PROJECTION OF GREENHOUSE GASES 2011-2035

Scientific Report from DCE – Danish Centre for Environment and Energy No. 48 2013

AARHUS UNIVERSITY
DCE – DANISH CENTRE FOR ENVIRONMENT AND ENERGY

PROJECTION OF GREENHOUSE GASES 2011-2035

Scientific Report from DCE – Danish Centre for Environment and Energy No. 48 2013

Ole-Kenneth Nielsen
Marlene S. Plejdrup
Morten Winther
Katja Hjelgaard
Malene Nielsen
Leif Hoffmann
Patrik Fauser
Mette H. Mikkelsen
Rikke Albrektsen
Steen Gyldenkærne
Marianne Thomsen

Aarhus University, Department of Environmental Science

AARHUS UNIVERSITY
DCE – DANISH CENTRE FOR ENVIRONMENT AND ENERGY

Data sheet

Series title and no.: Scientific Report from DCE – Danish Centre for Environment and Energy No. 48

Title: Projection of greenhouse gases 2011-2035

Authors: Ole-Kenneth Nielsen, Marlene S. Plejdrup, Morten Winther, Katja Hjelgaard, Malene Nielsen, Leif Hoffmann, Patrik Fauser, Mette H. Mikkelsen, Rikke Albrektsen, Steen Gyldenkærne, Marianne Thomsen

Institution: Aarhus University - Department of Environmental Science

Publisher: Aarhus University, DCE – Danish Centre for Environment and Energy ©
URL: http://dmu.au.dk/en

Year of publication: February 2013
Editing completed: January 2013

Financial support: No external financial support

Please cite as: Nielsen, O-K., Plejdrup, M.S., Winther, M., Hjelgaard, K., Nielsen, M., Hoffmann, L., Fauser, P., Mikkelsen, M.H., Albrektsen, R., Gyldenkærne, S. & Thomsen, M. 2013. Projection of greenhouse gases 2011-2035. Aarhus University, DCE – Danish Centre for Environment and Energy, 179 pp. Scientific Report from DCE – Danish Centre for Environment and Energy No. 48 http://www.dmu.dk/Pub/SR48.pdf

Abstract: This report contains a description of models, background data and projections of CO_2, CH_4, N_2O, HFCs, PFCs and SF_6 for Denmark. The emissions are projected to 2035 using a scenario combined with the expected results of a few individual policy measures. Official Danish forecasts of activity rates are used in the models for those sectors for which forecasts are available, i.e. the latest official forecast from the Danish Energy Agency. The emission factors refer to international guidelines and some are country-specific and refer to Danish legislation, Danish research reports or calculations based on emission data from a considerable number of industrial plants. The projection models are based on the same structure and method as the Danish emission inventories in order to ensure consistency.

Keywords: Greenhouse gases, projections, emissions, CO_2, CH_4, N_2O, HFCs, PFCs, SF_6

Layout: Ann-Katrine Holme Christoffersen
Front page photo: Ann-Katrine Holme Christoffersen (Sejeroe)

ISBN: 978-87-92825-87-2
ISSN (electronic): 2245-0203

Number of pages: 179

Internet version: The report is available in electronic format (pdf) at http://www.dmu.dk/Pub/SR48.pdf

Contents

List of abbreviations

CH_4	Methane
CHP	Combined Heat and Power
CHR	Central Husbandry Register
CO_2	Carbon dioxide
COPERT	COmputer Programme to calculate Emissions from Road Transport
CORINAIR	CORe INventory on AIR emissions
CRF	Common Reporting Format
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
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
GHG	Greenhouse gas
GWP	Global Warming Potential
HFCs	Hydrofluorocarbons
IDA	Integrated Database model for Agricultural emissions
IEF	Implied Emission Factor
IPCC	Intergovernmental Panel on Climate Change
LPG	Liquefied Petroleum Gas
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
NFI	National Forest Inventory
NIR	National Inventory Report
PFCs	Perfluorocarbons
SF_6	Sulphur hexafluoride
SNAP	Selected Nomenclature for Air Pollution
SWDS	Solid Waste Disposal Sites
UNFCCC	United Nations Framework Convention on Climate Change
WWTP	WasteWater Treatment Plant

Preface

This report contains a description of models and background data for projection of Carbon dioxide (CO_2), Methane (CH_4), Nitrous oxide (N_2O), Hydrofluorocarbons (HFCs), Perfluorocarbons (PFCs) and Sulphur hexafluoride (SF_6) for Denmark. The emissions are projected to 2035 using a basic scenario, which includes the estimated effects of policies and measures implemented by September 2012 on Denmark's greenhouse gas (GHG) emissions ('with existing measures' projections).

DCE – Danish Centre for Environment and Energy, Aarhus University, has carried out the work. The project has been financed by the Danish Energy Agency (DEA).

The project contact persons for the DEA and DCE are Erik Rasmussen and Ole-Kenneth Nielsen, respectively.

The authors would like to thank:

The Danish Energy Agency (DEA) - especially Iben M. Rasmussen & Erik Tang - for providing the energy consumption forecast and for valuable discussions during the project.

National Laboratory for Sustainable Energy, Technical University of Denmark (DTU), for providing the data on scenarios of the development of landfill deposited waste production.

Danish Centre for food and Agriculture (DCA) and the Knowledge Centre for Agriculture, the Danish Agricultural Advisory Service (DAAS) for providing data for the agricultural sector.

The Danish Environmental Protection Agency (DEPA) for partly financial support on the solvent projections.

Forest & Landscape, Faculty of Life Sciences, Copenhagen University for cooperation in the preparation of the Danish GHG inventory where Forest & Landscape is responsible for the forest category.

Summary

This report contains a description of the models, background data and projections of the greenhouse gases (GHG) carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6) for Denmark. The emissions are projected to 2035 using a scenario, which includes the estimated effects of policies and measures implemented by September 2012 on Denmark's GHG emissions ('with existing measures' projections). The official Danish forecasts, e.g. the latest official forecast from the Danish Energy Agency (DEA), are used to provide activity rates in the models for those sectors for which these forecasts are available. The emission factors refer to international guidelines or are country-specific and refer to Danish legislation, Danish research reports or calculations based on emission data from a considerable number of industrial plants in Denmark. The projection models are widely based on the same structure and methodology as the Danish emission inventories in order to ensure consistency.

The main sectors in the years 2008-2012 ('2010') are expected to be Energy Industries (38 %), Transport (23 %), Agriculture (16 %) and Other Sectors (10 %). For the latter sector the most important sources are fuel combustion in the residential sector. GHG emissions show a decreasing trend in the projection period from 2010 to 2035, with decreasing emissions from 2010 to 2025 and slightly increasing emissions from 2025 to 2035. In general, the emission share for the Energy Industries sector can be seen to be decreasing while the emission share for the Transport sector is increasing. The total emissions in '2010' are estimated to be 59 255 ktonnes CO_2 equivalents and 45 731 ktonnes in 2035, corresponding to a decrease of 23 %. From 1990 to '2010' the emissions are estimated to decrease 14 %.

