crops and fallow land	33058	1334	201	6311	2525	5787	5399	4478	7022
Other crops	11013	215	4	521	765	1989	1277	2105	4138
Fallow land	22045	1120	197	5791	1760	3798	4123	2373	2884
Total agricultural area	2632947	68073	33857	472869	231409	557860	332670	447089	489120
Set aside, total	4501	39	31	2006	194	381	468	625	757
Green house area	443	23	0	71	264	20	43	11	11

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	Northern Jutland
Winter wheat	80.3	77.4	82.7	88.7	84.2	76.6	81.2	71.2	73.2
Spring wheat	48.1	48	56.7	43.6	48	44.7	49.9	51	51.8
Rye	63.4	56.7	57.8	65.7	66.5	59.8	65.2	64.7	63.7
Triticale	52.7	52.9	52.9	61.1	49.2	42.9	54.9	47.9	55.7
Winter barley	67.6	60.1	73.1	71.1	71.6	64.3	69.8	64.2	66.8
Spring barley	59.6	62.2	63.4	71.5	65	53.7	61.5	52.3	55.9
Oat and mixed cereals	52.8	49.6	49	52.9	54.9	50.6	59	49.6	55.4
Winter rape	42.8	41.8	45.2	43.1	41.5	41.6	44.7	42.1	42.3
Pulses for maturity	43.1	43.8	43.8	54.1	43.8	41.6	35.2	38.9	45.5
Straw, gathered	38.6	38.2	41.6	43.6	42.5	35.2	40.9	34	37.3
Potatoes for seed	289	227	..	300	284	300	269	308	200
Potatoes for starch production	484	..	..	410	492	518	450	458	518
Potatoes for consumption	342	304	307	365	361	291	366	351	373
Sugar beet for sugar production	669	523	..	670	635	600	635	654	654
Sugar bean for feeding	726	655	655	758	884	653	891	697	740
Lucerne	509	407	430	528	653	532	392	377	411
Green maize for silage	305	251	415	370	377	330	294	252	271
Green cereals for silage	175	164	210	188	244	171	191	151	191
Grass and clover fields in rotation	489	428	472	409	551	491	516	524	462
Permanent grass outside rotation	162	142	142	115	170	148	174	171	192
Secondary grass crop yields	60	52	61	55	53	61	57	60	62

Table 3E.13 Area input format to C-TOOL in 2015 in hectares. Soil Group 1 represents sandy soils, 2 is sandy loam and 3 is loamy sand. Soil Group 4 is organic soils with >6% SOC. Organic soils are NOT included in the estimation of changes in SOC in mineral soils.

Crop type	Soil Group	Bornholm	Copen-hagen and North Zealand	Funen	Southern Jutland	Western Jutland	Eastern Jutland	Northern Jutland	Zealand
Bulbs and flowers	1				2.6	1.4	0	0	
Bulbs and flowers	2	0	0.6	2.4	2.1	1.2	0	0	3.6
Bulbs and flowers	3	0	0.3	4.2	1.9	0.2	0	0	16.6
Bulbs and flowers	4	0	0	0.2	0.5	0.3	0	0	0.7
Flax	1				0	2.9	0	0	
Flax	2	0	0	0	0	2.2	0	0	0
Flax	3	0	0	0	0	0.5	0	0	0
Flax	4	0	0	0	0	0.4	0	0	0
Grass and clover fields in rotation	1				30102.7	29212.4	2723.5	6753.5	
Grass and clover fields in rotation	2	185.8	3529.3	3612	23275.9	22043.8	9938.2	43569.5	2162.4
Grass and clover fields in rotation	3	2231.5	2148.9	6431.7	20273.1	5353	6696.8	6793	10023.6
Grass and clover fields in rotation	4	16.6	316.6	294.3	5291.3	4439.6	1170.4	6589.2	443.9
Green cereals for silage	1				6497.7	6936.5	470.8	1983.2	
Green cereals for silage	2	23.9	118.5	404.2	5024.2	5234.4	1718.1	12793.4	198.3
Green cereals for silage	3	287	72.1	719.9	4375.9	1271	1157.7	1994.6	919.7
Green cereals for silage	4	2.1	10.6	32.8	1142.1	1054.3	202.2	1934.7	40.7
Green maize for silage	1				28164.8	18305.3	1604.6	3554.8	
Green maize for silage	2	173.1	534.1	3866.7	21777.6	13813.2	5855.3	22933.3	1014.6
Green maize for silage	3	2077.5	325.2	6885.3	18968.1	3354.4	3945.5	3575.5	4703
Green maize for silage	4	15.4	48	314.9	4950.7	2782	689.5	3468.4	208.2
Lucerne	1				286.8	192.9	36	15.1	
Lucerne	2	3.3	51.8	128.1	221.6	145.6	131.2	97.9	87.6
Lucerne	3	41.3	31.5	228.4	193.1	35.4	88.5	15.2	406.4
Lucerne	4	0.2	4.6	10.4	50.4	29.3	15.4	14.9	17.9
Nursery area	1				426.8	152.1	15.2	3.1	
Nursery area	2	0	82.9	141.4	329.9	114.8	55.6	19.8	24.2
Nursery area	3	0.9	50.5	252	287.5	27.9	37.5	3	112.8
Nursery area	4	0	7.5	11.6	75.1	23.1	6.6	3	5
Oat and mixed cereals	1				4278.8	3841.8	457.1	1080.6	
Oat and mixed cereals	2	15.7	594	677.8	3308.5	2899.1	1667.6	6971.9	300.3
Oat and mixed cereals	3	188.8	361.6	1207.1	2881.7	703.9	1123.8	1086.9	1392.2
Oat and mixed cereals	4	1.4	53.2	55.1	752.1	583.8	196.4	1054.4	61.6
Other crops and fallow land	1				2206.9	2142.7	716.3	744.5	
Other crops and fallow land	2	15.3	785.5	882.2	1706.2	1616.9	2613.8	4802.5	1080.6
Other crops and fallow land	3	184.4	478.2	1570.9	1486.2	392.6	1761	748.7	5008.8
Other crops and fallow land	4	1.4	70.5	71.8	387.9	325.6	307.7	726.3	221.7
Other seeds for industrial use	1				24	17.8	5.6	2.6	
Other seeds for industrial use	2	1.3	12.3	3.2	18.7	13.5	20.2	16.4	92.4
Other seeds for industrial use	3	15.6	7.4	5.7	16.2	3.2	13.8	2.5	428.7
Other seeds for industrial use	4	0	1	0.3	4.2	2.8	2.5	2.4	19
Permanent grass outside rotation	1				20531.6	20459.7	4079.2	6577.6	
Permanent grass outside rotation	2	166.1	8615.4	6644.5	15875.3	15438.9	14884.4	42434.8	5059.7
Permanent grass outside rotation	3	1995.1	5245.5	11831.4	13827.2	3749.1	10029.5	6616.1	23453.7
Permanent grass outside rotation	4	14.7	773	541.2	3608.8	3109.4	1752.7	6417.6	1038.6
Potatoes for consumption	1				1518.4	2395.3	113.8	175.3	
Potatoes for consumption	2	0.3	140.1	211.1	1174.1	1807.6	415.3	1130.6	234.7
Potatoes for consumption	3	4.6	85.3	375.8	1022.6	438.9	279.9	176.2	1087.9
Potatoes for consumption	4	0	12.6	17.1	267	364.1	49	170.8	48.3
Potatoes for starch production	1				2515.5	4959.8	100.8	435.7	
Potatoes for starch production	2	0	60	10.9	1944.9	3742.5	367.4	2810.2	8.3
Potatoes for starch production	3	0	36.5	19.2	1694.1	908.9	247.7	438.2	39
Potatoes for starch production	4	0	5.3	0.8	442.3	753.7	43.2	425	1.8
Pulses for maturity	1				877	1009.6	246.2	263	
Pulses for maturity	2	28.1	33.5	363.7	678.1	761.8	898	1696.1	345.5
Pulses for maturity	3	337.4	20.5	647.7	590.7	185.1	605	264.5	1601.4
Pulses for maturity	4	2.6	3	29.8	154.3	153.4	105.8	256.6	70.9
Pulses, fodder cabbage etc	1				0	0	0	0	

Crop type	Soil Group	Bornholm	Copen-hagen and North Zealand	Funen	Southern Jutland	Western Jutland	Eastern Jutland	Northern Jutland	Zealand
Pulses, fodder cabbage etc	2	0	0	0	0	0	0	0	0
Pulses, fodder cabbage etc	3	0	0	0	0	0	0	0	0
Pulses, fodder cabbage etc	4	0	0	0	0	0	0	0	0
Rye	1				10332.2	14644.3	2140	3329.5	
Rye	2	43.2	3517.6	2315.6	7989.1	11050.5	7808.6	21478.8	1221.7
Rye	3	519.9	2141.7	4123	6958.3	2683.6	5261.7	3348.6	5662.6
Rye	4	3.8	315.7	188.7	1816.2	2225.6	919.6	3248.4	250.8
Seeds for sowing	1				2411.2	3220.3	1235.7	628.2	
Seeds for sowing	2	119.4	529.2	5411.3	1864.3	2430.1	4508.5	4052.9	4840.4
Seeds for sowing	3	1433.1	322.3	9635.9	1623.8	590.1	3038	631.9	22437
Seeds for sowing	4	10.6	47.6	440.6	423.8	489.5	531	612.9	993.6
Set aside with grass	1				145.3	299	62	80.2	
Set aside with grass	2	2.4	22.8	67.9	112.4	225.7	226.6	517.6	343.4
Set aside with grass	3	28.4	14	120.8	97.9	54.9	152.7	80.7	1592
Set aside with grass	4	0.2	2.1	5.5	25.5	45.5	26.6	78.2	70.4
Set aside, total	1				145.3	299	62	80.2	
Set aside, total	2	2.4	22.8	67.9	112.4	225.7	226.6	517.6	343.4
Set aside, total	3	28.4	14	120.8	97.9	54.9	152.7	80.7	1592
Set aside, total	4	0.2	2.1	5.5	25.5	45.5	26.6	78.2	70.4
Spring barley	1				43237.8	53539.9	6781.7	7630	
Spring barley	2	427.5	5472.1	12215.9	33432	40401.4	24745.6	49223.4	21698.5
Spring barley	3	5131.7	3331.8	21752.1	29119	9811	16674.5	7674.4	100579.7
Spring barley	4	37.8	491	995	7600.2	8136.8	2914.1	7444.3	4454
Spring rape	1				90.3	27.8	18.4	1.2	
Spring rape	2	0	20	2.4	69.8	20.9	67.4	8.3	36.3
Spring rape	3	0	12.1	4.2	60.8	5	45.3	1.3	168.3
Spring rape	4	0	1.7	0.2	15.8	4.3	7.9	1.2	7.4
Spring wheat	1				792.9	1011.1	266.8	278.8	
Spring wheat	2	28.3	180.1	130.6	612.8	762.9	973	1798.7	472.3
Spring wheat	3	339.3	109.7	232.6	533.8	185.3	655.8	280.3	2188.9
Spring wheat	4	2.6	16.1	10.7	139.2	153.7	114.6	272	97
Sugar beet for sugar production	1				0	3.3	0	0	
Sugar beet for sugar production	2	0	31.2	157.9	0	2.5	0	0	4193.2
Sugar beet for sugar production	3	0	19.1	281.1	0	0.5	0	0	19437.1
Sugar beet for sugar production	4	0	2.7	12.7	0	0.4	0	0	860.7
Sugar beets for feeding	1				514	451.2	81.3	208.9	
Sugar beets for feeding	2	1.3	26.5	15.3	397.5	340.5	297.2	1348.1	35.2
Sugar beets for feeding	3	16.5	16.1	27.3	346.2	82.7	200.3	210.1	162.7
Sugar beets for feeding	4	0	2.3	1.2	90.3	68.6	35	204	7.1
Triticale	1				2515.5	2932.3	628.8	645	
Triticale	2	5.9	216	781.6	1944.9	2212.7	2294.5	4161.7	654.2
Triticale	3	70.6	131.7	1391.9	1694.1	537.4	1546.3	648.8	3032.4
Triticale	4	0.5	19.2	63.6	442.3	445.6	270.2	629.3	134.4
Vegetables grown in the open, total	1				70.4	834.1	219.7	97.6	
Vegetables grown in the open, total	2	0.7	265.5	827.8	54.6	629.3	801.7	629	642
Vegetables grown in the open, total	3	7.4	161.8	1473.9	47.5	152.9	540.3	98	2975.4
Vegetables grown in the open, total	4	0	23.9	67.4	12.3	126.8	94.5	95.2	131.8
Winter barley	1				9147.6	8053.8	3521.5	2147.3	
Winter barley	2	139.7	743	4195.1	7073	6077.5	12849.1	13852.9	1962.6
Winter barley	3	1676	452.3	7470.2	6160.5	1475.8	8658.2	2159.7	9096.7
Winter barley	4	12.4	66.8	341.8	1608	1223.9	1513.2	2095.1	402.8
Winter rape	1				10316	7478.7	4378.6	3448.8	
Winter rape	2	271.4	4319.4	9058.4	7976.3	5643.4	15977	22248.7	8133.3
Winter rape	3	3258.7	2629.9	16129.7	6947.3	1370.3	10765.8	3468.8	37700.3
Winter rape	4	24	387.6	737.8	1813.3	1136.6	1881.5	3364.7	1669.5
Winter wheat	1				33480.8	28588	13473.5	11228.8	
Winter wheat	2	929.7	9739.1	26997.3	25887.8	21572.6	49162.9	72439.9	25293.2
Winter wheat	3	11162.9	5929.9	48072.7	22548.1	5238.6	33127.7	11294	117242.9
Winter wheat	4	82.5	873.8	2198.9	5885.2	4344.7	5789.7	10955.4	5191.7

Table 3E.14 Average annual temperatures for Denmark, 1977-2014, °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	2014	10.0
1992	8.958333	2015	9.1
1993	7.558333		
1994	8.608333		
1995	8.183333		
1996	6.833333		
1997	8.5		
1998	8.2		
1999	8.85		

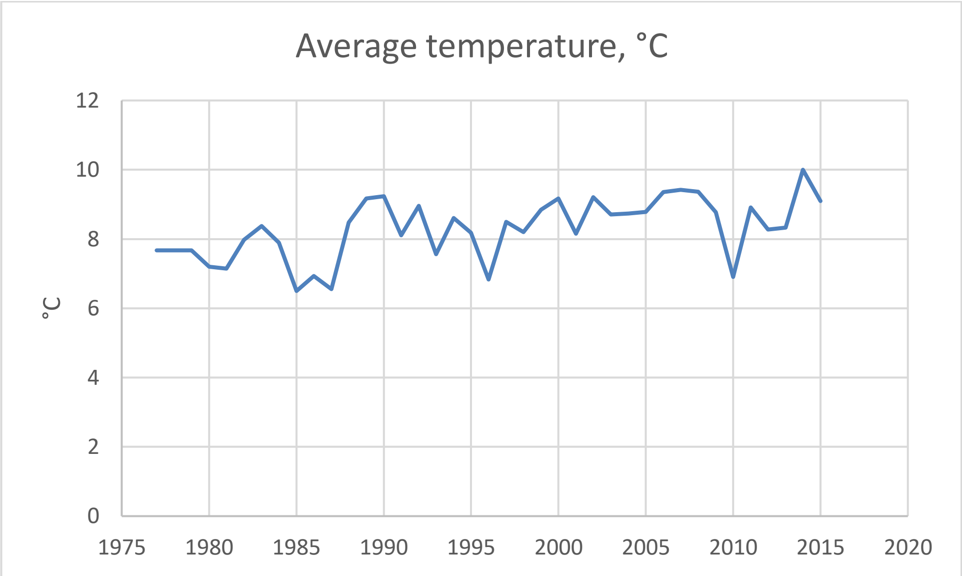

Figure 3E.1 Average annual temperatures for Denmark, 1977-2015, °C.

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 was previously given to approximately 400-800 km of hedgerow in the latter years only financial support has been given to app. 100 ha. From 2017 this subsidiary is ceased. 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).

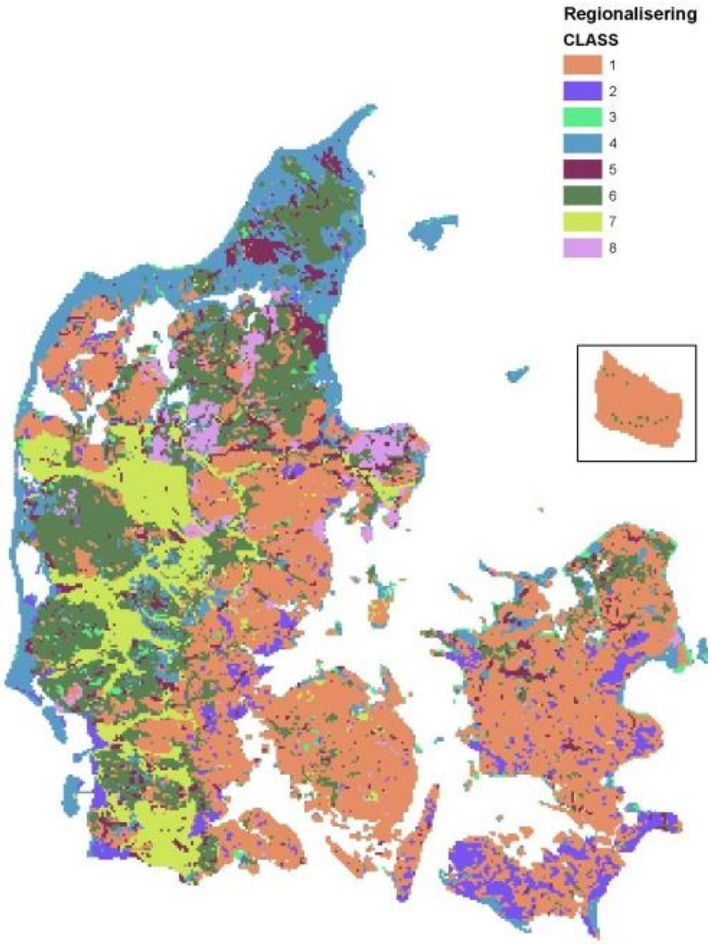

Figure 3E.2 Designated areas with different types/classes of hedges.