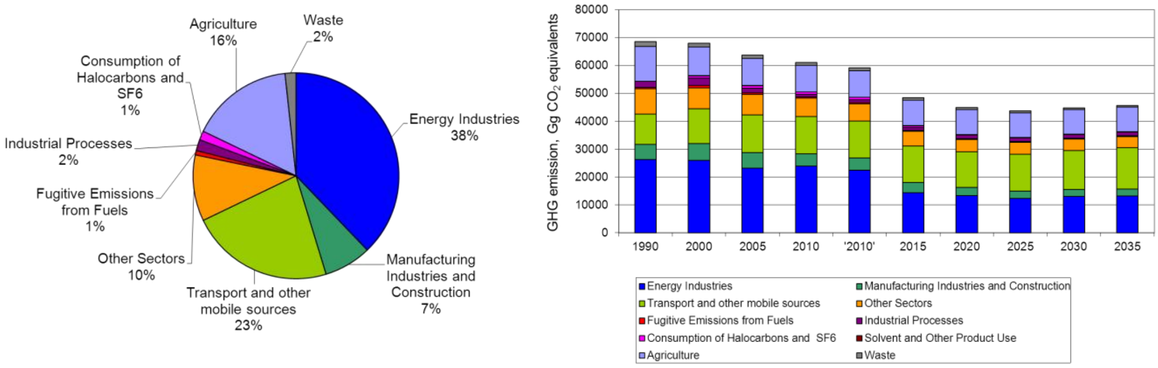


Figure S.1 Total GHG emissions in CO_2 equivalents. Distribution according to main sectors in '2010' and time series for 1990 to 2035.

Stationary combustion

Stationary combustion includes Energy industries, Manufacturing industries and construction and Other sectors. Other sectors include combustion in commercial/institutional, residential and agricultural plants. The GHG emissions in '2010' from the main source, which is public power production (64 %), are estimated to decrease significantly in the period from 2011 to 2024 due to a partial shift in fuel type from coal to wood and municipal waste. From 2025 to 2035 the emission is projected to be almost constant. Also, for residential combustion plants and combustion in manufacturing plants a significant decrease in emissions is projected; the emissions decrease by 46 % and 48 % from 2011 to 2035 respectively. The emissions from the other sectors remain almost constant over the period except for energy use in the offshore industry (oil and gas extraction), where the emissions are increasing by 274 % from 1990 to '2010' and projected to increase by 145 % from '2010' to 2035.

Fugitive emissions from fuels

The greenhouse gas emissions from the sector "Fugitive emissions from fuels" increased in the years 1990-2000, when the emission reached its maximum. Emissions are estimated to decrease in the projection period 2011-2035. The decrease mainly owe to expected decrease of offshore flaring in the oil and natural gas extraction. Further, technical improvements at the crude oil terminal leads to decreasing emissions from storage of crude oil in tanks at the terminal and to a lesser extent from onshore loading of ships in the harbor. Emissions from extraction of oil and natural gas are estimated to decline over the period 2011-2035 due to the expectation of a decrease of extracted amounts of oil and natural gas. Emissions of greenhouse gases from other sources are estimated to be constant or nearly constant over the projection period.

Industrial processes

The GHG emission from industrial processes increased during the nineties, reaching a maximum in 2000. Closure of a nitric acid/fertiliser plant in 2004 has resulted in a considerable decrease in the GHG emission. The most significant source of the process-related GHG emission in '2010' is cement production, which contributes by more than 83 %. Consumption of limestone and the emission of CO_2 from flue gas cleaning are assumed to follow the consumption of coal and waste for generation of heat and power. The GHG emission from this sector will continue to be strongly dependent on the cement production at Denmark's one cement plant.

Solvents and other product use

In 2010 solvent and other product use accounted for 0.2 % of the total GHG emission. The major sources of GHG emissions are N_2O from the use of anaesthesia and indirect CO_2 emissions from other use of solvents, which covers e.g. use of solvents in households. The CO_2 emission from use of solvents is expected to decrease in the projection timeframe.

Transport and other mobile sources

Road transport is the main source of GHG emissions in '2010' and emissions from this sector are expected to increase by 47 % from 1990 to 2035 due to a forecasted growth in traffic. The emission shares for the remaining mobile sources (e.g. domestic aviation, national navigation, railways and non-road machinery in industry, households and agriculture) are small compared with road transport. For industry, the emissions decrease from 1990-2035. For this sector there was a significant emission growth from 1990-2009 (due to increased activity), followed by a decline in the level of GHG emissions from 2010 onwards, due to use of gradually more fuel efficient machinery. For agriculture/fishing and navigation the projected emission in 2030 is almost the same as the 1990 emission.

Fluorinated gases

In the timeframe of this project, the total F-gas emission has a maximum in 2008-2009 and hereafter it decreases due to legislative requirements. HFCs are the dominant F-gases, which in 2010 are expected to contribute with 91 % of the F-gas emission.

Agriculture

From 1990 to 2010, the emission of GHGs in the agricultural sector decreased from 12 462 ktonnes CO_2 equivalents to 9 520 ktonnes CO_2 equivalents, which corresponds to a 24 % reduction. This development is expected to continue and the emission by 2035 is expected to decrease further to 8 859 ktonnes CO_2 equivalents. The reduction both in the historical data and the projection can mainly be explained by improved utilisation of nitrogen in manure, a significant reduction in the use of fertiliser and a reduced emission from N-leaching. These are consequences of an active environmental policy in this area. Measures in the form of technologies to reduce ammonia emissions in stables and expansion of biogas production are considered in the projections.

Waste

The total historical GHG emission from the waste sector has been decreasing since 1990. The level predicted for 2011 and onwards is decreasing compared with the latest historic year. In '2010', CH_4 emission from landfill sites is predicted to contribute 70 % of the emission from the sector as a whole. From 2010 a further decrease in the CH_4 emission from landfill is foreseen due to less waste deposition on landfills. An almost constant level for both the CH_4 and N_2O emission from wastewater in the period considered is foreseen. Emissions from wastewater handling in '2010' contribute with 16 %. The categories waste incineration & other waste contributes 14 % of the total GHG emission from the waste sector in '2010'. The emission is expected to increase due to increasing use of composting as a mean of waste disposal.

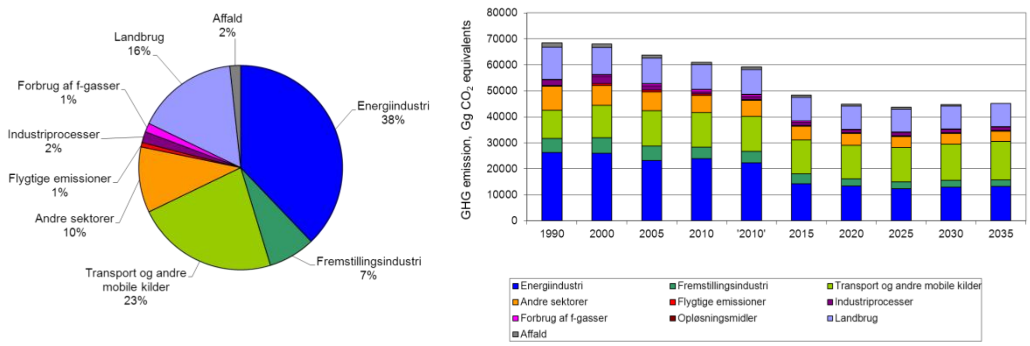
LULUCF

The overall picture of the LULUCF sector is a net source of 4 423 Gg CO_2 eqv. in 1990. In 2010 it was turned into a net sink of 2 176 Gg CO_2 eqv. In the future it is expected that the whole LULUCF sector will be a net source of 3 204 Gg CO_2 eqv. in 2015. Until 2035 it is assumed that this will remain relatively constant. The major reason for this increase is that calculation of emissions from agricultural soils uses a temperature dependent model, which takes into account the expected increased global warming. Afforestation is expected to continue to take place in Denmark with an estimated rate of 1 745 hectare per year. Together with a very small deforestation rate, the carbon stock in the Danish forest is expected to increase in the future. Cultivation of organic soils is a major steady source of emissions. Possible future regulations will reduce the area with cultivated agricultural organic soils further in the future, but there will continue to be a large net emission from these soils.