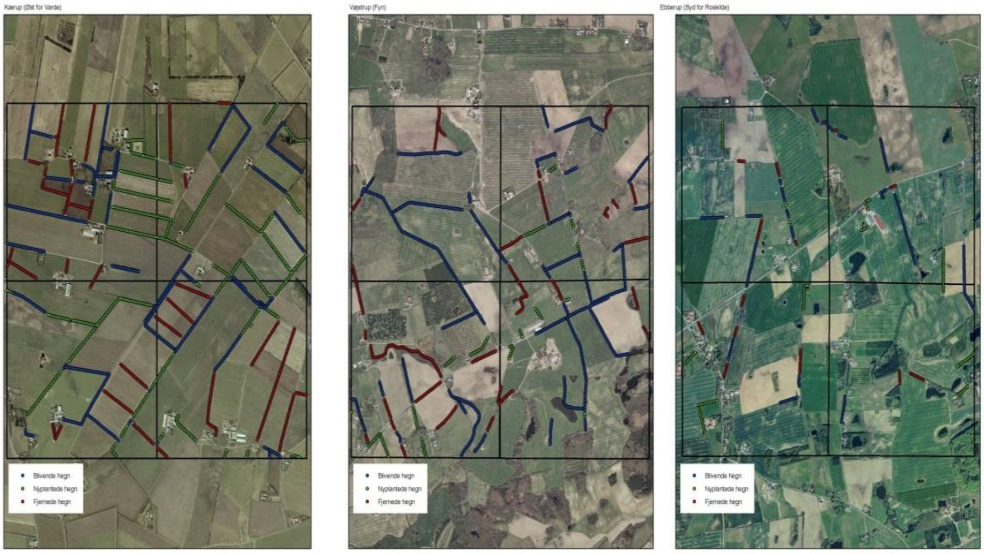

Figure 3E.3 The dynamics of hedgerows in the Danish Landscape 1990 to 2005. Blue colour indicates no changes, red colours are removed hedges and green colours are new hedges (Source: M. Fuglsang, DCE).

The overall results from the analysis of hedges are shown in Table 3E.15. 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 3E.15 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 3E.16. 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. No new planting data has been reported for 2014 and thus is the planting rate set to 0.

Table 3E.16 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 remowed, 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 3E.3).

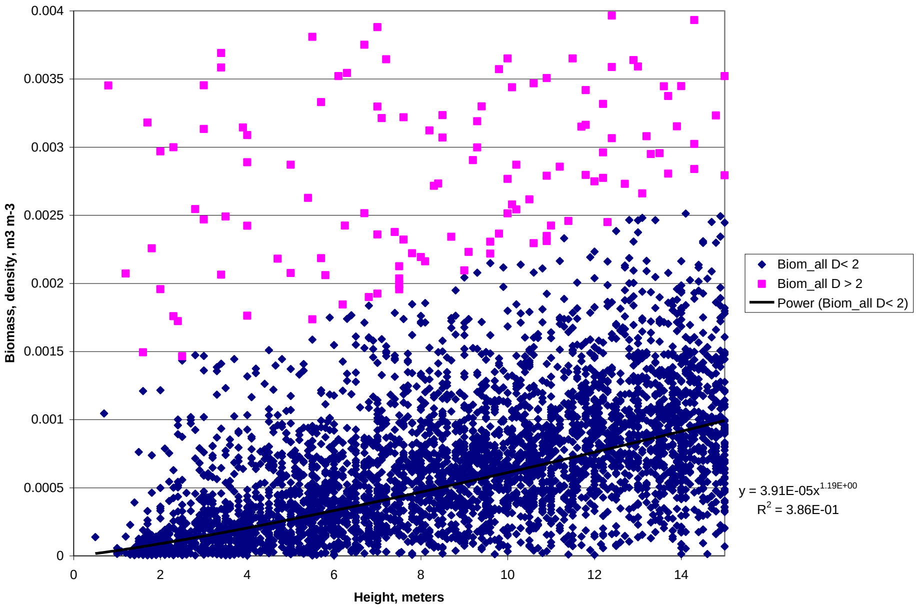

Figure 3E.4 Biomass function estimated as m^3 biomass per m^3 versus tree height in NFI plots less than 15 meter (Courtesy to Lector Thomas Nord-Larsen, IGN, Copenhagen University).

Annex 3F - Waste

Annex 3F-1 Emissions from the waste sector, 1990-2015

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	1,536	1,536	1,517	1,500	1,418	1,331	1,290	1,201	1,125	1,138
5.B. Biological treatment of solid waste	CH_4	38	44	47	53	57	57	67	78	83	93
5.B. Biological treatment of solid waste	N_2O	12	13	15	16	18	21	23	27	56	103
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 discharge	CH_4	96	96	96	96	97	99	99	101	101	102
5.D. Waste water treatment and discharge	N_2O	61	60	54	63	70	69	60	58	61	59
5.E. Other	CO_2	18	18	19	18	18	20	20	19	18	19
5.E. Other	CH_4	1.9	2.0	2.1	1.9	1.9	2.2	2.2	2.1	1.9	2.0
5. Waste	total	1,763	1,770	1,750	1,749	1,679	1,598	1,562	1,485	1,445	1,516
Continued		2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
5.A. Solid waste disposal	CH_4	1,073	1,117	1,042	1,064	936	909	954	907	877	838
5.B. Biological treatment of solid waste	CH_4	101	99	110	119	112	118	128	138	131	142
5.B. Biological treatment of solid waste	N_2O	153	148	229	223	59	59	70	87	86	97
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 discharge	CH_4	103	103	104	104	104	105	105	105	105	106
5.D. Waste water treatment and discharge	N_2O	63	61	73	58	55	64	54	63	79	54
5.E. Other	CO_2	18	18	18	19	18	18	19	19	21	21
5.E. Other	CH_4	2.0	2.0	1.9	2.1	1.9	2.0	2.0	2.2	2.3	2.2
5. Waste	total	1,513	1,548	1,577	1,589	1,286	1,276	1,332	1,322	1,302	1,260
Continued		2010	2011	2012	2013	2014	2015				
5.A. Solid waste disposal	CH_4	772	773	742	702	691	655				
5.B. Biological treatment of solid waste	CH_4	140	135	138	143	176	188				
5.B. Biological treatment of solid waste	N_2O	94	90	91	93	113	113				
5.C. Incineration and open burning of waste	CH_4	0.02	0.02	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	0.26	0.26				
5.D. Waste water treatment and discharge	CH_4	106	107	108	108	109	109				
5.D. Waste water treatment and discharge	N_2O	57	61	55	59	61	63				
5.E. Other	CO_2	18	18	16	16	21	21				
5.E. Other	CH_4	2.0	2.0	1.8	1.8	2.4	2.4				
5. Waste	total	1,190	1,187	1,152	1,123	1,175	1,153				

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, 2015, 2016)

Table 3F-2.1 All nationally produced waste categorised after handling method, collected for the ISAG database 1994-2009 and the new waste reporting system for 2010-2015.

Year	Recycled	Combusted	Landfilled, total waste		Special treatment	Temporary storage	Total excl. Soil	Total incl. soil
	Gg	Gg	Gg	%	Gg	Gg	Gg	Gg
1994	6,157	2,216	2,630	24	102	0		11,105
1995	7,046	2,306	1,969	17	145	0		11,466
1996	7,787	2,507	2,524	20	95	0		12,912
1997	8,046	2,622	2,103	16	86	0		12,857
1998	7,542	2,740	1,868	15	84	0		12,233
1999	7,815	2,929	1,552	13	17	0		12,313
2000	8,461	3,064	1,489	11	17	0		13,031
2001	8,101	3,221	1,317	10	20	109		12,768
2002	8,382	3,344	1,194	9	22	163		13,105
2003	8,218	3,287	981	8	20	108		12,614
2004	8,746	3,437	1,024	8	16	136		13,359
2005	9,545	3,473	983	7	18	191	14.210[c]	14,610
2006	10,768	3,489	1,002	6	19	181		15,459
2007	10,480	3,584	984	6	20	167		15,235
2008	10,725	3,590	1,072	7	21	167		15,575
2009	9,536	3,386	779[a]	6[b]	18	152	13.872[a]	16.348[b]
2010	8,028	3,390	1,075	8	115	60	12,667	
2011	6,851	3,288	725	7	139	87	11,091	13,274
2012	7,127	3,118	552	5	139	62	10,998	13,943
2013	7,354	3,065	487	4	117	117	11,140	16,475
2014	7,877	3,138	479	4	147	100	11,741	17,721
2015							11,384	16,349

[a] From 2009 to 2015, soil and stone is not included in the waste statistics. This does not change the percent of waste landfilled as "soil and stones" are excluded from the toal as well as from the amount of waste landfilled.

[b] In 2009 6 % of the waste was landfilled. Not included in the 6 % is an amount of waste from plant sources (176,000 tonnes) and non-hazardous waste exempted from taxes (2.3 million tonnes) - primarily soil and stones (DEPA, 2011).

[c] In 2005 400 Gg demolition waste is missing in the statistics (DEPA, 2008)

[d] Data on total waste amounts for 2011 to 2015 has been updated by the newest data extracted from the new official available waste reporting system, Report number R013 (https://www.ads.mst.dk/Forms/Reports/R013_Affaldsproduktion.aspx); waste amount inclusive and exclusive "soil and stones". Final disposal categories are reported in the official Waste statistics reported by the Danish EPA (DEPA, 2015 and 2016). Waste statisticsfor 2015 have not yet been published.

[e] The deposited amount of waste at landfills in Table 3G-2.1, both incl.[d] and excl.[a] soil and stones, differs from the waste amounts reported to be deposited at landfills according to the figures reported in Table 3G-2.2. This is due to the fact that Table 3G-2.1 are based on statistics on the primary produced amounts of waste, i.e. data corresponding the waste statistics in the report R013, while data reported in Table 3G-2.2 corresponds to the amounts of waste received at the individual landfills (report R028 available from the new waste data system, https://www.ads.mst.dk/Forms/Reports/R028_Behandlede_Maengder.aspx).

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	68.8	0.5	6.8	61.5	1536
1991	3,050	69.0	0.7	6.8	61.5	1536
1992	2,910	68.9	1.5	6.7	60.7	1517
1993	2,770	68.4	1.8	6.7	60.0	1500
1994	2,630	67.8	4.7	6.3	56.7	1418
1995	1,969	66.8	7.6	5.9	53.2	1331
1996	2,524	65.7	8.3	5.7	51.6	1290
1997	2,103	64.7	11.4	5.3	48.0	1201
1998	1,868	63.5	13.5	5.0	45.0	1125
1999	1,552	62.3	11.7	5.1	45.5	1138
2000	1,489	58.9	11.3	4.8	42.9	1073
2001	1,317	59.9	10.2	5.0	44.7	1117
2002	1,194	57.8	11.4	4.6	41.7	1042
2003	981	55.4	8.1	4.7	42.5	1064
2004	1,024	52.9	11.3	4.2	37.5	936
2005	983	50.4	9.9	4.0	36.4	909
2006	1,002	48.0	5.6	4.2	38.1	954
2007	984	45.9	5.5	4.0	36.3	907
2008	1,072	43.9	5.0	3.9	35.1	877
2009	779	42.0	4.8	3.7	33.5	838
2010	2,463	40.0	5.7	3.4	30.9	772
2011	2,587	38.3	3.9	3.4	30.9	773
2012	2,475	36.7	3.7	3.3	29.7	742
2013	1,417	35.2	4.0	3.1	28.1	702
2014	1,278	33.7	3.0	3.1	27.7	691
2015	1,084	32.3	3.2	2.9	26.2	655

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 (2017).

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	2014	2015
Food	1	1	1	1	0	0
Paper and cardboard	3	3	2	4	4	4

Continued						
Wood	9	17	9	7	6	10
Plastic*	7	6	9	5	5	6
Textile, fur and leather	3	4	3	4	4	4
Biodegradable garden waste	0	10	3	7	4	5
Chemicals, inert*	1	1	0	0	0	0
Electric & Hazardous*	3	2	1	1	1	0
Glass*	5	5	3	4	4	5
Metal*	179	156	133	124	162	93
Scrap vehicles*	21	17	2	0	0	0
Demolition	132	184	202	189	203	201
Soil & Stone*	1968	2012	1970	963	791	687
Particulate matter and dust*	3	4	25	8	6	3
Sludge, inert*	3	9	11	9	7	7
Sludge, degradable	25	27	19	10	6	5
Ash & Slag*	48	37	14	32	24	16
Other not combustible waste*	52	91	69	50	49	39
Total, [Gg]	2463	2587	2475	1417	1278	1084
Total inert, [Gg]	2290	2340	2236	1196	1050	856

*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 allocation of waste amounts reported according to the European waste codes. 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, 2017).

Table 3F.2.4 European waste codes allocated according to 18 characterised waste types.

Waste types	EWC codes
Food	020199*1/7,020201,020202,020203,020204,020299,020304,020305,020399,020501,020601,020602,020603,020699,190603,190604,190606,190699,200108
Paper and cardboard	020199*1/7,191211*1/7,191212*1/7,150106*1/7,150110*1/7,030307,030308,090107,090108,150101,191201,200101
Wood	170204*1/3,191211*1/7,191212*1/7,150106*1/7,150110*1/7,020107,030101,030104,030105,030199,030301,150103,170201,191206,191207,200137,200138
Plastic*	170204*1/3,020199*1/7,191211*1/7,191212*1/7,150106*1/7,150110*1/7,160119,020104,070213,120105,150102,160103,170203,191204,200139
Textile, fur and leather	191211*1/7,191212*1/7,150106*1/7,150110*1/7,040101,040108,040109,040199,040209,150109,150203,191208,200110,200111
Biodegradable garden waste	1905,190501,190502,190503,190599,200201
Chemicals, inert*	020199*1/7,010102,010304,010307,010407,010411,010412,030204,050701,050702,050799,060101,060102,060103,060104,060105,060106,060199,060201,060203,060204,060205,060299,060311,060313,060314,060315,060316,060399,060403,060404,060405,060499,060602,060603,060699,060701,060703,060704,060799,060802,060899,060902,060903,060904,060999,061002,061099,0611,061101,061199,061301,100309,101201,110501,110502,160111,160112,160304,180110,190401,190403,190404,200114,200115,080501,100105,100107,100109,101210,101212,200127
Electric & Hazardous*	010506,090101,090102,090110,090111,090112,100329,100403,100510,100810,100815,100817,100905,100907,100909,100911,100913,100916,101005,101009,101011,101013,101015,101109,101115,101117,101119,101209,101312,101401,110109,110111,110113,110115,110198,110205,110207,120114,150111,150202,160108,160110,160114,160121,160122,160212,160213,160214,160215,160216,160303,160401,160402,160403,160504,160505,160506,160507,160508,160509,160601,160602,160603,160604,160605,160606,160801,160802,160803,160804,160805,160806,160807,160901,160902,160903,160904,161001,161002,161003,161004,161101,161102,161103,161104,161105,161106,200117,170410,170411,200121,200133,200134,200135,200136
Glass*	170204*1/3,020199*1/7,191211*1/7,191212*1/7,150106*1/7,150110*1/7,101103,101110,101111,101112,101113,101114,101199,150107,160120,170202,191205,200102
Metal*	020199*1/7,191211*1/7,191212*1/7,150106*2/7,150110*2/7,100302,100305,100704,100811,100813,100814,100906,100908,101211,110206,110299,120101,120102,120103,160117,160118,191202,191203,200140,010101,010305,010306,010399,020110,100210,100299,100404,100504,100604,101007,101008,101010,101012,101014,101016,101099,150104,150105,170401,170402,170403,170404,170405,170406,170407,170409,190102,191001,191002,191003,191004,191005,191006
Scrap vehicles*	160106,160104,160199
Demolition	101309,101310,101314,101208,170101,170102,170103,170106,170107,170301,170302,170601,170603,170604,170605,170606,170801,170802,170901,170902,170903,170904
Continued	
Soil & Stone*	191211*1/7,191212*1/7,020401,191209,010408,010413,010499,010504,010507,010599,170503,170504,170505,170506,170507,170508,200202,200203,200303
Particulate matter and dust*	010308,010410,100319,100320,100321,100322,100405,100503,100603,100804,100816,100910,100912,100914,100915,100999,101105,101203,040106,101301,101304,101306,101311,101399,120104,120116,120117,120120,120121,120199,200141
Sludge, inert*	010309,010409,010508,020402,030309,050102,050103,050104,050107,050108,060502,060503,060702,061302,061303,061304,061305,061399,080201,080202,080203,100120,100121,100122,100123,100124,100126,100213,100214,100215,100328,100407,100505,100508,100509,100610,100705,100708,100818,100820,101118,101205,101206,101213,101307,110116,110202,110203,110301,110302,110503,110504,110599,120107,120109,120301,120302,190105,190106,190107,190110,190801,190802,190806,190807,190808,190899,190901,190902,190904,190905,190906,190999,191302,191306
Sludge, degradable	020199*1/7,010505,020101,020102,020103,020106,020108,020109,020301,020302,020303,020403,020499,020502,020599,020701,020702,020703,020704,020705,020799,030201,030202,030203,030205,030299,030302,030305,030310,030311,030399,040102,040103,040104,040105,040107,040210,040214,040215,040216,040217,040219,040220,040221,040222,040299,050105,050106,050109,050110,050111,050112,050113,050114,050116,050199,050601,050603,050604,050699,070101,070103,070104,070107,070108,070109,070110,070111,070112,070199,070201,070203,070204,070207,070208,070209,070210,070211,070212,070214,070215,070216,070217,070299,070301,070303,070304,070307,070308,070309,070310,070311,070312,070399,070401,070403,070404,070407,070408,070409,070410,070411,070412,070413,070499,070501,070503,070504,070507,070508,070509,070510,070511,070512,070513,070514,070599,070601,070603,070604,070607,070608,070609,070610,070611,070612,070699,070701,070703,070704,070707,070708,070709,070710,070711,070712,070799,080111,080112,080113,080114,080115,080116,080117,080118,080119,080120,080121,080199,080299,080307,080308,080312,080313,080314,080315,080316,0
Sludge, degradable	80317,080318,080319,080399,080409,080410,080411,080412,080413,080414,080415,080416,080417,08

Continued	0499,090103,090104,090105,090106,090113,090199,100125,100202,100211,100212,100317,100318,100327,100409,100410,100499,100511,100599,100609,100699,100707,100799,100812,100819,100899,101299,110105,110106,110107,110108,110110,110112,110114,110199,120106,120108,120110,120112,120113,120115,120118,120119,130101,130104,130105,130109,130110,130111,130112,130113,130204,130205,130206,130207,130208,130306,130307,130308,130309,130310,130401,130402,130403,130501,130502,130503,130506,130507,130508,130701,130702,130703,130801,130802,130899,140601,140602,140603,140604,140605,160107,160109,160113,160115,160116,160209,160210,160211,160305,160306,160708,160709,160799,170303,180101,180102,180103,180104,180106,180107,180108,180109,180201,180202,180203,180205,180206,180207,180208,190205,190206,190207,190208,190209,190210,190211,190299,190304,190305,190306,190307,1906,190605,190702,190703,190805,190809,190810,190811,190812,190813,190814,190903,191101,191102,191103,191104,191105,191106,191199,191210,191301,191303,191304,191305,191307,191308,200113,200119,200123,200125,200126,200128,200129,200130,200131,200132,200302,200304,200306
Ash & Slag*	050115,050117,100101,100102,100103,100104,100113,100114,100115,100116,100117,100118,100119,100199,100201,100207,100208,100304,100308,100323,100324,100325,100326,100330,100399,100401,100402,100406,100501,100506,100601,100602,100606,100607,100701,100702,100703,100808,100809,100903,101003,101006,101116,101120,101313,190111,190112,190113,190114,190115,190116,190117,190118,190119,190199,190203,190204,190402,191107
Other waste, inert*	200199
Combustible[1]	200301*1/2,200301*1/2,200307*1/2,200307*1/2,200399*1/2,200399*1/2,200199

[1]Other combustible is reallocated in a last step according to the relative amount of waste distributed according to the waste types with a content of degradable organic matter:
1.Food,
2.Paper and cardboard,
3. Textile, fur and leather,
4. Biodegradable garden waste and
5. Sludge, degradable

Table 3F-2.5 Fractional distribution of waste types for the whole time series 1990-2015.

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	2014	2015
Food	0.05	0.04	0.04	0.06	0.02	0.03
Paper and cardboard	0.11	0.13	0.09	0.25	0.33	0.34
Wood	0.38	0.67	0.35	0.49	0.51	0.89
Plastic*	0.27	0.25	0.38	0.33	0.43	0.51
Textile, fur and leather	0.12	0.15	0.12	0.25	0.34	0.35
Biodegradable garden waste	0.00	0.40	0.13	0.48	0.29	0.48
Chemicals, inert*	0.04	0.02	0.00	0.00	0.02	0.02
Electric & Hazardous*	0.13	0.06	0.04	0.09	0.08	0.02
Glass*	0.21	0.19	0.11	0.29	0.34	0.45
Metal*	7.27	6.02	5.36	8.75	12.65	8.59
Scrap vehicles*	0.87	0.66	0.06	0.00	0.00	0.00
Demolition	5.36	7.13	8.17	13.35	15.92	18.53
Soil & Stone*	79.90	77.76	79.61	67.94	61.92	63.37
Particulate matter and dust*	0.14	0.17	1.01	0.60	0.49	0.24
Sludge, inert*	0.11	0.35	0.44	0.62	0.53	0.62
Sludge, degradable	1.01	1.03	0.75	0.73	0.45	0.50
Ash & Slag*	1.94	1.44	0.55	2.23	1.84	1.47
Other waste, inert*	2.10	3.54	2.78	3.54	3.84	3.62

Annex 3F-3 Biological Treatment of Solid Waste, 5.B

Table 3F-3.1 and 3.2 shows the methane and nitroux oxide emissions associated to four types of composting and material for the whole time series 1990-2015.

Table 3F-3.1 National emissions from composting – 1990 to 2015, Mg.

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
CH_4	1,386	1,533	1,680	1,826	1,973	1,859	2,170	2,526	2,628	3,033
N_2O	41	46	51	56	60	73	79	93	190	350
Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
CH_4	3,242	3,062	3,394	3,532	3,221	3,420	3,629	4,019	3,688	4,009
N_2O	515	498	771	752	201	200	239	295	291	330
Year	2010	2011	2012	2013	2014	2015				
CH_4	3,873	3,736	3,744	3,828	4,661	4,652				
N_2O	318	307	307	315	385	384				

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
	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
	2010	2011	2012	2013	2013	2014	2015			
Composting of garden and park waste	817	787	789	808	989	987	817			
Composting of organic waste from households and other sources	68	65	65	67	82	82	68			
Composting of sludge	103	99	100	102	125	125	103			
Home composting of garden and vegetable food waste	23	23	23	23	23	23	23			
Total	800	952	954	976	1196	1194	800			

NO = Not Occurring

Table 3F-3.3 shows the whole time series for methane emissions from anaerobic digestion at biogas facilities and associated activity data on the amounts of produced biogas (TJ).

Table 3F-3.3 Activity data and methane emissions from anaerobic digestion at biogas facilities.

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Biogas production, TJ	266	393	383	574	544	746	945	1,053	1,235	1,246
CH4 emission, tonnes	145	215	209	313	297	407	516	575	674	680
	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Biogas production, TJ	1,442	1,633	1,872	2,268	2,294	2,375	2,735	2,748	2,814	3,077
CH4 emission, tonnes	787	892	1,022	1,238	1,253	1,297	1,493	1,500	1,537	1,680
	2010	2011	2012	2013	2013	2014	2015			
Biogas production, TJ	3,184	3,072	3,274	3,434	4,337	5,259	3,184			
CH4 emission, tonnes	1,739	1,678	1,788	1,875	2,368	2,872	1,739			

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 1990-2015.

Table 3F-4.1 Overall emission of greenhouse gases from the incineration of human bodies and animal carcasses

		1990	1991	1992	1993	1994	1995	1996
CO_2 emission from								
Human cremation	Gg	2,05	2,04	2,07	2,16	2,14	2,19	2,17
Animal cremation	Gg	0,12	0,12	0,13	0,14	0,15	0,15	0,16
Total biogenic	Gg	2,17	2,16	2,21	2,30	2,29	2,35	2,33
CH_4 emission from								
Human cremation	Mg	0,48	0,48	0,49	0,51	0,50	0,52	0,51
Animal cremation	Mg	0,03	0,03	0,03	0,03	0,03	0,04	0,04
Total	Mg	0,51	0,51	0,52	0,54	0,54	0,55	0,55
N_2O emission from								
Human cremation	Mg	0,60	0,60	0,61	0,63	0,63	0,64	0,64
Animal cremation	Mg	0,03	0,04	0,04	0,04	0,04	0,05	0,05
Total	Mg	0,64	0,63	0,65	0,68	0,67	0,69	0,68
5C. Waste incineration								
Sum of CH_4 and N_2O CO_2 eqvivalents	Gg	0,20	0,20	0,21	0,21	0,21	0,22	0,22
Continued								
		1997	1998	1999	2000	2001	2002	2003
CO_2 emission from								
Human cremation	Gg	2.15	2.09	2.12	2.08	2.09	2.13	2.10
Animal cremation	Gg	0.17	0.18	0.28	0.34	0.35	0.35	0.36
Total biogenic	Gg	2.32	2.27	2.40	2.43	2.44	2.48	2.46
CH_4 emission from								
Human cremation	Mg	0.50	0.49	0.50	0.49	0.49	0.50	0.49
Animal cremation	Mg	0.04	0.04	0.07	0.08	0.08	0.08	0.08
Total	Mg	0.54	0.53	0.56	0.57	0.57	0.58	0.58
N_2O emission from								
Human cremation	Mg	0.63	0.61	0.62	0.61	0.61	0.63	0.62
Animal cremation	Mg	0.05	0.05	0.08	0.10	0.10	0.10	0.10
Total	Mg	0.68	0.67	0.71	0.71	0.72	0.73	0.72
5C. Waste incineration								
Sum of CH_4 and N_2O CO_2 eqvivalents	Gg	0.22	0.21	0.22	0.23	0.23	0.23	0.23
Continued								
		2004	2005	2006	2007	2008	2009	2010
CO_2 emission from								
Human cremation	Gg	2.08	2.04	2.06	2.09	2.09	2.12	2.10
Animal cremation	Gg	0.44	0.59	0.86	0.99	1.03	1.03	1.12
Total biogenic	Gg	2.52	2.63	2.92	3.08	3.12	3.15	3.22
CH_4 emission from								
Human cremation	Mg	0.49	0.48	0.48	0.49	0.49	0.50	0.49
Animal cremation	Mg	0.10	0.14	0.20	0.23	0.24	0.24	0.26
Total	Mg	0.59	0.62	0.69	0.72	0.73	0.74	0.76
N_2O emission from								
Human cremation	Mg	0.61	0.60	0.61	0.61	0.61	0.62	0.62
Animal cremation	Mg	0.13	0.17	0.25	0.29	0.30	0.30	0.33
Total	Mg	0.74	0.77	0.86	0.90	0.92	0.93	0.95
5C. Waste incineration								
Sum of CH_4 and N_2O CO_2 eqvivalents	Gg	0.24	0.25	0.27	0.29	0.29	0.29	0.30

Continued		2011	2012	2013	2014	2015
CO2 emission from						
Human cremation	Gg	2.06	2.05	2.12	2.08	2.16
Animal cremation	Gg	0.94	0.96	0.88	0.89	0.86
Total biogenic	Gg	3.00	3.01	3.00	2.97	3.03
CH4 emission from						
Human cremation	Mg	0.49	0.48	0.50	0.49	0.51
Animal cremation	Mg	0.22	0.23	0.21	0.21	0.20
Total	Mg	0.71	0.71	0.71	0.70	0.71
N2O emission from						
Human cremation	Mg	0.61	0.60	0.62	0.61	0.64
Animal cremation	Mg	0.28	0.28	0.26	0.26	0.25
Total	Mg	0.88	0.88	0.88	0.87	0.89
5C. Waste incineration Sum of CH_4 and N_2O CO_2 eqvivalents	Gg	0.28	0.28	0.28	0.28	0.28

Table 3F-4.2 presents the activity data for human cremation for 1990-2015.

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	2014	2015
Nationally deceased	54,368	52,516	52,325	52,471	51,340	52,555
Cremations	42,050	41,248	40,909	42,349	41,532	43,238
Cremation fraction, %	77.3	78.6	79.6	80.7	80.9	82.3

Table 3F-4.3 presents the activity data for animal cremation for 1990-2015.

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	2014	2015				
Total, Mg	1,449	1,219	1,238	1,146	1,161	1,119				

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, 1990-2015.

Table 3F-5.1 Produced, recovered and emitted CH_4 from wastewater treatment, Gg, 1990-2015.

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
$CH_{4,AD, gross}$	12.7	13.3	12.2	11.5	14.1	18.4	19.0	24.1	22.0	22.8
$CH_{4,recovery}$	12.6	13.2	12.1	11.4	14.0	18.3	18.8	23.9	21.8	22.6
$CH_{4,AD,net}$	0.12	0.13	0.12	0.11	0.13	0.16	0.16	0.19	0.19	0.20
$CH_{4,sewer+MB}$	0.22	0.22	0.22	0.23	0.24	0.25	0.26	0.27	0.25	0.27
$CH_{4,st}$	3.49	3.49	3.50	3.52	3.53	3.54	3.56	3.58	3.59	3.61
$CH_{4,total}$	3.83	3.84	3.84	3.85	3.89	3.94	3.98	4.04	4.03	4.08
Continued	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
$CH_{4,AD, gross}$	21.20	23.88	21.36	23.89	21.50	20.87	19.18	19.01	15.20	20.29
$CH_{4,recovery}$	20.97	23.66	21.13	23.66	21.28	20.63	18.95	18.79	14.97	20.07
$CH_{4,AD,net}$	0.23	0.23	0.23	0.23	0.22	0.24	0.23	0.23	0.22	0.22
$CH_{4,sewer+MB}$	0.27	0.27	0.27	0.27	0.26	0.27	0.27	0.28	0.25	0.27
$CH_{4,st}$	3.62	3.63	3.64	3.65	3.66	3.67	3.68	3.70	3.72	3.74
$CH_{4,total}$	4.12	4.13	4.14	4.15	4.15	4.19	4.18	4.20	4.19	4.23
Continued	2010	2011	2012	2013	2014	2015				
$CH_{4,AD, gross}$	21.28	19.10	19.21	17.91	17.96	21.73				
$CH_{4,recovery}$	21.06	18.89	18.97	17.67	17.69	21.49				
$CH_{4,AD,net}$	0.22	0.22	0.24	0.25	0.27	0.24				
$CH_{4,sewer+MB}$	0.28	0.28	0.27	0.29	0.29	0.29				
$CH_{4,st}$	3.76	3.78	3.79	3.80	3.82	3.84				
$CH_{4,total}$	4.26	4.28	4.31	4.34	4.38	4.37				

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, 1990-2015.

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
N_2O, indirect	133	126	110	137	134	119	90	79	77	74
N_2O, direct	73	77	72	75	99	111	113	116	126	123
N_2O, total	206	203	182	212	233	231	202	195	203	197
Continued	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
N_2O, indirect	79	67	69	54	60	55	54	58	52	54
N_2O, direct	134	137	176	140	125	161	127	154	214	127
N_2O, total	213	204	244	194	184	216	181	212	265	181
Continued	2010	2011	2012	2013	2014	2015				
N_2O, indirect	55	53	52	52	55	58				
N_2O, direct	136	150	131	147	150	152				
N_2O, total	191	203	183	199	205	210				

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 documention an average COD/COD conversion factor of 2.7 for the Danish WWTPs. Lastly, the fraction of influent TOW treated at WWTPs using anaerobic digestion as sludge management strategy is derived based on a plan.

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, 1990-2015.

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Industrial inlet [%]	2.5	2.5	2.5	5	13.6	22.2	30.8	39.4	48	41
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)	295	295	296	301	314	327	342	356	332	360
TOW (Gg BOD/year)	97	96	97	99	108	116	125	134	143	136
COD/BOD ratio	3.1	3.1	3.1	3.0	2.9	2.8	2.7	2.7	2.3	2.6
$COD_{influent,anaerobic}$ [Gg]*	106	111	102	96	118	154	158	201	183	190
Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Industrial inlet [%]	38.0	38.0	37.0	40.5	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)	365	361	355	360	353	364	356	369	331	358
TOW (Gg BOD/year)	149	146	146	152	139	141	142	149	121	140
COD/BOD ratio	2.5	2.5	2.4	2.4	2.5	2.6	2.5	2.5	2.7	2.6
$COD_{influent,anaerobic}$ [Gg]*	177	199	178	199	179	174	160	158	127	169
Year	2010	2011	2012	2013	2014	2015				
Industrial inlet [%]	40.5	40.5	40.5	40.5	40.5	40.5				
Population-Estimate (1000)	5,535	5,561	5,581	5,603	5,627	5,660				
TOW (Gg COD/year)	372	378	364	383	384	385				
TOW (Gg BOD/year)	145	151	135	136	138	168				
COD/BOD ratio	2.6	2.5	2.7	2.8	2.8	2.3				
$COD_{influent,anaerobic}$ [Gg]*	177	159	160	149	150	181				

* 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	2014	2015				
Influent wastewater to WWTPs*	27357	30049	26316	29557	30033	30509				
Effluent wastewater from WWTP	4025	3916	3849	3467	3478	3705				
Effluent wastewater, total**	6960	6770	6597	6557	6997	7359				

*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 DNA 2007, 2009, 2010, 2011, 2012, 2013, 2014, 2015, 2016).

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, 1990-2015.

Year		**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**
CO_2 emission from											
Accidental building fires	Gg	63.1	65.1	70.7	62.2	62.6	72.2	73.0	67.5	60.4	64.9
- of which non-biogenic	Gg	11.4	11.8	12.8	11.2	11.3	13.1	13.2	12.2	10.9	11.7
Accidental vehicle fires	Gg	6.1	6.2	6.2	6.4	6.4	6.5	6.7	6.7	6.7	6.8
Total. non-biogenic	Gg	17.5	17.9	19.0	17.7	17.7	19.6	19.9	18.9	17.7	18.5
CH_4 emission from											
Accidental building fires	Mg	64.1	66.2	71.8	63.2	63.6	73.4	74.1	68.5	61.3	65.9
Accidental vehicle fires	Mg	12.8	12.9	12.9	13.4	13.4	13.6	13.9	13.9	14.1	14.2
Total	Mg	76.9	79.0	84.8	76.6	77.0	87.0	88.0	82.4	75.4	80.1
5E. Other											
CO_2-eqvivalents	Gg	19.5	19.9	21.1	19.6	19.7	21.8	22.1	20.9	19.5	20.5
Year		**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
CO_2 emission from											
Accidental building fires	Gg	63.8	63.3	61.5	69.5	60.1	62.4	64.2	76.3	72.6	69.6
- of which non-biogenic	Gg	11.5	11.4	11.1	12.6	10.9	11.3	11.6	13.7	13.3	12.6
Accidental vehicle fires	Gg	6.9	6.9	6.8	6.8	6.7	6.9	7.1	5.7	8.2	8.5
Total. non-biogenic	Gg	18.4	18.3	18.0	19.3	17.6	18.1	18.7	19.4	21.5	21.1
CH_4 emission from											
Accidental building fires	Mg	64.9	64.5	62.8	71.0	61.5	63.8	65.6	75.2	74.6	71.3
Accidental vehicle fires	Mg	14.3	14.3	14.2	14.1	14.0	14.3	14.8	11.8	17.0	17.7
Total	Mg	79.2	78.8	77.0	85.1	75.5	78.1	80.4	87.0	91.6	89.0
5E. Other											
CO_2-eqvivalents	Gg	20.4	20.3	19.9	21.5	19.5	20.1	20.7	21.5	23.8	23.3
Year		**2010**	**2011**	**2012**	**2013**	**2014**	**2015**				
CO_2 emission from											
Accidental building fires	Gg	61.7	67.6	60.5	58.9	96.4	96.4				
- of which non-biogenic	Gg	11.1	12.2	10.8	10.6	15.6	15.6				
Accidental vehicle fires	Gg	7.3	6.3	5.6	5.4	5.7	5.7				
Total. non-biogenic	Gg	18.3	18.4	16.4	16.0	21.3	21.3				
CH_4 emission from											
Accidental building fires	Mg	64.6	68.5	61.7	60.6	86.0	86.0				
Accidental vehicle fires	Mg	15.12	13.12	11.59	11.27	11.82	11.82				
Total	Mg	79.7	81.6	73.3	71.9	97.8	97.8				
5E. Other											
CO_2-eqvivalents	Gg	20.3	20.5	18.2	17.8	23.7	23.7				

Table 3F-6.2 presents the occurrence of all accidental fires. building fires and vehicle fires, 1990-2015. 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, 1990-2015.