Sammenfatning

Denne rapport indeholder en beskrivelse af modeller, baggrundsdata og fremskrivninger af de danske emissioner af drivhusgasser kuldioxid (CO_2), metan (CH_4), lattergas (N_2O), de fluorerede drivhusgasser HFCer, PFCer, svovlhexafluorid (SF_6). Emissionerne er fremskrevet til 2035 på baggrund af et scenarie, som medtager de estimerede effekter på Danmarks drivhusgas-udledninger af virkemidler iværksat indtil september 2012 (såkaldt "med eksisterende virkemidler" fremskrivning). I modellerne er der, for de sektorer hvor det er muligt, anvendt officielle danske fremskrivninger af aktivitetsdata, f.eks. er den seneste officielle energifremskrivning fra Energistyrelsen anvendt. Emissionsfaktorerne refererer enten til internationale vejledninger, dansk lovgivning, danske rapporter eller er baseret på målinger på danske anlæg. Fremskrivningsmodellerne bygger på samme struktur og metoder, som er anvendt for de danske emissionsopgørelser, hvilket sikrer at historiske og fremskrevne emissionsopgørelser er konsistente.

De vigtigste sektorer i forhold til emission af drivhusgas i 2008-2012 ('2010') forventes at være energiproduktion og -konvertering (38 %), transport (23 %), landbrug (16 %), og andre sektorer (10 %). For "andre sektorer" er den vigtigste kilde husholdninger (Figur R.1). Fremskrivningerne af drivhusgas-emissionerne viser en faldende tendens i prognoseperioden fra 2010 til 2035. Generelt falder emissionsandelen for energisektoren, mens emissionsandelen for transportsektoren stiger. De totale emissioner er beregnet til 59.255 ktons CO_2-ækvivalenter i '2010' og til 45.7 ktons i 2035 svarende til et fald på omkring 23 %. Fra 1990 til '2010' er emissionerne beregnet til at ville falde med ca. 14 %.



Figur R.1 Totale drivhusgasemissioner i CO_2-ækvivalenter fordelt på hovedsektorer for '2010' og tidsserier fra 1990 til 2035.

Stationær forbrænding

Stationær forbrænding omfatter Energiindustri, Fremstillingsindustri og Andre sektorer. Andre sektorer dækker over handel/service, husholdninger samt landbrug/gartneri. Drivhusgasemissionen fra kraft- og kraftvarme-værker, som er den største kilde i '2010' (64 %), er beregnet til at ville falde markant i perioden 2011 til 2024 grundet et delvis brændselsskift fra kul til træ og affald, for 2025 til 2035 vil emissionen være nogenlunde konstant. Emissionerne fra husholdningers og fremstillingsindustriers forbrændings-anlæg falder ifølge fremskrivningen også og bliver næsten halveret i perioden 2011 til 2035 (46 % og 48 % henholdsvis). Drivhusgasemissionerne fra andre sektorer vil være næsten konstante i hele perioden med undtagelse af off-shore-sektoren, hvor emissioner fra anvendelse af energi til udvinding af olie og gas stiger med 274 % fra 1990 til '2010' og med 145 % fra '2010' til 2035.

Flygtige emissioner

Emissionen af drivhusgasser fra sektoren "Emissioner af flygtige forbindelser fra brændsler" var stigende i perioden 1990-2000 hvor emissionen nåede sit maksimum. Emissionerne estimeres til at falde i fremskrivningsperioden 2011-2035. Faldet skyldes hovedsageligt at offshore flaring i forbindelse med udvinding af olie og naturgas forventes at falde. Desuden kan faldet tilskrives tekniske forbedringer på råolie terminalen og dermed faldende emissioner fra lagring i råolietanke på terminalen samt i mindre grad fra lastning af skibe i havneanlægget. Emissionerne fra udvinding af olie og naturgas er estimeret til at falde i perioden 2011-2035 som følge af forventning om faldende udvundne mængder af olie og naturgas. Emissionerne af drivhusgasser fra de øvrige kilder er estimeret til at være konstante eller næsten konstante i fremskrivningsperioden.

Industriprocesser

Emissionen af drivhusgasser fra industrielle processer er steget op gennem halvfemserne med maksimum i 2000. Ophør af produktion af salpetersyre/kunstgødning har resulteret i en betydelig reduktion af drivhusgasemissionen. Den væsentligste kilde er cementproduktion, som bidrager med mere end 83 % af den procesrelaterede drivhusgasemission i 2010. Forbrug af kalk og derved emission af CO_2 fra røggasrensning antages at følge forbruget af kul og affald i kraftvarmeanlæg. Drivhusgasemissionen fra industrielle processer forventes også i fremtiden at være meget afhængig af cementproduktionen.

Opløsningsmidler og anvendelse af produkter

CO_2-emissioner fra anvendelse af opløsningsmidler udgør 0,2 % af de samlede danske CO_2-emissioner. De største kilder til drivhusgasemission i denne sektor er N_2O fra anvendelse af bedøvelse og indirekte CO_2-emissioner fra anden brug af opløsningsmidler, dette dækker bl.a. brug af opløsningsmidler i husholdninger. CO_2-emissionen fra anvendelse af opløsningsmidler forventes at falde i fremskrivningsperioden pga. stigende lovkrav til industrien.

Transport og andre mobile kilder

Vejtransport er den største emissionskilde for drivhusgasser i '2010', og fra 1990 til 2030 forventes emissionerne at stige med 47 % pga. vækst i trafikken. Den samlede emission for andre mobile kilder er noget lavere end vejtransporten totalt. For non-road maskiner i industrien falder emissionerne. Fra 1990-2008 steg emissionerne markant pga. øget aktivitet, hvorefter emissionerne forventes at falde pga. gradvist mere energi-effektive motorer. For landbrug/fiskeri og søfart er de fremskrevne emissioner i 2030 tæt på emissionerne i 1990.

F-gasser

I den aktuelle periode er det forventet, at den samlede F-gasemission havde sit maksimum i 2008-2009 og derefter været stærkt faldende på grund af danske reguleringer på området. Den dominerende F-gasgruppe er HFC'erne som i '2010' forventes at bidrage med 91 % til den samlede F-gasemission.

Landbrug

I perioden fra 1990 til 2010 faldt emissionen af drivhusgasser fra 12 462 ktons CO_2-ækvivalenter til 9 520 ktons CO_2-ækvivalenter, hvilket svarer til en reduktion på 24 %. Denne udvikling forventes at fortsætte og emissionen forudses at falde yderligere til 8 859 ktons CO_2-ækvivalenter i 2035. Årsagen til faldet i emissionen for den historiske såvel som den fremtidige udvikling kan forklares med en forbedring i udnyttelsen af kvælstof i husdyrgødningen, og hermed et markant fald i anvendelsen af handelsgødning samt lavere emission fra kvælstofudvaskning – som resultat af en aktiv miljøpolitik på området. I fremskrivningen er der taget højde for teknologiske tiltag i form af ammoniakreducerende teknologi i stald og en øget vækst i biogasanlæg.

Affald

Affaldssektorens samlede drivhusgasemissioner har i de historiske opgørelser vist et fald siden 1990. Fremskrivningen viser, at de samlede emissioner vil være faldende. I '2010' forventes CH_4 fra lossepladser stadig at dominere sektoren og udgøre 70 % af hele sektorens emissioner. Fra '2010' er der forudset et fald i CH_4-emissioner fra lossepladser, dette skyldes, at mindre affald bliver deponeret og at tidligere deponeret affald har afgivet meget af CH_4-potentialet. CH_4 og N_2O-emissioner fra spildevand er forudset at være omtrent konstant; bidraget fra spildevandsbehandling til sektorens samlede emission i '2010' er beregnet til 16 %. Kategorien affaldsforbrænding og anden affaldshåndtering bidrager med 14 % af den totale drivhusgasemission fra affaldssektoren i '2010'. Emissionen fra denne kilde forventes at stige pga. øget anvendelse af kompostering.

LULUCF

Overordnet var LULUCF-sektoren en nettokilde i 1990 på 4 423 Gg CO_2-ækvivalenter. I 2010 er dette opgjort til en nettobinding på 2 176 Gg CO_2-ækvivalenter. Fremover er det forventet at hele LULUCF-sektoren vil være en nettokilde på 3 204 Gg CO_2-ækvivalenter i 2015. Frem til 2035 forventes en relativt jævn emissionstrend fra sektoren. Årsagen til stigningen er, at emissionen fra mineralske landbrugsjorde beregnes med en temperaturafhængig dynamisk model og at der er en forventning om stigende temperaturer i fremtiden, som medfører en stigende emission fra de mineralske landbrugsjorde. Yderligere skovrejsning forventes at ske med 1 745 hektar per år. Sammen med en forventet lille skovrydning vil kulstofmængden i de danske skove stige fremover. Dyrkning af de organiske landbrugsjorde medfører en betydelig årlig emission. Mulige fremtidige reguleringer vil reducere arealet og dermed reducere udledningen her fra. De organiske jorde forventes dog stadig at være en stor kilde i fremtiden.

1 Introduction

In the Danish Environmental Protection Agency's project 'Projection models 2010' a range of sector-related partial models were developed to enable projection of the emissions of SO_2, NO_x, NMVOC and NH_3 forward to 2010 (Illerup et al., 2002). Subsequently, the project "Projection of GHG emissions 2005 to 2030" was carried out in order to extend the projection models to include the GHGs CO_2, CH_4, N_2O as well as HFCs, PFCs and SF_6, and project the emissions for these gases to 2030 (Illerup et al., 2007). This was further updated in the project "Projection of greenhouse gas emissions 2007 to 2025" (Nielsen et al., 2008), "Projection of Greenhouse Gas Emissions 2009 to 2030" (Nielsen et al., 2010) and "Projection of Greenhouse Gas Emissions 2010 to 2030" (Nielsen et al., 2011). The purpose of the present project, "Projection of greenhouse gas emissions 2011 to 2035" has been to update the emission projections for all sectors based on the latest national energy projections, other relevant activity data and emission factors.

1.1 Obligations

In relation to the Kyoto Protocol, the EU has committed itself to reduce emissions of GHGs for the period 2008-2012 by 8 % (on average) compared to the level in the so-called base year: 1990 for CO_2, CH_4, and N_2O and either 1990 or 1995 for industrial GHGs (HFCs, PFCs and SF_6). Under the Kyoto Protocol, Denmark has committed itself to a reduction of 21 % as a part of the Burden Sharing agreement within the EU. On the basis of the GHG inventory submission in 2006 and Denmark's choice of 1995 as the base year for industrial GHGs, Denmark's total GHG emissions in the base year amount to 69,323 ktonnes CO_2 equivalents. Calculated as 79 % of the base year Denmark's assigned amount under the Burden Sharing Agreement amounts to 273,827 ktonnes CO_2 equivalents in total or on average 54,765 ktonnes CO_2 equivalents per year in the period 2008-2012.

Since 1990 Denmark has implemented policies and measures aiming at reductions of Denmark's emissions of CO_2 and other GHGs. In this report the estimated effects of policies and measures implemented until September 2012 are included in the projections and the projection of total GHG emissions is therefore a so-called 'with existing measures' projection.

In addition to the implementation of policies and measures with an effect on Denmark's GHG emissions by sources, Parties to the Kyoto Protocol can also make use of certain removals by sinks and emission reductions achieved abroad through Joint Implementation projects (JI) or projects under the Clean Development Mechanism (CDM).

1.2 Greenhouse gases

The GHGs reported under the Climate Convention and projected in this report are:

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

- Sulphur hexafluoride SF_6

The main GHG responsible for the anthropogenic influence on the heat balance is CO_2. The atmospheric concentration of CO_2 has increased from 280 to 379 ppm (about 35 %) since the pre-industrial era in the nineteenth century (IPCC, Fourth Assessment Report). The main cause is the use of fossil fuels, but changing land use, including forest clearance, has also been a significant factor. Concentrations of the GHGs CH_4 and N_2O, which are very much linked to agricultural production, have increased by approximately 150 % and 18 %, respectively (IPCC, 2007). 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 atmospheric lifetimes for different substances differ greatly, e.g. for CH_4 and N_2O, approximately 12 and 120 years, respectively. So the time perspective clearly plays a decisive role. The lifetime chosen is typically 100 years. The effect of the various GHGs can then be converted into the equivalent quantity of CO_2, i.e. the quantity of CO_2 producing the same effect with regard to absorbing solar radiation. According to the IPCC and their Second Assessment Report, which UNFCCC has decided to use as reference, the global warming potentials for a 100-year time horizon are:

- CO_2 1
- CH_4 21
- N_2O 310

Based on weight and a 100 year period, CH_4 is thus 21 times more powerful a GHG than CO_2, and N_2O is 310 times more powerful. Some of the other GHGs (hydrofluorocarbons, perfluorocarbons and sulphur hexafluoride) have considerably higher global warming potential values. For example, sulphur hexafluoride has a global warming potential of 23,900 (IPCC, 1996).

This projection has been prepared in accordance with the current obligations for annual emission inventories. However, from 2015 the reporting of emissions will be carried out in accordance with the 2006 IPCC Guidelines and using the GWPs from the IPCC Fourth Assessment Report.

1.3 Historical emission data

The GHG emissions are estimated according to the IPCC guidelines and are aggregated into seven main sectors. The GHGs include CO_2, CH_4, N_2O, HFCs, PFCs and SF_6. Figure 1.1 shows the estimated total GHG emissions in CO_2 equivalents from 1990 to 2010 (Nielsen et al., 2012). The emissions are not corrected for electricity trade or temperature variations. CO_2 is the most important GHG, followed by N_2O and CH_4 in relative importance. The contribution to national totals from HFCs, PFCs and SF_6 is approximately 1 %. Stationary combustion plants, transport and agriculture represent the largest sources, followed by Industrial Processes, Waste and Solvents. The net CO_2 removal by forestry and soil in 2010 was approximately 4 % of the total emission in CO_2 equivalents. The national total GHG emission in CO_2 equivalents excluding LULUCF has decreased by 11.0 % from 1990 to 2010 and decreased 19.4 % including LULUCF.

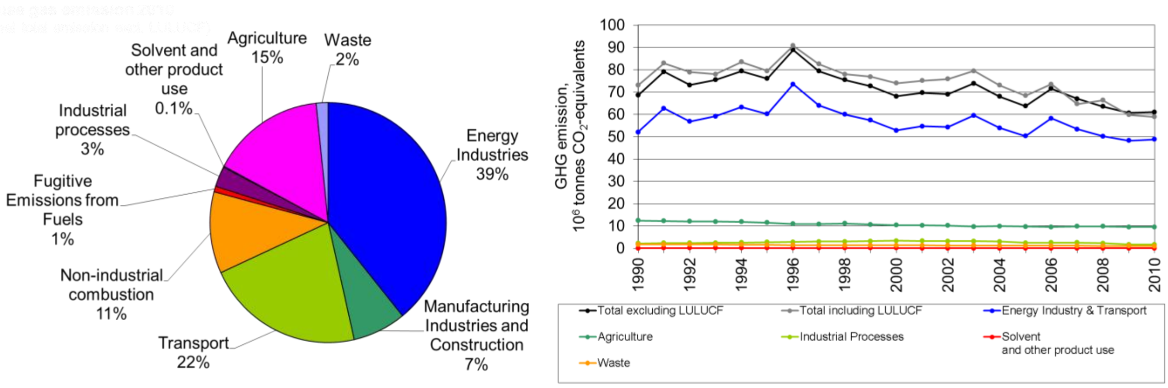


Figure 1.1 Greenhouse gas emissions in CO_2 equivalents distributed on main sectors for 2010 and time series for 1990 to 2010.