	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	2014	2015				
All fires	16,728	16,157	14,084	14,546	13,180	13,180				
Building fires	9,325	11,447	9,932	9,893	9,473	9,473				
Vehicle fires	3,459	3,255	2,889	2,841	2,981	2,981				
Other fires	3,944	1,455	1,263	1,764	398	398				

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	2014	2015				
Container fires	594	729	584	584	584	584				
Detached house fires	833	818	742	761	660	660				
Undetached house fires	194	206	181	162	318	318				
Apartment building fires	348	362	327	316	299	299				
Industry building fire	281	334	298	275	751	751				
Additional building fires	429	740	610	619	577	577				

Table 3F-6.4a, b and c presents emission factors for 1990-2015 for accidental fires in detached houses, undetached houses and apartment buildings respectively.

Table 3F-6.4a Emission factors for accidental detached building fires, 1990-2015.

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	2014	2015				
CO_2 - total	Mg	32.0	32.3	32.4	32.4	32.4	32.4				
CO_2 - biogenic	Mg	26.1	26.3	26.4	26.4	26.4	26.4				
CO_2 - non-biogenic	Mg	5.9	6.0	6.0	6.0	6.0	6.0				
CH_4	kg	42.3	42.7	43.0	43.0	43.0	43.0				

Table 3F-6.4b Emission factors for accidental undetached building fire, 1990-2015.

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	2014	2015				
CO_2 - total	Mg	26.2	26.0	26.2	26.2	26.2	26.2				
CO_2 - biogenic	Mg	21.4	21.2	21.4	21.4	21.4	21.4				
CO_2 - non-biogenic	Mg	4.9	4.8	4.9	4.9	4.9	4.9				
CH_4	kg	34.7	34.4	34.7	34.7	34.7	34.7				

Table 3F-6.4c Emission factors for accidental apartment building fires, 1990-2015.

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	2014	2015				
CO_2 - total	Mg	15.1	15.2	15.2	15.2	15.2	15.2				
CO_2 - biogenic	Mg	12.3	12.4	12.4	12.4	12.4	12.4				
CO_2 - non-biogenic	Mg	2.8	2.8	2.8	2.8	2.8	2.8				
CH_4	kg	20.0	20.2	20.2	20.2	20.2	20.2				

Table 3F-6.5 states the average building floor space, 1990-2015.

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	2014	2015				
Detached houses	163	164	165	166	166	166				
Undetached houses	134	132	134	133	133	133				
Apartment buildings	77	78	78	78	78	78				
Industrial buildings	500	500	500	500	500	500				
Additional buildings	20	20	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, 1990-2015.

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
2014	2,390,554	514	12,846	11	310,417	32	43,568	53
2015	2,390,554	514	12,846	11	310,417	32	43,568	53

Table 3F-6.6b Number of nationally registered vehicles and full scale equivalent vehicle fires.

	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
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
2014	295,948	82	141,418	33	3,085	2	1,722	14
2015	295,948	82	141,418	33	3,085	2	1,722	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			
2014	1,053	0	79,045	68	12,998	18			
2015	1,053	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 1990-2015.

Table 3F-6.7 Average weight of different vehicle categories, kg, 1990-2015.

	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
2014*	1,162	11,463	4,046	10,861	134

*set equal to 2014.

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	2014	2015				
Passenger cars	739	674	592	555	524	524				
Buses	266	160	130	121	217	217				
Light duty vehicles	171	185	133	118	105	105				
Heavy duty vehicles	715	606	579	455	422	422				
Motorcycle. moped	10	12	11	11	12	12				
Other transport	33	29	29	26	27	27				
Caravan	63	59	57	59	55	55				
Train	24	28	23	18	18	18				
Ship	189	249	160	100	111	111				
Airplane	7	3	5	5	4	4				
Bicycle	0	0	0	0	0	0				
Tractor	347	254	283	330	346	346				
Combined harvester	398	271	236	402	469	469				
Machine	43	51	53	53	53	53				
Total	3,006	2,580	2,291	2,253	2364	2364				

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	71.0	71.0	70.2	69.4	66.1	62.2	60.4	56.8	53.7	54.2
CH_4, recalculated	Gg	61.5	61.5	60.7	60.0	56.7	53.2	51.6	48.0	45.0	45.5
Change, CO_2 equivalents	Gg	-237.8	-238.6	-238.0	-236.2	-233.3	-224.8	-221.2	-220.0	-218.2	-215.9
Change	%	-15.5	-15.5	-15.7	-15.7	-16.5	-16.9	-17.1	-18.3	-19.4	-19.0

Continued	Unit	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
CH_4, previous inventory	Gg	51.0	53.1	49.9	50.5	45.3	44.0	45.5	43.4	41.9	40.1
CH_4, recalculated	Gg	42.9	44.7	41.7	42.5	37.5	36.4	38.1	36.3	35.1	33.5
Change, CO_2 equivalents	Gg	-203.4	-209.9	-204.8	-200.0	-195.8	-190.1	-183.0	-176.8	-171.2	-165.2
Change	%	-19.0	-18.8	-19.7	-18.8	-20.9	-20.9	-19.2	-19.5	-19.5	-19.7

Continued	Unit	2010	2011	2012	2013	2014	2015
CH_4, previous inventory	Gg	37.2	37.1	35.3	33.9	33.0	
CH_4, recalculated	Gg	30.9	30.9	29.7	28.1	27.7	26.2
Change, CO_2 equivalents	Gg	-6.4	-6.2	-5.6	-5.8	-5.4	
Change	%	-20.6	-20.0	-18.8	-20.7	-19.4	

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	1532	1747	1888	2139	2270	2267	2687	3102	3302	3713
CH_4, recalculated	Mg	1532	1748	1889	2140	2270	2266	2686	3101	3303	3714
N_2O, previous inventory	Mg	41	46	51	56	61	73	79	93	191	350
N_2O, recalculated	Mg	41	45	50	41	59	70	77	90	188	347
Change, CO_2 equivalents	Mg	-268	-301	-397	-4537	-519	-765	-712	-856	-764	-849
Change	%	-1	-1	-1	-7	-1	-1	-1	-1	-1	0

Continued	Unit	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
CH_4, previous inventory	Mg	4027	3951	4419	4773	4475	4717	5121	5517	5222	5691
CH_4, recalculated	Mg	4029	3954	4416	4771	4474	4717	5122	5519	5225	5689
N_2O, previous inventory	Mg	516	498	771	753	202	200	239	295	292	330
N_2O, recalculated	Mg	513	495	767	749	199	197	236	293	289	326
Change, CO_2 equivalents	Mg	-792	-859	-1211	-1242	-984	-798	-826	-732	-745	-1320
Change	%	0	0	0	0	-1	0	0	0	0	-1

Continued	Unit	2010	2011	2012	2013	2014	2015
CH_4, previous inventory	Mg	4811	5539	5342	6910	7181	
CH_4, recalculated	Mg	5611	5414	5531	5703	7029	7523
N_2O, previous inventory	Mg	253	318	293	414	414	
N_2O, recalculated	Mg	315	303	304	311	380	380
Change, CO_2 equivalents	Gg	38	-7	7	-60	-13	
Change	%	16	-3	3	-26	-5	

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	0	0	0	0	0	0	0	0	0
Change	%	0	0	0	0	0	0	0	0	0	0

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	0	0	0	0	0	0	0	0	0
Change	%	0	0	0	0	0	0	0	0	0	0

Continued	Unit	2010	2011	2012	2013	2014	2015
CH_4, previous inventory	Mg	0.76	0.71	0.70	0.71	0.70	
CH_4, recalculated	Mg	0.76	0.71	0.70	0.71	0.70	0.71
N_2O, previous inventory	Mg	0.95	0.88	0.88	0.88	0.87	
N_2O, recalculated	Mg	0.95	0.88	0.88	0.88	0.89	0.89
Change, CO_2 equivalents	Gg	0	0	0	0	4.64	
Change	%	0	0	0	0	1.64	

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	3.83	3.84	3.84	3.85	3.89	3.94	3.98	4.04	4.03	4.08
CH_4, recalculated	Gg	3.83	3.84	3.84	3.85	3.89	3.94	3.98	4.04	4.03	4.08
N_2O, previous inventory	Gg	0.21	0.20	0.18	0.21	0.23	0.23	0.20	0.20	0.20	0.20
N_2O, recalculated	Gg	0.21	0.20	0.18	0.21	0.23	0.23	0.20	0.20	0.20	0.20
Change, CO_2 equivalents	Gg	0	0	0	0	0	0	0	0	0	0
Change	%	0	0	0	0	0	0	0	0	0	0
Continued	Unit	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
CH_4, previous inventory	Gg	4.12	4.13	4.14	4.15	4.15	4.19	4.18	4.20	4.19	4.23
CH_4, recalculated	Gg	4.12	4.13	4.14	4.15	4.15	4.19	4.18	4.20	4.19	4.23
N_2O, previous inventory	Gg	0.21	0.20	0.24	0.19	0.18	0.22	0.18	0.21	0.27	0.18
N_2O, recalculated	Gg	0.21	0.20	0.24	0.19	0.18	0.22	0.18	0.21	0.27	0.18
Change, CO_2 equivalents	Gg	0	0	0	0	0	0	0	0	0	0
Change	%	0	0	0	0	0	0	0	0	0	0
Continued	Unit	2010	2011	2012	2013	2014	2015				
CH_4, previous inventory	Gg	4.26	4.28	4.31	4.34	4.38					
CH_4, recalculated	Gg	4.26	4.28	4.31	4.34	4.38	4.37				
N_2O, previous inventory	Gg	0.19	0.20	0.18	0.20	0.20					
N_2O, recalculated	Gg	0.19	0.20	0.18	0.20	0.20	0.21				
Change, CO_2 equivalents	Gg	0.0	0.0	0.0	-0.4	0.7					
Change	%	0.0	0.0	0.0	-0.3	0.4					

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	18.52
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	7.00	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	0	0	0	0	0	0	-2061	0	0
Change	%	0	0	0	0	0	0	0	-416	0	0
Continued	Unit	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
CO_2, previous inventory	Gg	18.40	18.30	17.95	19.34	17.60	18.13	18.70	19.29	21.42	21.02
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	0	0	0	0	0	0	0	0	0
Change	%	0	0	0	0	0	0	0	0	0	0
Continued	Unit	2010	2011	2012	2013	2014	2015				
CO_2, previous inventory	Gg	18.30	18.34	16.29	15.97	21.27					
CO_2, recalculated	Gg	18.30	18.34	16.29	15.97	21.27	21.27				
CH_4, previous inventory	Gg	0.08	0.08	0.07	0.07	0.10					
CH_4, recalculated	Gg	0.08	0.08	0.07	0.07	0.10	0.10				
Change, CO_2 equivalents	Gg	0.0	0.0	0.0	0.0	0.0					
Change	%	0.0	0.0	0.0	0.0	0.0					

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	18.8	17.7	18.5
CO_2, recalcula-ted	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	76.4	76.7	76.0	75.5	72.3	68.5	67.2	64.0	61.1	62.0
CH_4, recalcula-ted	Gg	66.9	67.1	66.5	66.1	63.0	59.5	58.3	55.2	52.4	53.4
N_2O, previous inventory	Gg	0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.3	0.4	0.5
N_2O, recalcula-ted	Gg	0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.3	0.4	0.5
Change, CO_2 equivalents	Gg	-238	-239	-238	-237	-234	-226	-222	-221	-219	-217
Change	%	-14	-13	-14	-14	-14	-14	-14	-15	-15	-14
Continued	Unit	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
CO_2, previous inventory	Gg	18.4	18.3	17.9	19.3	17.6	18.1	18.7	19.3	21.4	21.0
CO_2, recalcula-ted	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	59.3	61.2	58.5	59.6	54.0	53.0	54.9	53.2	51.4	50.1
CH_4, recalcula-ted	Gg	51.1	52.8	50.3	51.6	46.2	45.4	47.5	46.1	44.6	43.5
N_2O, previous inventory	Gg	0.7	0.7	1.0	0.9	0.4	0.4	0.4	0.5	0.6	0.5
N_2O, recalcula-ted	Gg	0.7	0.7	1.0	0.9	0.4	0.4	0.4	0.5	0.6	0.5
Change, CO_2 equivalents	Gg	-204	-211	-206	-201	-197	-191	-184	-177	-172	-166
Change	%	-13	-14	-13	-13	-15	-15	-14	-13	-13	-13
Continued	Unit	2010	2011	2012	2013	2014	2015				
CO_2, previous inventory	Gg	18.3	18.3	16.3	16.0	21.3					
CO_2, recalcula-ted	Gg	18.3	18.3	16.3	16.0	21.3	21.3				
CH_4, previous inventory	Gg	46.4	47.0	45.0	45.2	44.7					
CH_4, recalcula-ted	Gg	40.8	40.7	39.6	38.2	39.2	38.2				
N_2O, previous inventory	Gg	0.4	0.5	0.5	0.6	0.6					
N_2O, recalcula-ted	Gg	0.5	0.5	0.5	0.5	0.6	0.6				
Change, CO_2 equivalents	Gg	-121	-162	-131	-206	-147					
Change	%	-10	-14	-11	-18	-13					

Annex 4 - Information on the energy statistics

This description of the Danish energy statistics has been prepared by DCE in cooperation 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 the 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] https://ens.dk/en/our-services/statistics-data-key-figures-and-energy-maps/annual-and-monthly-statistics

- 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				
- - Bitumenl				
- - Biodiesel				
Distribution				
- Electricity Used in Distribution				
- - Electricity 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

Continued			
- - Biogas, Others		010100	309A
- - 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			

Continued			
- - Electricity			
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
- - Bio Oil		010200	215A
- - Electricity for Heat Pumps			
- Own Use			
- - District Heating			
- Net Production			
- - District Heating			
Auto producers, 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			
Auto producers, 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			

Continued				
- - District Heating, Net				
Auto producers, 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 Pellets			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 Gas Works Gas				
- - 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				
- Biodiesel				
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 Forestry and Horticulture		
- 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		
- 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 Chips		
- Wood Pellets	030100 111A	
- Wood Waste	030100 111A	
- Biogas, Landfill	030100 111A	
- 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	
- Other Kerosene	020100 206A	
- Gas-/Diesel Oil	020100 204A	
- Petroleum Coke	020100 110A	
- Natural Gas	020100 301A	
- Wood Waste	020100 111A	
- Electricity		
- District Heating		
Retail Trade		
- LPG	020100 303A	
- Other Kerosene	020100 206A	

Continued			
- 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	
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			

Continued		
- 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 1990-2015 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.

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 this submission).

Table A6.1 Total quantities of Kyoto Protocol units by account type at beginning of reported year.

Account type	Unit type					
	AAUs	ERUs	RMUs	CERs	tCERs	lCERs
Party holding accounts	NO	NO	NO	150 896	NO	NO
Entity holding accounts	NO	NO	NO	642 946	NO	NO
Retirement account	NO	NO	NO	NO	NO	NO
Previous period surplus reserve account	NO					
Article 3.3/3.4 net source cancellation accounts	NO	NO	NO	NO		
Non-compliance cancellation account	NO	NO	NO	NO		
Voluntary cancellation account	NO	NO	NO	11 164	NO	NO
Cancellation account for remaining units after carry-over	NO	NO	NO	NO	NO	NO
Article 3.1 ter and quater ambition increase cancellation account	NO					
Article 3.7 ter cancellation account	NO					
tCER cancellation account for expiry					NO	
lCER cancellation account for expiry						NO
lCER cancellation account for reversal of storage						NO
lCER cancellation account for non-submission of certification report						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	NO	NO	NO	805 006	NO	NO

Table A6.2a Annual internal transactions.

Transaction type	Additions						Subtractions					
	AAUs	ERUs	RMUs	CERs	tCERs	lCERs	AAUs	ERUs	RMUs	CERs	tCERs	lCERs
Art6 issuance and conversion												
Party verified projects		NO					NO		NO			
Independently verified projects		NO					NO		NO			
Art3.3 and 3.4 issuance or cancellation												
3.3 Afforestation refor-estation			NO				NO	NO	NO	NO		
3.3 Deforestation			NO				NO	NO	NO	NO		
3.4 Forest management			NO				NO	NO	NO	NO		
3.4 Cropland manage-ment			NO				NO	NO	NO	NO		
3.4 Grazing land man-agement			NO				NO	NO	NO	NO		
3.4 Revegetation			NO				NO	NO	NO	NO		
3.4 Wetland drainage and rewetting			NO				NO	NO	NO	NO		
Art 12 afforestation and reforestation												
Replacement of expired tCERs							NO	NO	NO	NO	NO	
Replacement of expired lCERs							NO	NO	NO	NO		
Replacement for rever-sal of storage							NO	NO	NO	NO		NO
Cancellation for reversa of storage												NO
Replacement for non-submission of certifica-tion report							NO	NO	NO	NO		NO
Cancellation for non-submission of certifica-tion report												NO
Other cancelation												
Voluntary cancellation							NO	NO	NO	11 164	NO	NO
Article 3.1 ter and quate ambition increase cancellation							NO					
Subtotal		NO	NO				NO	NO	NO	11 164	NO	NO

Table A6.2a Annual internal transactions.