1.3.1 Carbon dioxide

The largest source to the emission of CO_2 is the energy sector, which includes combustion of fossil fuels like oil, coal and natural gas (Figure 1.2). Energy Industries contribute with 48 % of the emissions. About 27 % of the CO_2 emission comes from the transport sector. In 2010, the actual CO_2 emission was about 7.6 % lower than the emission in 1990.

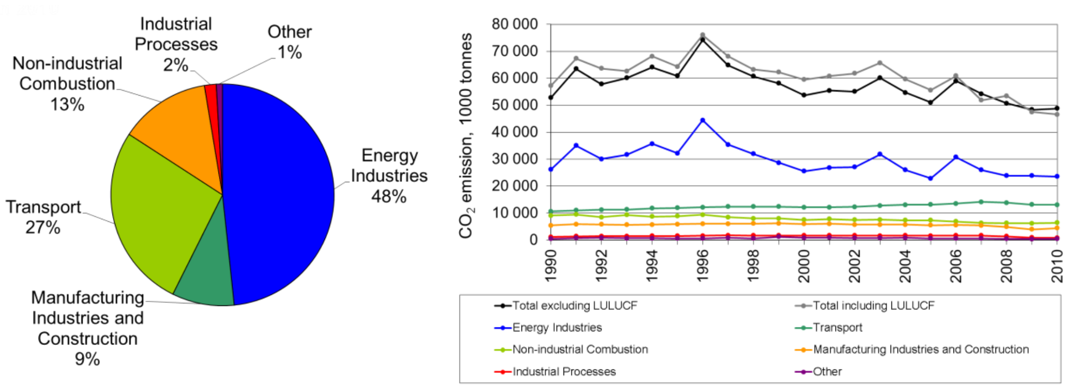


Figure 1.2 CO_2 emissions. Distribution according to the main sectors (2010) and time series for 1990 to 2010.

1.3.2 Nitrous oxide

Agriculture is the most important N_2O emission source in 2010 contributing 91.2 % (Figure 1.3) of which N_2O from soil dominates (84 %). 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 fertilisers. The main reason for the drop in the emissions of N_2O in the agricultural sector of 34.6 % from 1990 to 2010 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 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 6.4 %. The N_2O emission from transport contributes by 2.5 % in 2010. This emission increased during the 1990s 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 zero from 2005 onwards. The sector Solvent and Other Product Use covers N_2O from e.g. anaesthesia.

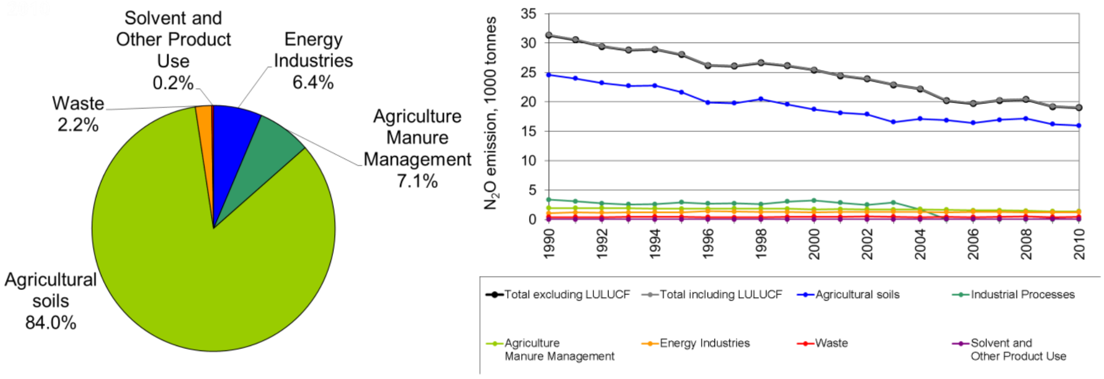


Figure 1.3 N_2O emissions. Distribution according to the main sectors (2010) and time series for 1990 to 2010.

1.3.3 Methane

The largest sources of anthropogenic CH_4 emissions are agricultural activities contributing in 2010 with 74.9 %, waste (15.4 %), public power and district heating plants (4.2 %), see Figure 1.4. The emission from agriculture derives from enteric fermentation (51.6 %) and management of animal manure (23.3 %). The CH_4 emission from public power and district heating plants increases due to the increasing use of gas engines in the decentralized cogeneration plant sector. Up to 3 % of the natural gas in the gas engines is not combusted. In more recent years the natural gas consumption in gas engines has declined causing a lowering of emissions from this source. Over the time series from 1990 to 2010, the emission of CH_4 from enteric fermentation has decreased 12.0 % mainly due to the decrease in the number of cattle. However, the emission from manure management has in the same period increased 29.7 % due to a change from traditional solid manure housing systems towards slurry-based housing systems. Altogether, the emission of CH_4 from the agriculture sector has decreased by 2.3 % from 1990 to 2010.

CH_4 emissions from Waste has decreased by 45.8 % from 1990 to 2010 due to decreasing emissions from solid waste disposal (53.1 %) and waste water handling (23.4 %).

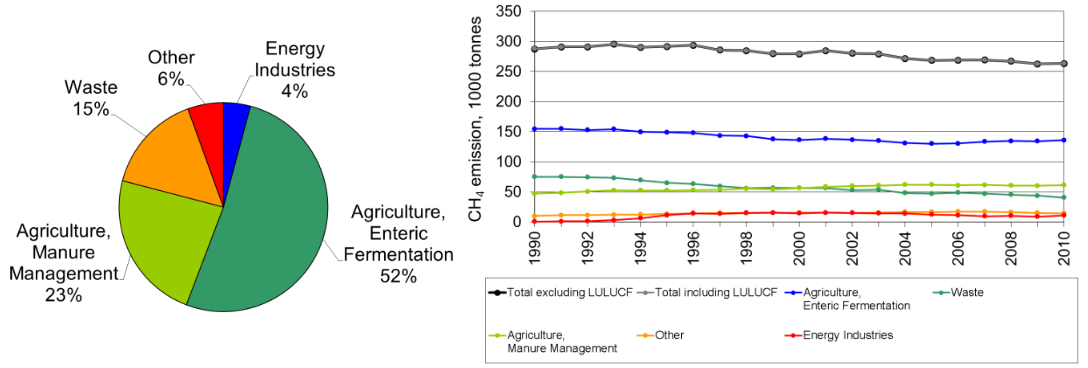


Figure 1.4 CH_4 emissions. Distribution according to the main sectors (2010) and time series for 1990 to 2010.

1.3.4 HFCs, PFCs and SF_6

This part of the Danish inventory only comprises a full data set for all substances from 1995. From 1995 to 2000, there was 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 1.5. 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. From 2008 to 2010 the emission of F-gases expressed in CO_2 equivalents decreased. The increase in emission from 1995 to 2010 is 162 %. SF_6 contributed considerably to the F-gas sum in earlier years, with 33 % in 1995. Environmental awareness and regulation of this gas under Danish law has reduced its use in industry, see Figure 1.5. A further result is that the contribution of SF_6 to F-gases in 2009 was only 4.4 %. The use of HFCs has increased several folds. HFCs have, therefore, become the dominant F-gases, comprising 66.9 % in 1995, but 94.0 % in 2010. 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 are still allowed and the use of air conditioning in mobile systems increases.

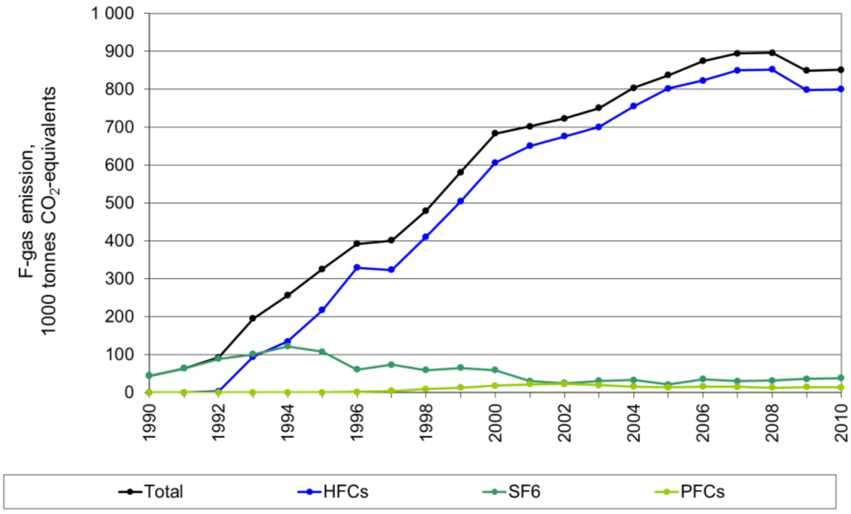


Figure 1.5 F-gas emissions. Time series for 1990 to 2010.

1.4 Projection models

Projection of emissions can be considered as emission inventories for the future in which the historical data is replaced by a number of assumptions and simplifications. In the present project the emission factor method is used and the emission as a function of time for a given pollutant can be expressed as:

$$E = \sum_{s} A_s(t) \cdot \overline{EF_s}(t) \tag{1.1}$$

where A_s is the activity for sector s for the year t and $EF_s(t)$ is the aggregated emission factor for sector s.

In order to model the emission development as a consequence of changes in technology and legislation, the activity rates and emission factors of the emission source should be aggregated at an appropriate level, at which relevant parameters such as process type, reduction targets and installation type can be taken into account. If detailed knowledge and information of the technologies and processes are available, the aggregated emission factor for a given pollutant and sector can be estimated from the weighted emission factors for relevant technologies as given in equation 1.2:

$$\overline{EF}_s(t) = \sum_{k} P_{s,k}(t) \cdot EF_{s,k}(t) \tag{1.2}$$

where P is the activity share of a given technology within a given sector, $EF_{s,k}$ is the emission factor for a given technology and k is the type of technology.

Official Danish forecasts of activity rates are used in the models for those sectors for which the forecasts are available. For other sectors projected activity rates are estimated in co-operation with relevant research institutes and other organisations. The emission factors are based on recommendations from the IPCC Guidelines (IPCC, 1997), IPCC Good Practice Guidance and Uncertainty Management (2000) and the Joint EMEP/EEA Guidebook (EMEP/EEA, 2009) as well as data from measurements made in Danish plants. The influence of legislation and ministerial orders on the development of the emission factors has been estimated and included in the models.

The projection models are based on the same structure and method as the Danish emission inventories in order to ensure consistency. In Denmark the emissions are estimated according to the CORINAIR method (EMEP/-CORINAIR, 2007) and the SNAP (Selected Nomenclature for Air Pollution) sector categorisation and nomenclature are used. The detailed level makes it possible to aggregate to both the UNECE/EMEP nomenclature (NFR) and the IPCC nomenclature (CRF).

1.5 References

EMEP/CORINAIR, 2007: Emission Inventory Guidebook 3rd edition, prepared by the UNECE/EMEP Task Force on Emissions Inventories and Projections, 2007 update. Available at: http://reports.eea.europa.eu/EMEPCORINAIR5/en/page002.html

EMEP/EEA, 2009: EMEP/EEA air pollutant emission inventory guidebook 2009. Technical report No 9/2009. Available at: http://www.eea.europa.eu/publications/emep-eea-emission-inventory-guidebook-2009/

Illerup, J.B., Birr-Pedersen, K., Mikkelsen, M.H, Winther, M., Gyldenkærne, S., Bruun, H.G. & Fenhann, J. (2002): Projection Models 2010. Danish Emissions of SO_2, NO_X, NMVOC and NH_3. National Environmental Research Institute. - NERI Technical Report 414: 192 pp. Available at: http://www2.dmu.dk/1_viden/2_Publikationer/3_fagrapporter/rapporter/FR414.pdf

Illerup, J.B., Nielsen, O.K., Winther, M., Mikkelsen, M.H., Lyck, E., Nielsen, M., Hoffmann, L., Gyldenkærne, S. & Thomsen, M., 2007: Projection of Greenhouse Gas Emissions. 2005 to 2030. National Environmental Research Institute, University of Aarhus. - NERI Technical Report 611: 116 pp. Available at: http://www.dmu.dk/Pub/FR611.pdf

IPCC, 1996: Climate Change 2005: The Science of Climate Change. Contribution of Working Group I to the Second Assessment Report of the Intergovernmental Panel on Climate Change (IPCC). Edited by J. T. Houghton, L.G. Meira Filho, B.A. Callender, N. Harris, A. Kattenberg, and K. Maskell. Cambridge University Press, Cambridge, United Kingdom and NY, USA, 572 pp. Available at: http://www.ipcc.ch/pub/sa(E).pdf

IPCC, 1997: Greenhouse Gas Inventory Reporting Instructions. Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories, Vol. 1, 2 and 3.

The Intergovernmental Panel on Climate Change (IPCC), IPCC WGI Technical Support Unit, United Kingdom. Available at:
http://www.ipcc-nggip.iges.or.jp/public/gl/invs1.htm

IPCC, 2000: IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories. Available at:
http://www.ipcc-nggi-p.iges.or.jp/public/gp/gpgaum.htm

IPCC, 2007: Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, 2007 Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.). Available at:
http://www.ipcc.ch/publications_and_data/publications_and_data_reports.shtml

Nielsen, O-K., Winther, M., Mikkelsen, M.H., Gyldenkærne, S., Lyck, E., Plejdrup, M., Hoffmann, L., Thomsen, M., Fauser, P., 2008: Projection of Greenhouse Gas Emissions 2007 to 2025 National Environmental Research Institute, Denmark. 211 pp. – NERI Technical Report no. 703. Available at: http://www.dmu.dk/Pub/FR703

Nielsen, O-K., Winther, M., Mikkelsen, M.H., Gyldenkærne, S., Lyck, E., Plejdrup, M., Hoffmann, L., Thomsen, M., Hjelgaard, K. & Fauser, P., 2010: Projection of Greenhouse Gas Emissions 2009 to 2030 National Environmental Research Institute, Aarhus University, Denmark. 143 pp. – NERI Technical Report no. 793. Available at: http://www.dmu.dk/Pub/FR793

Nielsen, O-K., Winther, M., Nielsen, M., Mikkelsen, M.H., Albrektsen, R., Gyldenkærne, S., Plejdrup, M., Hoffmann, L., Thomsen, M., Hjelgaard, K. & Fauser, P., 2011b: Projection of Greenhouse Gas Emissions 2010 to 2030. National Environmental Research Institute, Aarhus University, Denmark. 178 pp. – NERI Technical Report no. 841. http://www.dmu.dk/Pub/FR841

Nielsen, O.-K., Mikkelsen, M.H., Hoffmann, L., Gyldenkærne, S., Winther, M., Nielsen, M., Fauser, P., Thomsen, M., Plejdrup, M.S., Albrektsen, R., Hjelgaard, K., Bruun, H.G., Johannsen, V.K., Nord-Larsen, T., Bastrup-Birk, A., Vesterdal, L., Møller, I.S., Rasmussen, E., Arfaoui, K., Baunbæk, L. & Hansen, M.G. 2012. Denmark's National Inventory Report 2012. Emission Inventories 1990-2010 - Submitted under the United Nations Framework Convention on Climate Change and the Kyoto Protocol. Aarhus University, DCE – Danish Centre for Environment and Energy, 1168 pp. Scientific Report from DCE – Danish Centre for Environment and Energy No. 19. Available at: http://www.dmu.dk/Pub/SR19.pdf

2 Stationary combustion

2.1 Methodology

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

The methodology for emission projections are, just as the Danish emission inventory for stationary combustion plants, based on the CORINAIR system described in the EMEP/CORINAIR Guidebook (EMEP/CORIN-AIR, 2007). The emission projections are based on official activity rates forecast from the Danish Energy Agency and on emission factors for different fuels, plants and sectors. For each of the fuels and categories (sector and e.g. type of plant), a set of general emission factors has been determined. Some emission factors refer to the IPPC Guidelines (IPCC, 1997) and some are country-specific and refer to Danish legislation, EU ETS reports from Danish plants, 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. The CO_2 from incineration of the plastic part of municipal waste is included in the projected emissions.