Transaction type	Retirement					
	AAUs	ERUs	RMUs	CERs	tCERs	lCERs
Retirement	NO	NO	NO	NO	NO	NO
Retirement from PPSR	NO					
Total	NO	NO	NO	NO	NO	NO

Table A6.2b Annual external transactions.

	Additions						Subtractions					
Total transfers and acquisitions	AAUs	ERUs	RMUs	CERs	tCERs	lCERs	AAUs	ERUs	RMUs	CERs	tCERs	lCERs
CDM	NO	NO	NO	59 850	NO	NO	NO	NO	NO	NO	NO	NO
SE	NO	NO	NO	945	NO	NO	NO	NO	NO	NO	NO	NO
EU	NO	NO	NO	NO	NO	NO	NO	NO	NO	634 856	NO	NO
Subtotal	NO	NO	NO	60 795	NO	NO	NO	NO	NO	634 856	NO	NO

Table A6.2c Annual transactions between PPSR accounts.

	AAUs	ERUs	RMUs	CERs	tCERs	lCERs	AAUs	ERUs	RMUs	CERs	tCERs	lCERs
Subtotal	NO						NO					

Table A6.2d Share of proceeds transactions under decision 1/CMP.8, paragraph 21 - Adaptation Fund.

	AAUs	ERUs	RMUs	CERs	tCERs	lCERs	AAUs	ERUs	RMUs	CERs	tCERs	lCERs
First international transfers of AAUs	NO						NO					
Issuance of ERU from Party-verified projects		NO						NO				
Issuance of independently verified ERUs		NO						NO				

Table A6.2e Total annual transactions.

	AAUs	ERUs	RMUs	CERs	tCERs	lCERs	AAUs	ERUs	RMUs	CERs	tCERs	lCERs
Total (Sum of sub-totals in table 2a and table 2b)	NO	NO	NO	60 795	NO	NO	NO	NO	NO	634 856	NO	NO

Table A6.3 Expiry, cancellation and replacement.

Transaction or event type	Requirement to replace or cancel			Replacement						Cancellation					
Transaction or event type	tCERs	lCERs	CERs	AAUs	ERUs	RMUs	CERs	tCERs	lCERs	AAUs	ERUs	RMUs	CERs	tCERs	lCERs
Temporary CERs															
Expired in retirement and replacement accounts	NO			NO	NO	NO	NO	NO							
Expired in holding accounts	NO													NO	
Long-term CERs															
Expired in retirement and replacement accounts		NO		NO	NO	NO	NO								
Expired in holding accounts		NO													NO
Subject to reversal of Storage		NO		NO	NO	NO	NO		NO						NO
Subject to non submission of certification Report		NO		NO	NO	NO	NO		NO						NO
Carbon Capture and Storage CERs															
Subject to net reversal of storage			NO							NO	NO	NO	NO		
Subject to non submission of certification report			NO							NO	NO	NO	NO		
Total	NO	NO	NO	NO	NO	NO	NO	NO	NO	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	NO	NO	NO	209 438	NO	NO
Entity holding accounts	NO	NO	NO	10 343	NO	NO
Retirement account	NO	NO	NO	NO	NO	NO
Previous period surplus reserve account	NO					
Article 3.3/3.4 net source cancellation accounts	NO	NO	NO	NO		
Non-compliance cancellation account	NO	NO	NO	NO		
Voluntary cancellation account	NO	NO	NO	11 164	NO	NO
Cancellation account for remaining units after carry-over	NO	NO	NO	NO	NO	NO
Article 3.1 ter and quater ambition increase cancellation account	NO					
Article 3.7 ter cancellation account	NO					
tCER cancellation account for expiry					NO	
lCER cancellation account for expiry						NO
lCER cancellation account for reversal of storage						NO
lCER cancellation account for non-submission of certification report						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	NO	NO	NO	230 945	NO	NO

Table A6.5 (a). Summary information on additions and subtractions.

	Additions						Subtractions					
	AAUs	ERUs	RMUs	CERs	tCERs	lCERs	AAUs	ERUs	RMUs	CERs	tCERs	lCERs
Assigned amount units issued	NO											
Article 3 Paragraph 7 ter cancellations							NO					
Cancellation following increase in ambition							NO					
Cancellation of remaining units after carry over							NO	NO	NO	NO	NO	NO
Non-compliance cancellation							NO	NO	NO	NO		
Carry-over		NO		NO								
Carry-over to PPSR	NO						NO					
Total	NO	NO		NO			NO	NO	NO	NO	NO	NO

Table A6.5 (b). Summary information on annual transactions.

	Additions						Subtractions					
	AAUs	ERUs	RMUs	CERs	tCERs	lCERs	AAUs	ERUs	RMUs	CERs	tCERs	lCERs
Year 1 (2013)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Year 2 (2014)	NO	NO	NO	37 361	NO	NO	NO	NO	NO	3 142	NO	NO
Year 3 (2015)	NO	NO	NO	815 943	NO	NO	NO	NO	NO	56 320	NO	NO
Year 4 (2016)	NO	NO	NO	60 795	NO	NO	NO	NO	NO	634 856	NO	NO
Year 5 (2017)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Year 6 (2018)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Year 7 (2019)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Year 8 (2020)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Year 2021	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Year 2022	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Year 2023	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Total	NO	NO	NO	914 099	NO	NO	NO	NO	NO	694 318	NO	NO

Table A6.5 (c). Summary information on annual transactions between PPSR accounts.

	Additions						Subtractions					
	AAUs	ERUs	RMUs	CERs	tCERs	lCERs	AAUs	ERUs	RMUs	CERs	tCERs	lCERs
Year 1 (2013)	NO						NO					
Year 2 (2014)	NO						NO					
Year 3 (2015)	NO						NO					
Year 4 (2016)	NO						NO					
Year 5 (2017)	NO						NO					
Year 6 (2018)	NO						NO					
Year 7 (2019)	NO						NO					
Year 8 (2020)	NO						NO					
Year 2021	NO						NO					
Year 2022	NO						NO					
Year 2023	NO						NO					
Total	NO						NO					

Table A6.5 (d). Summary information on expiry, cancellation and replacement.

	Requirement to replace or cancel			Replacement						Cancellation					
	tCERs	lCERs	CERs	AAUs	ERUs	RMUs	CERs	tCERs	lCERs	AAUs	ERUs	RMUs	CERs	tCERs	lCERs
Year 1 (2013)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Year 2 (2014)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Year 3 (2015)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Year 4 (2016)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Year 5 (2017)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Year 6 (2018)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Year 7 (2019)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Year 8 (2020)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Year 2021	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Year 2022	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Year 2023	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Total	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO

Table A6.5 (e). Summary information on retirement.

	Retirement – Unit type					
Year	AAUs	ERUs	RMUs	CERs	tCERs	lCERs
Year 1 (2013)	NO	NO	NO	NO	NO	NO
Year 2 (2014)	NO	NO	NO	NO	NO	NO
Year 3 (2015)	NO	NO	NO	NO	NO	NO
Year 4 (2016)	NO	NO	NO	NO	NO	NO
Year 5 (2017)	NO	NO	NO	NO	NO	NO
Year 6 (2018)	NO	NO	NO	NO	NO	NO
Year 7 (2019)	NO	NO	NO	NO	NO	NO
Year 8 (2020)	NO	NO	NO	NO	NO	NO
Year 2021	NO	NO	NO	NO	NO	NO
Year 2022	NO	NO	NO	NO	NO	NO
Year 2023	NO	NO	NO	NO	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

Changes in procedures in the Danish Emission Trading registry

Changes to the security procedures
Security strategy updated on 15 June 2016:

The security strategy for the Danish Emission Trading Registry was updated on 15 June 2016 in order to optimize procedures and enhance security. The changes include:

- An extended, personalized password for all team members containing at minimum 12 characters.
- Procedure for the teams IT-security is updated. SMS-passcode is implemented for log-on to all the team member's computers
- Procedure for confidential information
- All national Administrators with full access to the registry must be approved by the police intelligence.
- All security standards for the Danish Business Authority (It-related as well as for the building (e.g. access control) and the special procedures for the registry team (access to IT, tel, token, how to behave in case of catastrophe etc.) has been included, but has not changed
- Updated procedure for managing security breach
- Updated list of information assets Penetration test is planned every 4th year for internal IT-systems related to the registry.

Strategy for checks performed by the Danish Emission Trading Registry updated 15 June 2016:

The control strategy for the Danish Emission Trading Registry was updated on 15 June 2016 in order to optimize procedures and the checks performed by the Registry Team. The changes include:

- Data validity is automatically checked on a weekly basis. This relates to data obtained from governmental registries
- Transactions in the registry are checked regularly to discover signs of fraud.
- Yearly check of administrator access to the registry for administrators not working in the Danish Business Authority without full access to the registry (IT-service desk, Danish Tax authority etc.).

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.A.A), 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 the 2014 delivery of data it had not been possible to rearrange the data for foreign fishing vessels from Statistics Faroe Islands to fully comply with the IPCC guidelines. 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 2014 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 1990-2015 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
1996-2015	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, 2013, 2014 and 2015 for GHG CO_2 equivalents, CO_2, CH_4, N_2O and F-gases (CRF: Table 10) and emission trend summary table 1990, 2000, 2010, 2011, 2012, 2013, 2014 and 2015 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, 92.8 %, 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 2015. The total greenhouse gas emission in CO_2 equivalents has increased by 20 % from 1990 to 2015. Comments on the overall trends etc. are given in the sections below.

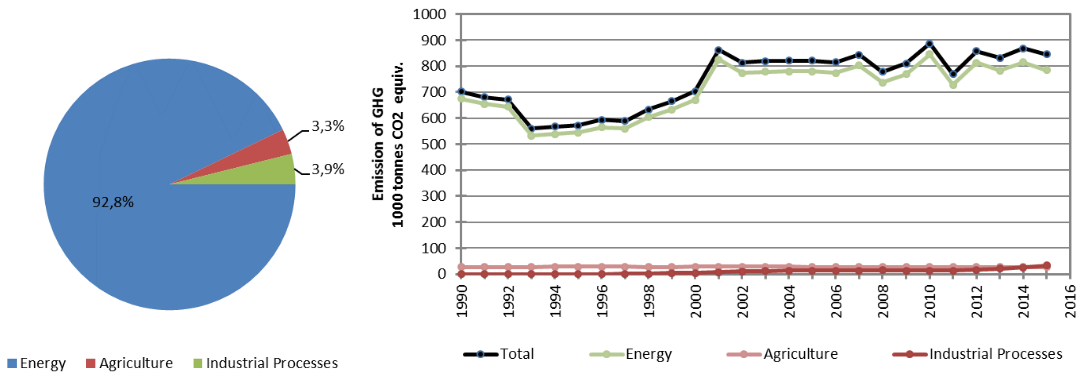

Figure 1 Greenhouse gas emissions in CO_2 equivalents distributed on main sectors for 2015 and time series for 1990 to 2015.

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 2015, calculated in GWP values. CO_2 is the most important greenhouse gas contributing in 2015 with 92.2 %, followed by F-gases (HFCs and SF_6) and CH_4 with 3.9 % and 2.6 % each and N_2O with 1.3 %.

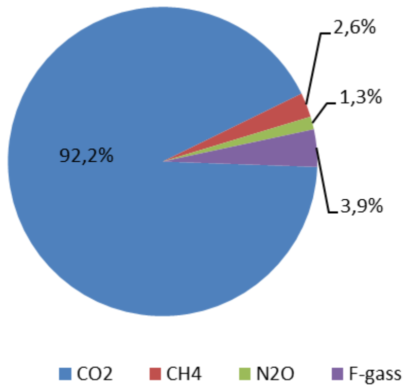

Figure 2   Emissions of GHG in CO_2 equivalents in 2015 distributed on type of gas.

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 1990-2015. 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 2015 the emissions were 20 % above 1990, the base year.

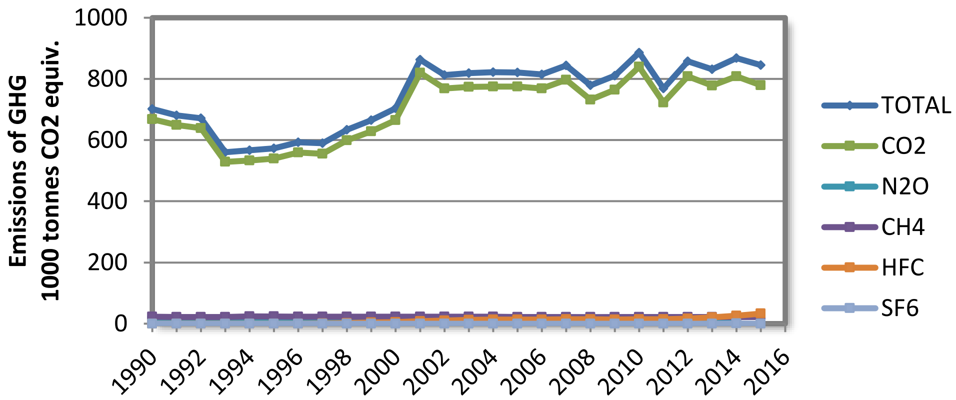

Figure 3   GHG emission in CO_2 equivalents, time series 1990-2015.

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 2015. After the economic decline in the 1990's, the emissions rose and were rather constant until 2007. From 2008 to 2011 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.

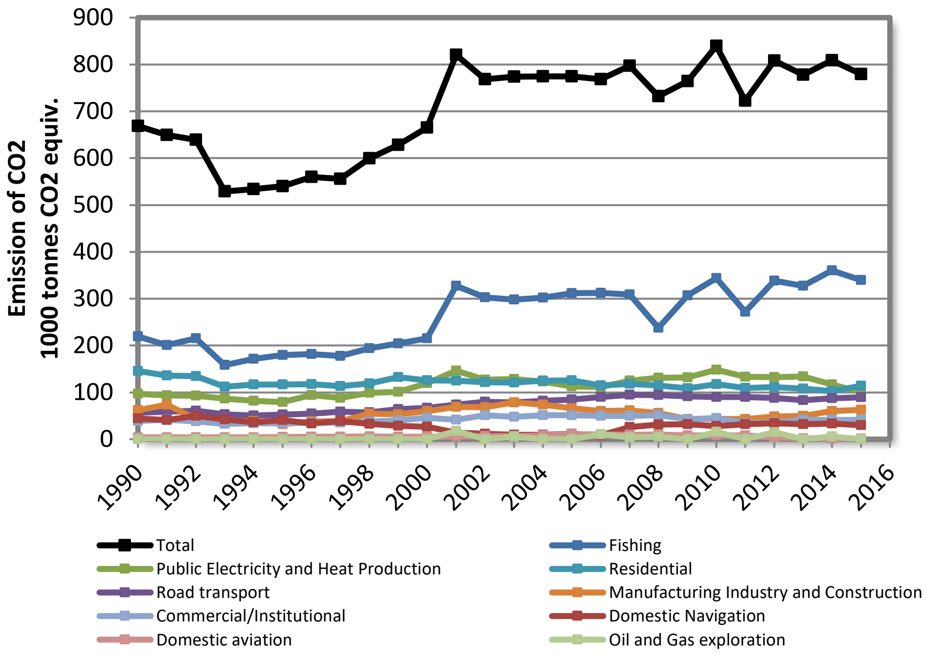

Figure 4 Total CO_2 emissions, time series for 1990-2015.

Figure 5 shows how the emissions are distributed between categories. In 2015, 44 % of the CO_2 emissions came from fishing vessels. Households and public electricity and heat production accounted for 15 % and 13 % and road transport for 11 % of the total CO_2 emission.

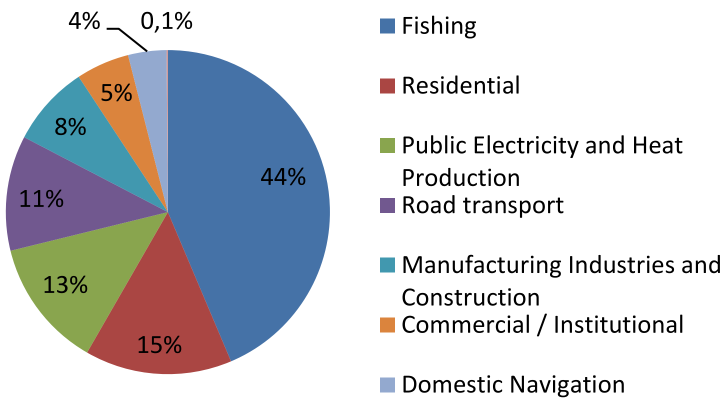

Figure 5 Emissions of CO_2 in the Energy sector, divided in fuel consumption categories, 2015.

Nitrous oxide

Figure 6 shows the emissions of nitrous oxide in the Faroe Islands 1990-2015. Most of the N_2O is from the agriculture sector, especially from animals grazing on agricultural soils.

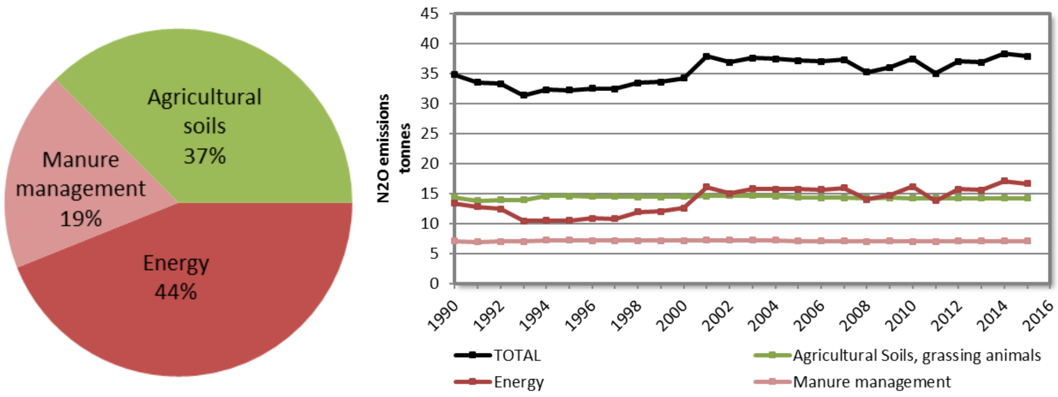

Figure 6 N_2O emissions in tonnes distributed on sector and time series for 1990-2015.