The fuel consumption in the energy projections have been divided into ETS and non-ETS consumption. Together with knowledge of the industrial process emissions that are covered by the EU ETS, it has been possible to provide an emission projection estimate for the ETS sector. The result of this is included in Chapter 14.

2.2 Sources

The combustion of fossil fuels is one of the most important sources of greenhouse gas emissions and this chapter covers all sectors, which use fuels for energy production, with the exception of the transport sector and mobile combustion in e.g. manufacturing industries, households and agriculture. Table 2.1 shows the sector categories used and the relevant classification numbers according to SNAP and IPCC.

Table 2.1 Sectors included in stationary combustion.

Sector	IPCC	SNAP
Public power	1A1a	0101
District heating plants	1A1a	0102
Petroleum refining plants	1A1b	0103
Oil/gas extraction	1A1c	0105
Commercial and institutional plants	1A4a	0201
Residential plants	1A4b	0202
Plants in agriculture, forestry and aquaculture	1A4c	0203
Combustion in industrial plants	1A2	03

In Denmark, all municipal waste incineration is utilised for heat and power production. Thus, incineration of waste is included as stationary combustion in the IPCC Energy sector (source categories *1A1*, *1A2* and *1A4a)*.

Fugitive emissions from fuels connected with extraction, transport, storage and refining of oil and gas are described in Chapter 3. Emissions from flaring in oil refineries and in oil and gas extraction are also included in Chapter 3 on fugitive emissions.

Stationary combustion is the largest sector contributing with roughly 50 % of the total greenhouse gas emission. As seen in Figure 1.1 in Section 1.3, the subsector contributing most to the greenhouse gas emission is energy industries.

2.3 Fuel consumption

Energy consumption in the model is based on the Danish Energy Agency's energy consumption projections to 2035 (Danish Energy Agency, 2012a) and energy projections for individual plants (Danish Energy Agency, 2012b).

In the projection model the sources are separated into area sources and large point sources, where the latter cover all plants larger than 25 MW_e. The projected fuel consumption of area sources is calculated as total fuel consumption minus the fuel consumption of large point sources and mobile sources.

The emission projections are based on the amount of fuel, which is expected to be combusted in Danish plants and is not corrected for international trade in electricity. For plants larger than 25 MW_e, fuel consumption is specified in addition to emission factors. Fuel use by fuel type is shown in Table 2.2, and Figures 2.1 and 2.3.

Table 2.2 Fuel consumption distributed on fuel types, TJ.

Fuel type	2011	2015	2020	2025	2030	2035
Natural gas	156 472	139 516	115 360	114 451	116 277	113 022
Steam coal	135 312	76 169	70 268	54 795	56 410	52 574
Wood and simil.	79 367	93 154	93 082	93 304	96 880	97 098
Municipal waste	38 550	39 572	43 637	45 036	48 294	51 731
Gas oil	20 060	20 829	13 583	14 044	12 682	11 775
Agricultural waste	19 761	16 588	15 589	15 609	15 614	12 637
Refinery gas	14 958	14 958	14 958	14 958	14 958	14 958
Residual oil	7 800	8 333	6 655	5 714	5 741	10 576
Petroleum coke	6 489	6 343	6 326	6 072	5 783	5 545
Biogas	3 089	9 300	16 800	24 300	31 800	35 000
LPG	1 323	1 313	1 397	1 417	1 372	1 335
Coke	716	531	196	177	153	134
Kerosene	48	49	51	54	56	59
Total	483 944	426 656	397 902	389 930	406 020	406 443

Natural gas is the most important fuel throughout the time series. After 2013, wood and similar wood wastes are expected to exceed stem coal as the second most important fuel. The largest variations are seen for coal use, biogas and wood. Coal use peaks in 2011 and decreases significantly until 2014. For biogas the projected consumption increases throughout the period as a whole and from 2019 onwards the consumption of biogas is projected to be higher than the consumption of gasoil. The use of wood is projected to increase until 2013, but after that it is expected to remain rather constant.

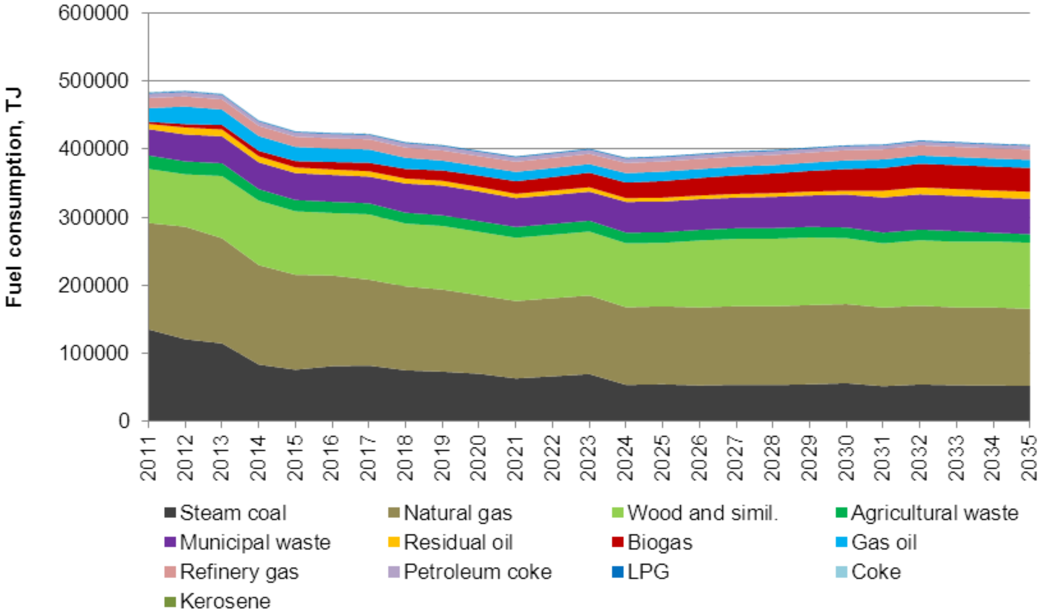


Figure 2.1 Projected energy consumption by fuel type.

Fuel use by sector is shown in Figure 2.2. The sectors consuming the most fuel are public power, residential, manufacturing industries, district heating and off-shore. According to the energy projection the fuel consumption in the public power sector will decrease with 35 % from 2011 to 2035, and the off-shore sector will increase by more than 50 % over the same period.

The fuel consumption in district heating plants is included under public power for 2011. This is due to the fact that the historic EU ETS data for 2011 were used and it was not possible within the timeframe to disaggregate between CHP plants and district heating plants.