Methane

Figure 7 shows the emissions of methane in the Faroe Islands 1990-2015. Most of the methane emission is from the agriculture sector, especially from enteric fermentation (93 %). Most of the emission of CH_4 in the energy sector is due to aviation activity.

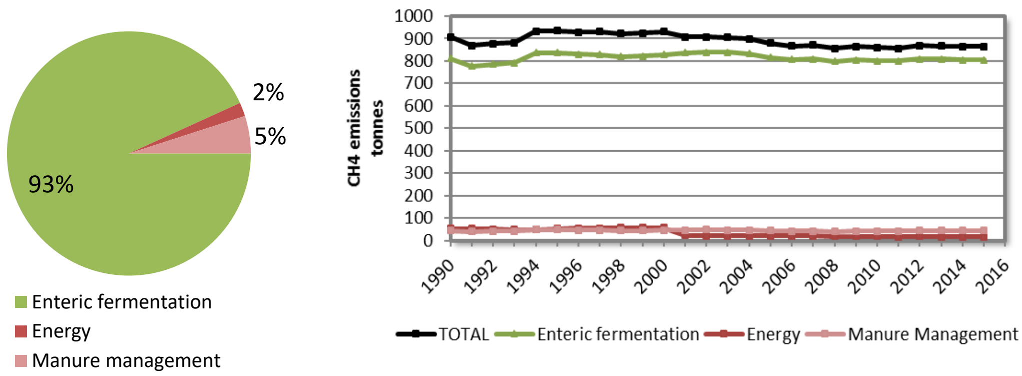

Figure 7 CH_4 emissions in tonnes distributed on sectors and time series for 1990-2015.

HFCs, PFCs, SF_6 and NF_3

Figure 8 shows the emissions of F-gases, HFCs and SF_6 respectively in the years 1990-2015. 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 14,000 tonnes of CO_2 equivalents pr. year until 2011. Since then the emission has increased each year, and were in 2015 the emissions of HFC were 32,755 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.

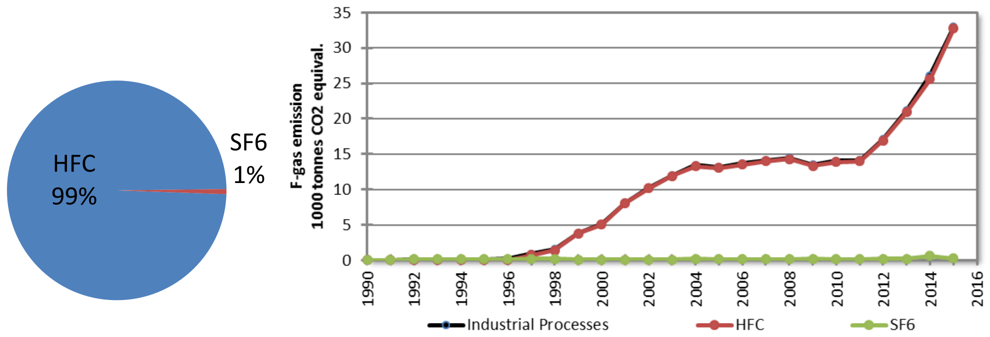

Figure 8 F-gas emissions in CO_2 equivalents, contribution from type of F-gas and time series for 1990-2015.

In 2014 a top was in the actual emission of SF_6 was 248 tonnes CO_2 equivalents. This significant increase in SF_6 emission was primarily due to the opening of a windmill park in Húsahagi, just outside Tórshavn, where 13 new mills were installed in 2014, belonging to SEV, the electricity company. In 2015 the emission was similar to the years before 2014.

PFC nor NF_3 have been in use in the Faroe Islands.

Description and interpretation of emission trends by source

In 2015, nearly 93 % of all GHG emissions were from the Energy sector, including waste incineration. Nearly 4 % were from Industrial processes and Product Use and 3.3 % from Agriculture, see Figure 1.

The fluctuations in the GHG emissions in the Energy sector are decisive for the fluctuations in the total GHG emissions, see Figure 9. The emissions from the Agriculture sector and from Industrial processes and Product Use are relative small and constant.

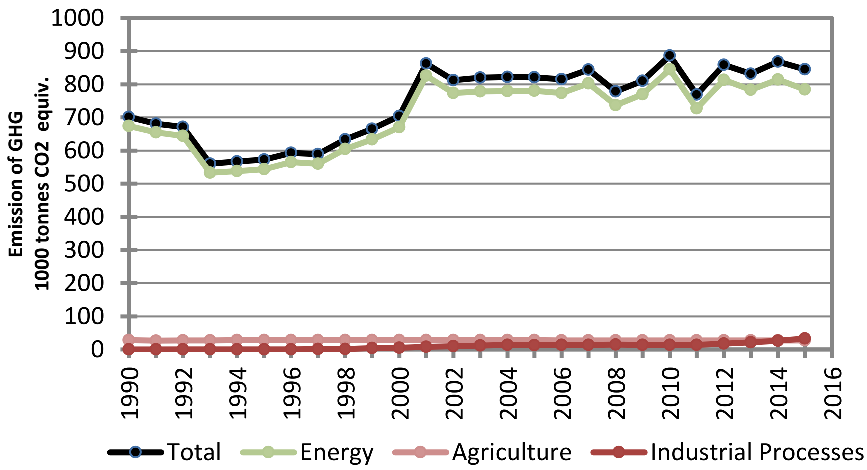

Figure 9 GHG emissions in CO_2 equivalents, main sectors, time series 1990-2015.

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 10. Most of the fuel is used by fishing vessels.

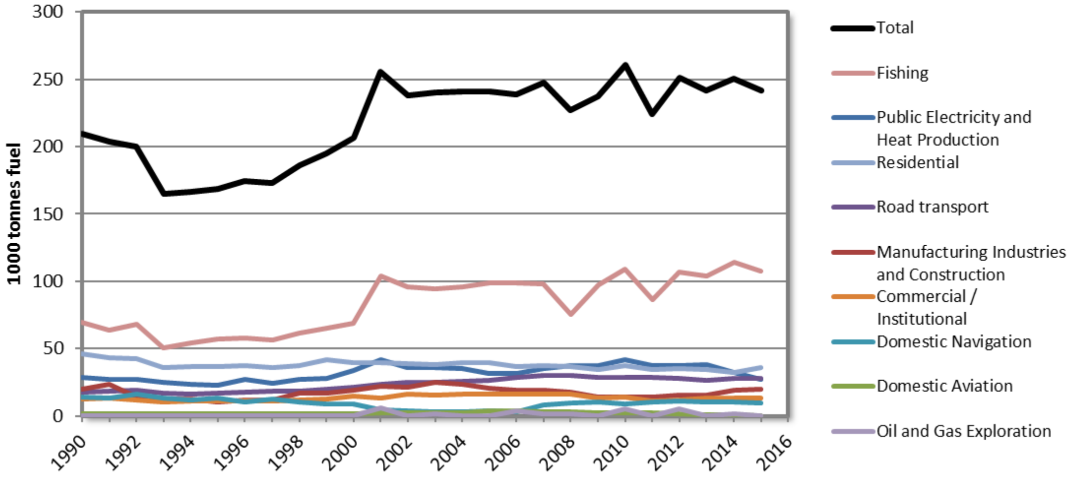

Figure 10 Fuel consumption (tonnes) in the Energy sector, including waste incineration, 1990-2015.

Figure 11 shows the GHG emissions in the Energy sector on the Faroe Islands 1990-2015. The trend is just the same as in Figure 10.

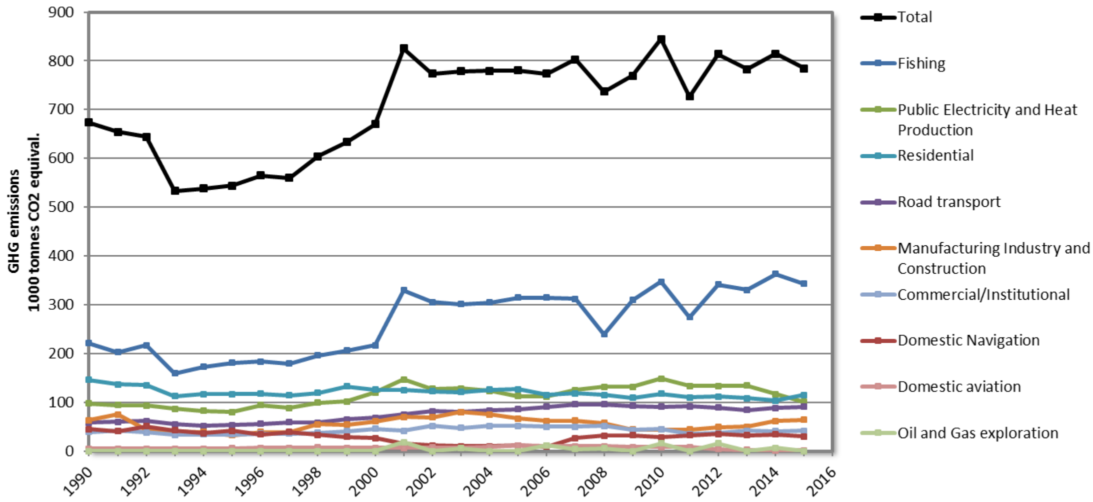

Figure 11 GHG emissions in CO_2 equivalents, categories in the Energy sector, 1990-2015.

Figure 12 shows how the emission of GHG in 2015 was distributed between groups of fuel users. Fishing vessels, Residential, Electricity production and Road transport had 44, 15, 13 and 12 %, respectively, of the emissions in the Energy sector in 2015

Waste incineration has been included under sector 1A1a (Electricity and Heat production), comprising 13 % of the total emissions in the sector and 1.6 % of the total emissions in 2015.

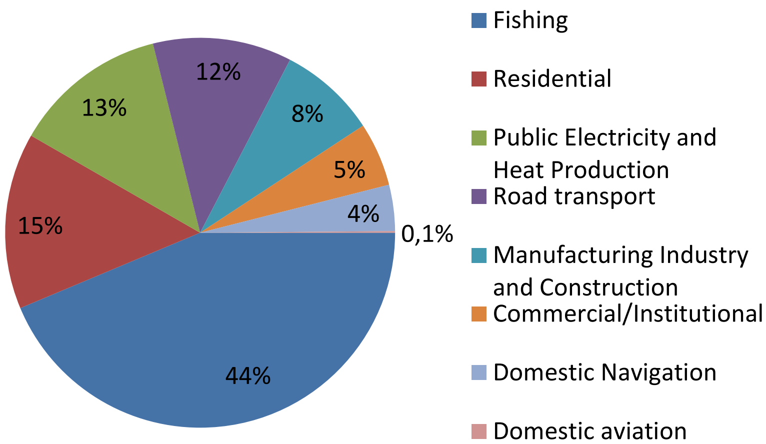

Figure 12 GHG emissions in CO_2 equivalents; Energy sector divided in categories, 2015.

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.

Overview of the sector

Figure 13 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 also Figure 8.

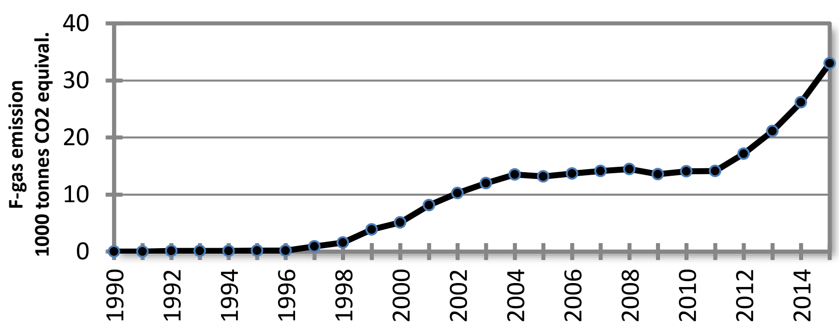

Figure 13 GHG emissions in CO_2 equivalents, Industrial processes, 1990-2015.

Mineral Industry (2A)

There is no mineral production in the Faroe Islands, other than 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 3.9 % 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 1990-2015, are seen in Table 4.

Table 4 Emissions of HFCs from Refrigeration and Air Conditioning, 1990, 2000, 2005-2015 (tonnes).

	1990	2000	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Domestic refrigeration													
HFC-134a	0,00	0,003	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01
Commercial refrigeration													
HFC-134a	0,00	0,04	0,13	0,12	0,12	0,12	0,12	0,14	0,18	0,17	0,19	0,24	0,26
HFC-32	0,00	0,09	0,32	0,30	0,29	0,27	0,25	0,26	0,23	0,21	0,19	0,14	0,09
HFC-125	0,00	0,15	0,50	0,49	0,50	0,56	0,58	0,72	0,80	1,28	1,75	2,43	3,28
HFC-143a	0,00	0,06	0,19	0,19	0,22	0,32	0,35	0,51	0,62	1,14	1,63	2,36	3,25
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	0,25	0,23
HFC-125	0,00	0,33	0,97	1,03	1,06	1,01	0,87	0,78	0,69	0,59	0,60	0,49	0,52
HFC-143a	0,00	0,39	1,15	1,22	1,25	1,19	1,02	0,91	0,80	0,68	0,70	0,56	0,59
HFC-32	0,00	0,00	0,00	0,00	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,02
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	1,03	1,04

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

Figure 14 shows the emissions of SF_6 and four specific HFCs.

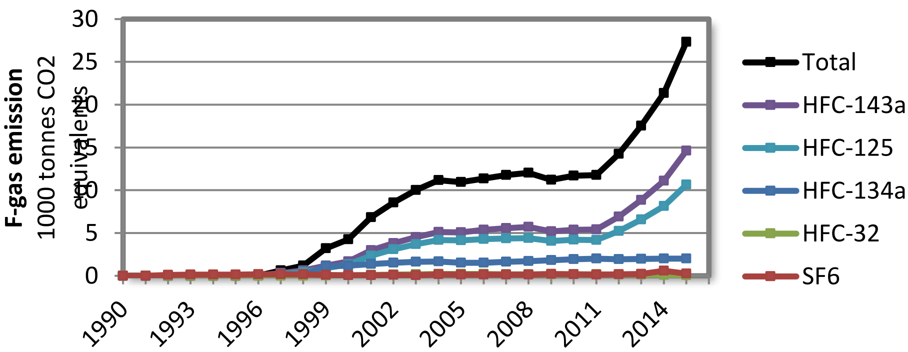

Figure 14 Emission of F-gases (HFCs and SF_6) in CO_2 equivalents, time series for 1990-2015.

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.

3.3 % of the total GHG emissions on the Faroe Islands are due to agriculture. The sources are cattle and sheep.

Figure 15 shows the number of cattle in the Faroe Islands from 1990 to 2015. 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.

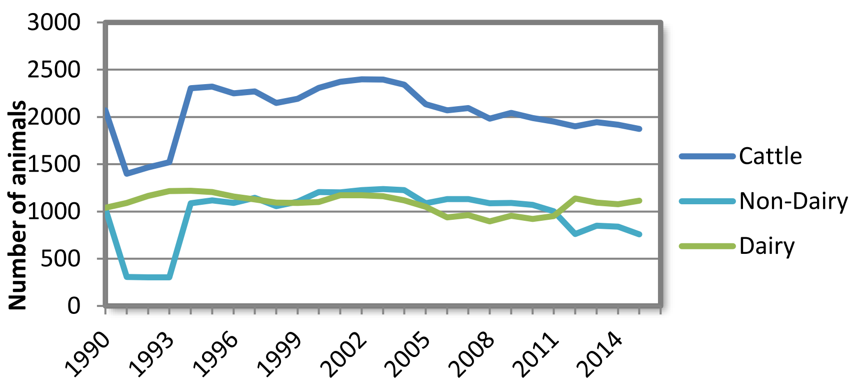

Figure 15 Number of cattle (dairy and non-dairy), time series for 1990-2015.

Figure 16 shows the total emissions from the Agriculture sector.

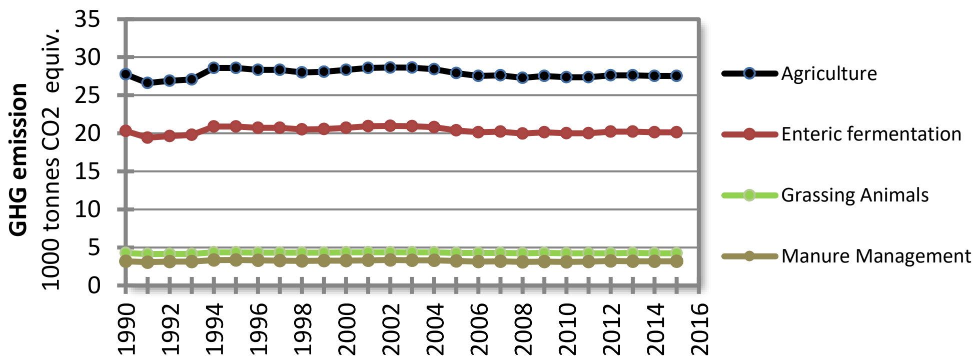

Figure 16 GHG emissions in CO_2 equivalents, in the Agriculture sector, 1990-2015.

CH_4 emission from Enteric Fermentation (CRF Sector 3A)

Figure 17 shows emissions of CH_4 from enteric fermentation in livestock on the Faroe Islands, 1990-2015. The emissions are very constant.

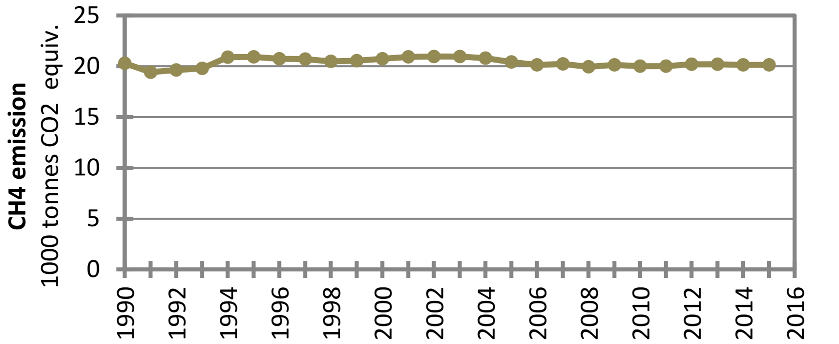

Figure 17 CH_4 emissions in CO_2 equivalents from enteric fermentation, 1990-2015.

CH_4 and N_2O emission from Manure Management (CRF Sector 3B)

Figure 18 shows emissions of N_2O and CH_4 from manure management on the Faroe Islands.

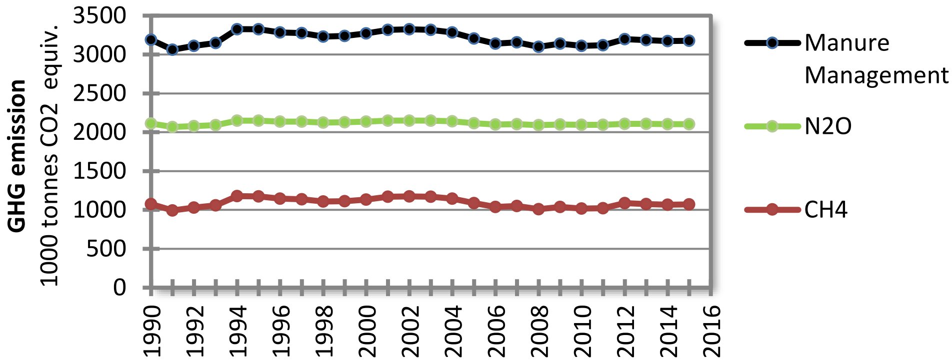

Figure 18 N_2O and CH_4 emission in CO_2 equivalents from Manure management, time series 1990-2015.

N_2O emission from Agricultural Soils (CRF Sector 3D)

The N_2O emission from sheep and cows grazing on agricultural soil is about 14.2 tonnes N_2O per year. This corresponds to 4,240 tonnes of CO_2 equivalents.

Figure 19 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.

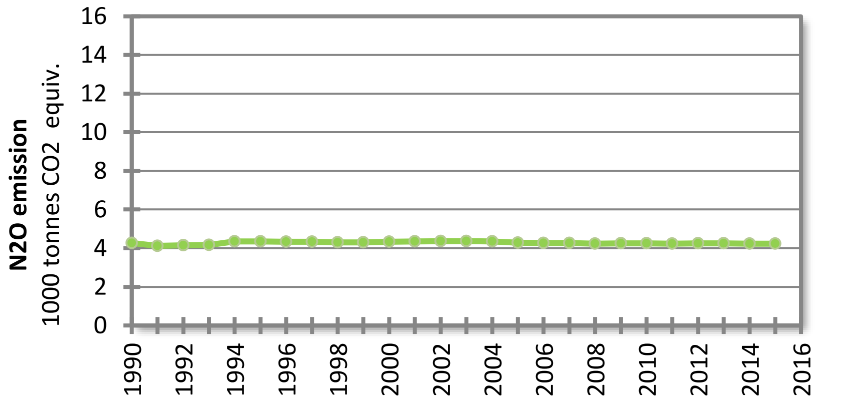

Figure 19 N_2O emissions (tonnes) from Agricultural Soils, grazing animals, time series 1990-2015.

NMVOC emission
The emission of NMVOC is not calculated.

Uncertainties
The uncertainties have not been calculated.

Recalculation
No recalculations were made in the Agriculture section in 2015.

Planned improvements
A little project where all data from the Agricultural sector are 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. Get better data for number of 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 primarily only 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 20 shows the amounts of waste incinerated on the Faroe Islands 1990-2015.

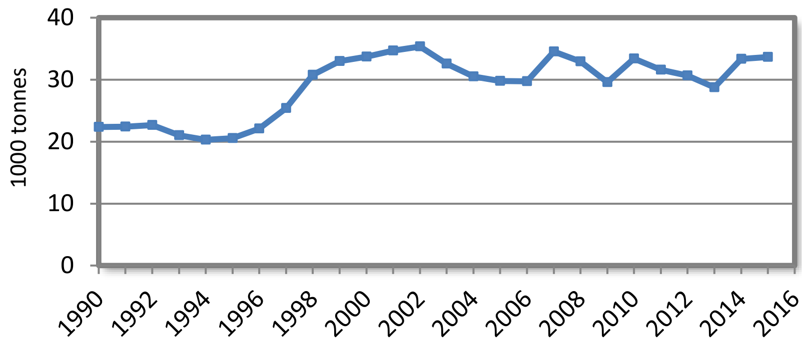

Figure 20 Incineration of municipal waste on the Faroe Islands, 1990-2015.

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 2017 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, and thus explained in the main part of the report for the Danish Kingdom.

Explanations and justifications for recalculations
The following recalculations and improvements to the emission inventories have been made since the reporting in 2016.

Energy
Road transport
Emission factors for road transport, diesel, CH_4 and N_2O, 1990-2014, and for gasoline, CH_4 and N_2O, 1990-2014 have been updated.

Public electricity and Heat Production
The emission factor for public electricity and heat production, heavy fuel, CO2 has been changed 1990-2014.

Manufacturing industries and construction
The emission factor for public electricity and heat production, heavy fuel, CO2 has been changed 1990-2014.

Aviation
The emission factor for aviation, Jet fuel, CH_4, has been changed for the whole time series 1990-2014.

Agriculture
No changes.

Implications for emission levels
Most of the recalculations have only had small implication for the emissions levels.

Implications for emission trends, including time series consistency
The recalculations have not had significant implication for the trends.

Improvements
Improvement to implement in next year's delivery:

Fishing vessels

In the 2014 delivery, the recalculation made for fishing vessels for certain reasons only could be done for the time-series 2001-2011. Therefor the time series for fishing vessels, 2001-2015, 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.

Agriculture

Improvements regarding emission factors and methods are planned.

Annexes

Annex 1 Emission trend tables 1990, 2000, 2010, 2011, 2012, 2013 and 2014 for GHG CO_2 eqv., CO_2, CH_4, N_2O, F-gases (CO_2 equivalents) and Trend tables 1990, 2000, 2010, 2011, 2012, 2013 and 2014 for Summary (all gases)

The tables are copied from the CRF 2014 spreadsheet file, Tables 10.1-10.6.

Table 5 EMISSION TRENDS GHG CO_2 eqv. - Inventory 2015 - Submission 2017 v1 - FAROE ISLANDS.

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	1990	2000	2010	2011	2012	2013	2014	2015
	Gg							
Total (net emissions)	700,86	862,22	886,09	768,41	857,86	831,69	867,65	844,96
1. Energy	673,28	825,68	844,83	727,11	813,29	783,10	814,14	784,42
A. Fuel combustion (sectoral approach)	673,28	825,68	844,83	727,11	813,29	783,10	814,14	784,42
1. Energy industries	97,28	164,09	164,46	133,47	148,25	134,38	122,80	100,42
2. Manufacturing industries and construction	63,26	69,72	43,99	43,58	49,07	50,11	61,04	63,67
3. Transport	106,72	95,15	126,94	131,22	127,06	118,61	123,43	121,50
4. Other sectors	406,02	496,72	509,44	418,85	488,91	480,00	506,87	498,83
5. Other	NE	NE	NE	NE	NE	NE	NE	NE
B. Fugitive emissions from fuels	NO	NO	NO	NO	NO	NO	NO	NO
1. Solid fuels	NO	NO	NO	NO	NO	NO	NO	NO
2. Oil and natural gas and other emissions from energy production	NO	NO	NO	NO	NO	NO	NO	NO
C. CO_2 transport and storage	NO	NO	NO	NO	NO	NO	NO	NO
2. Industrial Processes	NO,NE,NA	8,15	14,07	14,12	17,13	21,15	26,15	33,00
A. Mineral industry	NO	NO	NO	NO	NO	NO	NO	NO
B. Chemical industry	NO	NO	NO	NO	NO	NO	NO	NO
C. Metal industry	NO	NO	NO	NO	NO	NO	NO	NO
D. Non-energy products from fuels and solvent use	NE	NE	NE	NE	NE	NE	NE	NE
E. Electronic industry	NE	NE	NE	NE	NE	NE	NE	NE
F. Product uses as ODS substitutes	NO	8,08	13,90	13,97	16,95	20,95	25,56	32,76
G. Other product manufacture and use	NA,NO	0,08	0,16	0,15	0,18	0,20	0,59	0,25
H. Other	NE	NE	NE	NE	NE	NE	NE	NE
3. Agriculture	27,58	28,39	27,20	27,18	27,44	27,44	27,36	27,54
A. Enteric fermentation	20,30	20,92	20,00	19,99	20,20	20,20	20,14	20,13
B. Manure management	3,01	3,11	2,95	2,95	3,00	2,99	2,98	3,18
C. Rice cultivation	NO	NO	NO	NO	NO	NO	NO	NO
D. Agricultural soils	4,27	4,35	4,24	4,24	4,24	4,25	4,24	4,23
E. Prescribed burning of savannas	NO	NO	NO	NO	NO	NO	NO	NO
F. Field burning of agricultural residues	NO	NO	NO	NO	NO	NO	NO	NO
G. Liming	NO	NO	NO	NO	NO	NO	NO	NO
H. Urea application	NO	NO	NO	NO	NO	NO	NO	NO
I. Other carbon-containing fertilizers	NO	NO	NO	NO	NO	NO	NO	NO
J. Other	NO	NO	NO	NO	NO	NO	NO	NO
4. Land use, land-use change and forestry	NE	NE	NE	NE	NE	NE	NE	NE
5. Waste	NO,NE, IE	NO,NE, IE	NO,NE, IE	NO,NE, IE	NO,NE, IE	NO,NE, IE	NO,NE, IE	NO,NE, IE
A. Solid waste disposal	NE	NE	NE	NE	NE	NE	NE	NE
B. Biological treatment of solid waste	NE	NE	NE	NE	NE	NE	NE	NE
C. Incineration and open burning of waste	NO,IE	NO,IE	NO,IE	NO,IE	NO,IE	NO,IE	NO,IE	NO,IE
D. Waste water treatment and discharge	NE	NE	NE	NE	NE	NE	NE	NE
E. Other	NE	NE	NE	NE	NE	NE	NE	NE

Continued

6. Other *(as specified in summary 1.A)*								
Memo items:								
International bunkers	NE,NO	148,36	43,60	50,95	61,45	27,35	38,37	24,26
Aviation	NE,NO	1,48	0,77	1,20	1,29	1,13	0,84	0,36
Navigation	NE,NO	146,89	42,83	49,75	60,15	26,22	37,53	23,90
Multilateral operations	NO	NO	NO	NO	NO	NO	NO	NO
CO_2 emissions from biomass	15,90	28,99	27,91	26,41	25,63	24,28	28,14	28,39
CO_2 captured	NO	NO	NO	NO	NO	NO	NO	NO
Long-term storage of C in waste disposal sites	NE	NE	NE	NE	NE	NE	NE	NE
Indirect N_2O	NE	NE	NE	NE	NE	NE	NE	NE
Indirect CO_2	NE	NE	NE	NE	NE	NE	NE	NE
Total CO_2 equivalent emissions with-out land use, land-use change and forestry	700,86	862,22	886,09	768,41	857,86	831,69	867,65	844,96
Total CO_2 equivalent emissions with land use, land-use change and for-estry	700,86	862,22	886,09	768,41	857,86	831,69	867,65	844,96
Total CO_2 equivalent emissions, including indirect CO2, without land use, land-use change and forestry	NA	NA	NA	NA	NA	NA	NA	NA
Total CO_2 equivalent emissions, including indirect CO2, with land use, land-use change and forestry	NA	NA	NA	NA	NA	NA	NA	NA

Table 6 EMISSION TRENDS CO_2 - Inventory 2015 - Submission 2017 v1 - FAROE ISLANDS.

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	1990	2000	2010	2011	2012	2013	2014	2015
	Gg							
1. Energy	667,99	665,02	839,53	722,61	808,17	778,06	808,64	779,07
A. Fuel combustion (sectoral approach)	667,99	665,02	839,53	722,61	808,17	778,06	808,64	779,07
1. Energy industries	97,08	119,49	163,99	133,18	147,82	134,10	122,47	100,17
2. Manufacturing industries and construction	62,46	59,76	43,57	43,22	48,75	49,57	60,40	62,97
3. Transport	104,67	99,17	125,71	129,93	125,81	117,43	122,19	120,27
4. Other sectors	403,78	386,60	506,25	416,28	485,79	476,96	503,58	495,67
5. Other	NE	NE	NE	NE	NE	NE	NE	NE
B. Fugitive emissions from fuels	NO	NO	NO	NO	NO	NO	NO	NO
1. Solid fuels	NO	NO	NO	NO	NO	NO	NO	NO
2. Oil and natural gas and other emissions from energy production	NO	NO	NO	NO	NO	NO	NO	NO
C. CO_2 transport and storage	NO	NO	NO	NO	NO	NO	NO	NO
2. Industrial processes	NO,NE	NO,NE	NO,NE	NO,NE	NO,NE	NO,NE	NO,NE	NO,NE
A. Mineral industry	NO	NO	NO	NO	NO	NO	NO	NO
B. Chemical industry	NO	NO	NO	NO	NO	NO	NO	NO
C. Metal industry	NO	NO	NO	NO	NO	NO	NO	NO
D. Non-energy products from fuels and solvent use	NE	NE	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	NE	NE
H. Other	NE	NE	NE	NE	NE	NE	NE	NE
3. Agriculture	NO	NO	NO	NO	NO	NO	NO	NO
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	NO	NO
H. Urea application	NO	NO	NO	NO	NO	NO	NO	NO
I. Other carbon-containing fertilizers	NO	NO	NO	NO	NO	NO	NO	NO
J. Other	NE	NE	NE	NE	NE	NE	NE	NE
4. Land use, land-use change and forestry	NE	NE	NE	NE	NE	NE	NE	NE
5. Waste	NO, NE,IE	NO, NE,IE	NO, NE,IE	NO, NE,IE	NO, NE,IE	NO, NE,IE	NO, NE,IE	NO, NE,IE
A. Solid waste disposal	NE	NE	NE	NE	NE	NE	NE	NE
B. Biological treatment of solid waste								
C. Incineration and open burning of waste	NO,IE	NO,IE	NO,IE	NO,IE	NO,IE	NO,IE	NO,IE	NO,IE
D. Waste water treatment and discharge								
E. Other	NE	NE	NE	NE	NE	NE	NE	NE
6. Other *(as specified in summary 1.A)*	NE	NE	NE	NE	NE	NE	NE	NE
Memo items:								
International bunkers	NE,NO	136,46	43,25	50,54	60,96	27,14	38,07	24,07
Aviation	NE,NO	0,88	0,77	1,20	1,29	1,13	0,84	0,36
Navigation	NE,NO	135,59	42,48	49,35	59,67	26,01	37,23	23,71
Multilateral operations	NO	NO	NO	NO	NO	NO	NO	NO
CO_2 emissions from biomass	15,90	28,18	27,91	26,41	25,63	24,28	28,14	28,39
CO_2 captured	NO	NO	NO	NO	NO	NO	NO	NO

Continued

Long-term storage of C in waste disposal sites	NE	NE	NE	NE	NE	NE	NE	NE
Indirect N_2O								
Indirect CO_2	NE	NE	NE	NE	NE	NE	NE	NE
Total CO_2 equivalent emissions without land use, land-use change and forestry	667,99	665,02	839,53	722,61	808,17	778,06	808,64	779,07
Total CO_2 equivalent emissions with land use, land-use change and forestry	667,99	665,02	839,53	722,61	808,17	778,06	808,64	779,07
Total CO_2 equivalent emissions, including indirect CO2, without land use, land-use change and forestry	NA	NA	NA	NA	NA	NA	NA	NA
Total CO_2 equivalent emissions, including indirect CO2, with land use, land-use change and forest-ry	NA	NA	NA	NA	NA	NA	NA	NA

Table 7 EMISSION TRENDS CH_4 – Inventory 2015 - Submission 2017 v1 - FAROE ISLANDS.

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	1990	2000	2010	2011	2012	2013	2014	2015
	Gg							
1. Energy	0,05	0,06	0,02	0,02	0,02	0,02	0,02	0,02
A. Fuel combustion (sectoral approach)	0,05	0,06	0,02	0,02	0,02	0,02	0,02	0,02
1. Energy industries	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
3. Transport	0,04	0,05	0,01	0,01	0,01	0,00	0,00	0,00
4. Other sectors	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01
5. Other	NE	NE	NE	NE	NE	NE	NE	NE
B. Fugitive emissions from fuels	NO	NO	NO	NO	NO	NO	NO	NO
1. Solid fuels	NO	NO	NO	NO	NO	NO	NO	NO
2. Oil and natural gas and other emissions from energy production	NO	NO	NO	NO	NO	NO	NO	NO
C. CO_2 transport and storage								
2. Industrial processes	NO,NE	NO,NE	NO,NE	NO,NE	NO,NE	NO,NE	NO,NE	NO,NE
A. Mineral industry								
B. Chemical industry	NO	NO	NO	NO	NO	NO	NO	NO
C. Metal industry	NO	NO	NO	NO	NO	NO	NO	NO
D. Non-energy products from fuels and solvent use	NE	NE	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	NE	NE
H. Other	NE	NE	NE	NE	NE	NE	NE	NE
3. Agriculture	0,85	0,87	0,83	0,83	0,84	0,84	0,84	0,85
A. Enteric fermentation	0,81	0,83	0,80	0,80	0,81	0,81	0,81	0,81
B. Manure management	0,04	0,04	0,03	0,03	0,04	0,04	0,04	0,04
C. Rice cultivation	NO	NO	NO	NO	NO	NO	NO	NO
D. Agricultural soils	NE	NE	NE	NE	NE	NE	NE	NE
E. Prescribed burning of savannas	NO	NO	NO	NO	NO	NO	NO	NO
F. Field burning of agricultural residues	NO	NO	NO	NO	NO	NO	NO	NO
G. Liming								
H. Urea application								
I. Other carbon-containing fertilizers								
J. Other	NE	NE	NE	NE	NE	NE	NE	NE
4. Land use, land-use change and forestry	NE	NE	NE	NE	NE	NE	NE	NE
5. Waste	NO, NE,IE	NO, NE,IE	NO, NE,IE	NO, NE,IE	NO, NE,IE	NO, NE,IE	NO, NE,IE	NO, NE,IE
A. Solid waste disposal	NE	NE	NE	NE	NE	NE	NE	NE
B. Biological treatment of solid waste	NE	NE	NE	NE	NE	NE	NE	NE
C. Incineration and open burning of waste	NO,IE	NO,IE	NO,IE	NO,IE	NO,IE	NO,IE	NO,IE	NO,IE
D. Waste water treatment and discharge	NE	NE	NE	NE	NE	NE	NE	NE
E. Other	NE	NE	NE	NE	NE	NE	NE	NE
6. Other *(as specified in summary 1.A)*	NE	NE	NE	NE	NE	NE	NE	NE
Total CH_4 emissions without CH_4 from LULUCF	0,90	0,92	0,85	0,85	0,86	0,86	0,86	0,86
Total CH_4 emissions with CH_4 from LULUCF	0,90	0,92	0,85	0,85	0,86	0,86	0,86	0,86
Memo items:								
International bunkers	NE,NO	0,01	0,00	0,00	0,00	0,00	0,00	0,00
Aviation	NE,NO	0,01	0,00	0,00	0,00	0,00	0,00	0,00
Navigation	NE,NO	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Multilateral operations	NO	NO	NO	NO	NO	NO	NO	NO
CO_2 emissions from biomass								
CO_2 captured								
Long-term storage of C in waste disposal sites								
Indirect N_2O								
Indirect CO_2								

Table 8 EMISSION TRENDS N2O - Inventory 2015 - Submission 2017 v1 - FAROE ISLANDS

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	1990	2000	2010	2011	2012	2013	2014	2015
	Gg							
1. Energy	0,01	0,01	0,02	0,01	0,02	0,02	0,02	0,02
A. Fuel combustion (sectoral approach)	0,01	0,01	0,02	0,01	0,02	0,02	0,02	0,02
1. Energy industries	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
3. Transport	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
4. Other sectors	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01
5. Other	NE	NE	NE	NE	NE	NE	NE	NE
B. Fugitive emissions from fuels	NO	NO	NO	NO	NO	NO	NO	NO
1. Solid fuels	NO	NO	NO	NO	NO	NO	NO	NO
2. Oil and natural gas and other emissions from energy production	NO	NO	NO	NO	NO	NO	NO	NO
C. CO_2 transport and storage								
2. Industrial processes	NO,NE	NO,NE	NO,NE	NO,NE	NO,NE	NO,NE	NO,NE	NO,NE
A. Mineral industry								
B. Chemical industry	NO	NO	NO	NO	NO	NO	NO	NO
C. Metal industry	NO	NO	NO	NO	NO	NO	NO	NO
D. Non-energy products from fuels and solvent use	NE	NE	NE	NE	NE	NE	NE	NE
E. Electronic industry								
F. Product uses as ODS substitutes								
G. Other product manufacture and use	NO	NO	NO	NO	NO	NO	NO	NO
H. Other	NE	NE	NE	NE	NE	NE	NE	NE
3. Agriculture	0,02	0,02	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	0,01	0,01
C. Rice cultivation								
D. Agricultural soils	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01
E. Prescribed burning of savannas	NO	NO	NO	NO	NO	NO	NO	NO
F. Field burning of agricultural residues	NO	NO	NO	NO	NO	NO	NO	NO
G. Liming								
H. Urea application								
I. Other carbon containing fertlizers								
J. Other	NE	NE	NE	NE	NE	NE	NE	NE
4. Land use, land-use change and forestry	NE	NE	NE	NE	NE	NE	NE	NE
5. Waste	NO, NE,IE	NO, NE,IE	NO, NE,IE	NO, NE,IE	NO, NE,IE	NO, NE,IE	NO, NE,IE	NO, NE,IE
A. Solid waste disposal								
B. Biological treatment of solid waste	NE	NE	NE	NE	NE	NE	NE	NE
C. Incineration and open burning of waste	NO,IE	NO,IE	NO,IE	NO,IE	NO,IE	NO,IE	NO,IE	NO,IE
D. Waste water treatment and discharge	NE	NE	NE	NE	NE	NE	NE	NE
E. Other	NE	NE	NE	NE	NE	NE	NE	NE
6. Other *(as specified in summary 1.A)*	NE	NE	NE	NE	NE	NE	NE	NE
Total direct N_2O emissions without N_2O from LULUCF	0,03	0,03	0,04	0,04	0,04	0,04	0,04	0,04
Total direct N_2O emissions with N_2O from LULUCF	0,03	0,03	0,04	0,04	0,04	0,04	0,04	0,04
Memo items:								
International bunkers	NE,NO	0,01	0,00	0,00	0,00	0,00	0,00	0,00
Aviation	NE,NO	0,01	0,00	0,00	0,00	0,00	0,00	0,00
Navigation	NE,NO	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Multilateral operations	NO	NO	NO	NO	NO	NO	NO	NO
CO_2 emissions from biomass								
CO_2 captured								
Long-term storage of C in waste disposal sites								
Indirect N_2O	NE	NE	NE	NE	NE	NE	NE	NE
Indirect CO_2								

Table 9 EMISSION TRENDS HFCs, PFCs and SF6 - Inventory 2015 - Submission 2017 v1 - FAROE ISLANDS.

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	1990	2000	2010	2011	2012	2013	2014	2015
	kt CO_2 equivalent							
Emissions of HFCs and PFCs - (kt CO_2 equivalent)	NO	5,01	13,90	13,97	16,95	20,95	25,56	32,76
Emissions of HFCs - (kt CO_2 equivalent)	NO	5,01	13,90	13,97	16,95	20,95	25,56	32,76
HFC-23	NO	NO	NO	NO	NO	NO	NO	NO
HFC-32	NO	0,00	0,00	0,00	0,00	0,00	0,00	0,00
HFC-41	NO	NO	NO	NO	NO	NO	NO	NO
HFC-43-10mee	NO	NO	NO	NO	NO	NO	NO	NO
HFC-125	NO	0,00	0,00	0,00	0,00	0,00	0,00	0,00
HFC-134	NO	NO	NO	NO	NO	NO	NO	NO
HFC-134a	NO	0,00	0,00	0,00	0,00	0,00	0,00	0,00
HFC-143	NO	NO	NO	NO	NO	NO	NO	NO
HFC-143a	NO	0,00	0,00	0,00	0,00	0,00	0,00	0,00
HFC-152	NO	NO	NO	NO	NO	NO	NO	NO
HFC-152a	NO	NO	NO	NO	NO	NO	NO	NO
HFC-161	NO	NO	NO	NO	NO	NO	NO	NO
HFC-227ea	NO	NO	NO	NO	NO	NO	NO	NO
HFC-236cb	NO	NO	NO	NO	NO	NO	NO	NO
HFC-236ea	NO	NO	NO	NO	NO	NO	NO	NO
HFC-236fa	NO	NO	NO	NO	NO	NO	NO	NO
HFC-245ca	NO	NO	NO	NO	NO	NO	NO	NO
HFC-245fa	NO	NO	NO	NO	NO	NO	NO	NO
HFC-365mfc	NO	NO	NO	NO	NO	NO	NO	NO
Unspecified mix of HFCs - (kt CO_2 equivalent)	NO	NO	NO	NO	NO	NO	NO	NO
Emissions of PFCs - (kt CO_2 equivalent)	NO	NO	NO	NO	NO	NO	NO	NO
Unspecified mix of HFCs and PFCs - (kt CO_2 equivalent)	NO	NO	NO	NO	NO	NO	NO	NO
Emissions of SF_6 - (kt CO_2 equivalent)	NA,NO	0,08	0,16	0,15	0,18	0,20	0,59	0,25
SF_6	NA,NO	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Emissions of NF_3 - (kt CO_2 equivalent)	NO	NO	NO	NO	NO	NO	NO	NO
NF_3	NO	NO	NO	NO	NO	NO	NO	NO

Table 10 EMISSION TRENDS SUMMARY - Inventory 2015 - Submission 2017 v1 - FAROE ISLANDS.

GREENHOUSE GAS EMISSIONS	1990	2000	2010	2011	2012	2013	2014	2015
	kt CO_2 equivalents							
CO_2 emissions without net CO_2 from LULUCF	667,99	665,02	839,53	722,61	808,17	778,06	808,64	779,07
CO_2 emissions with net CO_2 from LULUCF	667,99	665,02	839,53	722,61	808,17	778,06	808,64	779,07
CH_4 emissions without CH_4 from LULUCF	22,50	23,06	21,33	21,24	21,53	21,48	21,43	21,59
CH_4 emissions with CH_4 from LULUCF	22,50	23,06	21,33	21,24	21,53	21,48	21,43	21,59
N_2O emissions without N_2O from LULUCF	10,37	10,21	11,16	10,44	11,03	11,00	11,43	11,30
N_2O emissions with N_2O from LULUCF	10,37	10,21	11,16	10,44	11,03	11,00	11,43	11,30
HFCs	NO	5,01	13,90	13,97	16,95	20,95	25,56	32,76
PFCs	NO	NO	NO	NO	NO	NO	NO	NO
Unspecified mix of HFCs and PFCs	NO	NO	NO	NO	NO	NO	NO	NO
SF_6	NA,NO	0,08	0,16	0,15	0,18	0,20	0,59	0,25
NF_3	NO	NO	NO	NO	NO	NO	NO	NO
Total (without LULUCF)	700,86	703,38	886,09	768,41	857,86	831,69	867,65	844,96
Total (with LULUCF)	700,86	703,38	886,09	768,41	857,86	831,69	867,65	844,96
Total (without LULUCF, with indirect)	NA	NA	NA	NA	NA	NA	NA	NA
Total (with LULUCF, with indirect)	NA	NA	NA	NA	NA	NA	NA	NA

GREENHOUSE GAS SOURCE AND SINK CATEGO-RIES	1990	2000	2010	2011	2012	2013	2014	2015
	kt CO_2 equivalents							
1. Energy	673,28	670,16	844,83	727,11	813,29	783,10	814,14	784,42
2. Industrial processes and product use	NO,NE,NA	5,08	14,07	14,12	17,13	21,15	26,15	33,00
3. Agriculture	27,58	28,14	27,20	27,18	27,44	27,44	27,36	27,54
4. Land use, land-use change and forestry	NE	NE	NE	NE	NE	NE	NE	NE
5. Waste	NO,NE,IE	NO,NE,IE	NO,NE,IE	NO,NE,IE	NO,NE,IE	NO,NE,IE	NO,NE,IE	NO,NE,IE
6. Other	NE	NE	NE	NE	NE	NE	NE	NE
Total (including LULUCF)	700,86	703,38	886,09	768,41	857,86	831,69	867,65	844,96

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, 1990-2015.

Category	Fuel	Pollutant	1990-2006	2007-2015
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)	78,6	78,5-79,5
		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)	78,6	78,6
		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 12.

Table 12 Emission factors for Waste Incineration, 1990-2015.

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
1996-2003	41,2	37	79,6	0,59	1,2
2004	41,2	37	79,6	0,51	1,2
2005	41,2	37	79,6	0,42	1,2
2006-2015	41,2	37	79,6	0,34	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 13, Table 14 and Table 15.

Table 13 Emission factors for aviation, 1990-2015.

	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	0,141	72,0	2,602
2002	0,141	72,0	2,604
2003	0,138	72,0	2,604
2004	0,143	72,0	2,613
2005	0,163	72,0	2,647
2006	0,161	72,0	2,644
2007	0,166	72,0	2,651
2008	0,166	72,0	2,651
2009	0,166	72,0	2,651
2010	0,164	72,0	2,651
2011	0,165	72,0	2,647
2012	0,215	72,0	2,631
2013	0,244	72,0	2,620
2014	0,270	72,0	2,612
2014	0,273	72,0	2,607

Table 14 Emission factors for road transport, 1990-2015.

	Diesel			Gasoline		
	CH_4	CO_2	N_2O	CH_4	CO_2	N_2O
1990	6,8401	74	1,8416	27,6018	73	2,8523
1991	6,7558	74	1,7912	27,1945	73	2,8747
1992	6,7338	74	1,7785	26,1667	73	2,9467
1993	6,6815	74	1,7340	25,3549	73	3,0006
1994	6,7383	74	1,6881	23,9280	73	3,0902
1995	6,8396	74	1,6066	22,5627	73	3,1680
1996	6,8613	74	1,5013	21,2849	73	3,2368
1997	6,7735	74	1,4272	19,9609	73	3,2820
1998	6,5984	74	1,3853	18,8008	73	3,2268
1999	6,3574	74	1,3642	17,6057	73	3,1977
2000	6,0071	74	1,3598	16,6712	73	3,1857
2001	5,7567	74	1,3611	15,6864	73	3,1265
2002	5,4470	74	1,3748	14,6136	73	3,0378
2003	5,1634	74	1,3850	13,6239	73	2,9218
2004	4,8987	74	1,4119	12,5206	73	2,7946
2005	4,5787	74	1,4443	11,5625	73	2,6140
2006	4,1864	74	1,5081	10,5401	73	2,4055
2007	3,4872	74	1,6938	9,7659	73	2,2310
2008	2,7016	74	1,9482	9,1044	73	2,0491
2009	2,1587	74	2,1520	8,5875	73	1,9377
2010	1,8074	74	2,3693	8,2134	73	1,7817
2011	1,5142	74	2,6345	7,8088	73	1,6525
2012	1,1868	74	2,8671	7,4686	73	1,4797
2013	0,9551	74	3,0583	7,1113	73	1,3155
2014	0,8101	74	3,2275	6,7100	73	1,1649
2015	0,6559	74	3,3398	6,3734	73	1,0285

Table 15 Emission factors for Navigation (diesel and residual) and Fisheries (diesel), 1990-2015.

	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	1,559	74	1,8735	1,653	78	1,956	1,519	74	1,874
1991	1,566	74	1,8735	1,645	78	1,956	1,530	74	1,874
1992	1,575	74	1,8735	1,642	78	1,956	1,541	74	1,874
1993	1,577	74	1,8735	1,646	78	1,956	1,553	74	1,874
1994	1,580	74	1,8735	1,649	78	1,956	1,565	74	1,874
1995	1,593	74	1,8735	1,651	78	1,956	1,578	74	1,874
1996	1,587	74	1,8735	1,668	78	1,956	1,592	74	1,874
1997	1,504	74	1,8735	1,694	78	1,956	1,606	74	1,874
1998	1,495	74	1,8735	1,712	78	1,956	1,622	74	1,874
1999	1,463	74	1,8735	1,724	78	1,956	1,639	74	1,874
2000	1,472	74	1,8735	1,737	78	1,956	1,656	74	1,874
2001	1,490	74	1,8735	1,753	78	1,956	1,673	74	1,874
2002	1,523	74	1,8735	1,767	78	1,956	1,689	74	1,874
2003	1,516	74	1,8735	1,820	78	1,956	1,704	74	1,874
2004	1,509	74	1,8735	1,828	78	1,956	1,718	74	1,874
2005	1,512	74	1,8735	1,869	78	1,956	1,731	74	1,874
2006	1,488	74	1,8735	1,897	78	1,956	1,743	74	1,874
2007	1,499	74	1,8735	1,906	78	1,956	1,753	74	1,874
2008	1,510	74	1,8735	1,912	78	1,956	1,762	74	1,874
2009	1,514	74	1,8735	1,925	78	1,956	1,770	74	1,874
2010	1,507	74	1,8735	1,934	78	1,956	1,775	74	1,874
2011	1,499	74	1,8735	1,943	78	1,956	1,780	74	1,874
2012	1,696	74	1,8735	1,952	78	1,956	1,785	74	1,874
2013	1,802	74	1,8735	1,960	78	1,956	1,791	74	1,874
2014	1,793	74	1,8735	1,969	78	1,956	1,797	74	1,874
2015	1,833	74	1,8735	1,977	78	1,956	1,803	74	1,874

Annex 8 - Key category analysis for Denmark and Greenland

The KCAs for Denmark and Greenland includes 6 KCAs shown in Table A8-1 – A8-6 below.

Table A8-1 KCA for Denmark+Greenland, level assessment, base year excl. LULUCF.
This table is available at:
http://envs.au.dk/videnudveksling/luft/emissioner/supporting_documentation/greenhouse-gases-nir/

Table A8-2 KCA for Denmark+Greenland, level assessment, base year incl. LULUCF.
This table is available at:
http://envs.au.dk/videnudveksling/luft/emissioner/supporting_documentation/greenhouse-gases-nir/

Table A8-3 KCA for Denmark+Greenland, level assessment, 2015 excl. LULUCF.
This table is available at:
http://envs.au.dk/videnudveksling/luft/emissioner/supporting_documentation/greenhouse-gases-nir/

Table A8-4 KCA for Denmark+Greenland, level assessment, 2015 incl. LULUCF.
This table is available at:
http://envs.au.dk/videnudveksling/luft/emissioner/supporting_documentation/greenhouse-gases-nir/

Table A8-5 KCA for Denmark+Greenland, trend assessment 1990-2015, excl. LULUCF.
This table is available at:
http://envs.au.dk/videnudveksling/luft/emissioner/supporting_documentation/greenhouse-gases-nir/

Table A8-6 KCA for Denmark+Greenland, trend assessment 1990-2015, incl. LULUCF.
This table is available at:
http://envs.au.dk/videnudveksling/luft/emissioner/supporting_documentation/greenhouse-gases-nir/

DENMARK'S NATIONAL INVENTORY REPORT 2017

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This report is Denmark's National Inventory Report 2017. The report contains information on Denmark's emission inventories for all years' from 1990 to 2015 for CO_2, CH_4, N_2O, HFCs, PFCs and SF_6, NOx, CO, NMVOC, SO_2.

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