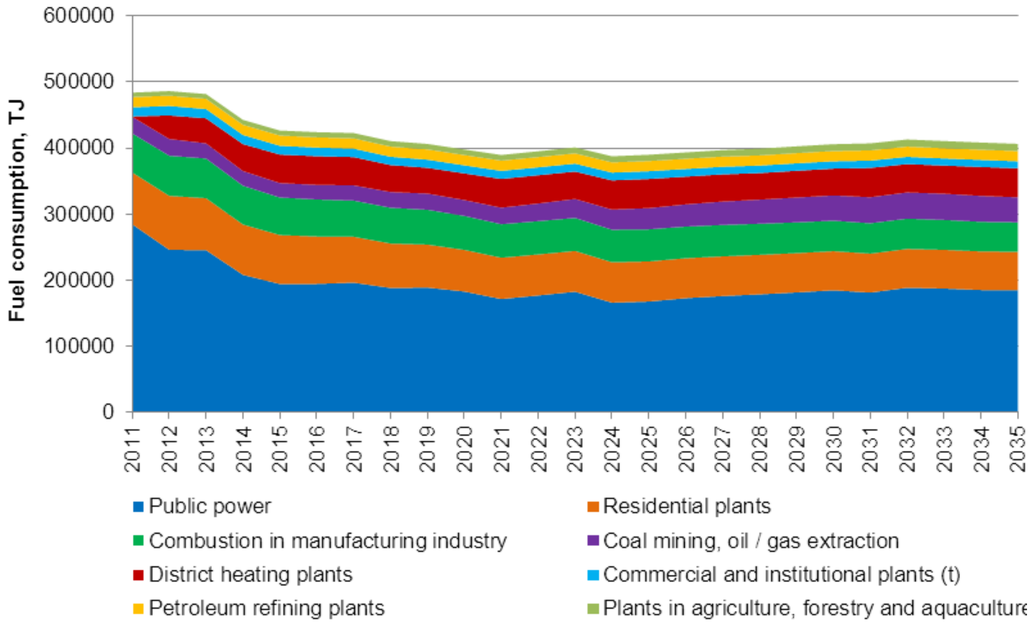


Figure 2.2 Energy use by sector.

Power plants larger than 25 MW_e use between 36 % and 47 % of total fuel, the fuel consumption in these sources decline from 2011 to 2015, thereafter the consumption remain relatively stable but with fluctuations. The amount of wood combusted by large point sources increases whereas the coal and natural gas consumption decreases. The share of fuel use comprised by exported/imported electricity constitutes -3.9 - 8.0 % of total fuel consumption over the period 2011 to 2035. In absolute terms the fuel consumption for electricity export varies between -18 000 TJ and 34 000 TJ (Figure 2.4).

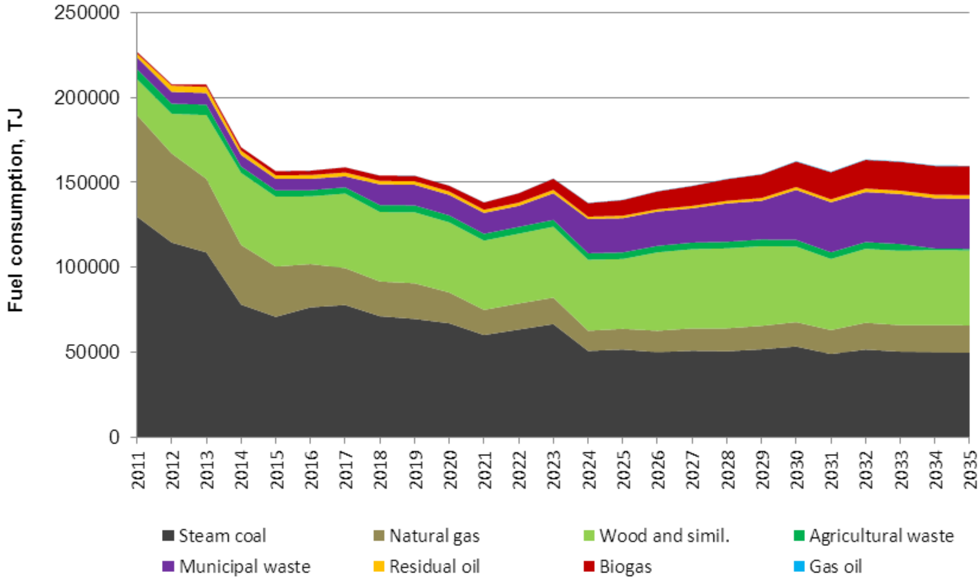


Figure 2.3 Energy consumption for plants > 25 MW_e.

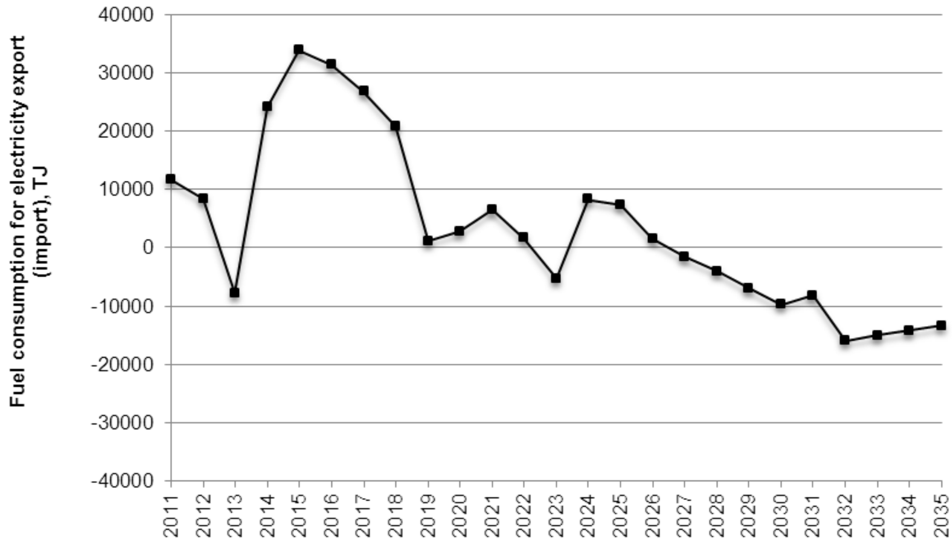


Figure 2.4 Fuel consumption associated with electricity export.

2.4 Emission factors

2.4.1 Area sources

In general, emission factors for areal sources refer to the 2010 emission factors (Nielsen et al., 2012).

However, the CO_2 emission factors for coal, residual oil applied in public power and heat production, off-shore combustion of natural gas (off-shore gas turbines) are all based on EU ETS data and updated annually in the historic emission inventories. In the projection, the average 2006-2010 emission factors have been applied rather than including only the 2010 data.

A time series for the CH_4 emission factor for residential wood combustion have been estimated based on technology specific emission factors and projections of the applied technology. The same methodology is applied in the historic inventories.

The emission factor for CO_2 is only fuel-dependent whereas the N_2O and CH_4 emission factors depend on the sector (SNAP) in which the fuel is used.

The energy projections are not made at similarly detailed SNAP level as the historic emissions inventories. The majority of emissions factors are, however, the same within the aggregated SNAP categories, which are combined in the projections.

Some of the CH_4 and N_2O emission factors for residual oil, gas oil, refinery gas and biogas are however different in the aggregated sector categories applied in the projections and therefore Implied Emission Factors (IEF) have been estimated. In calculating the IEFs, it is assumed that the distribution of fuel use across technologies within each SNAP category remains the same over the period 2011-2035. The applied IEFs are shown in Table 2.3. The IEFs are assumed to remain unchanged over the period 2011-2035.

The fuel consumption in natural gas fuelled engines has been projected separately. Thus the emission factors for gas engines that differ considerably from the emission factors for other technologies are not included in the area source emission factors for other technologies. For biogas fuelled engines the consumption in engines installed in future years has been projected separately and thus the area source emission factor is an implied emission factor for the current technology distribution for biogas fuelled engines.

Table 2.3 Implied emission factors (IEF) for CH_4 and N_2O. Calculation of implied emission factors are based on emission factors from 2010 and fuel consumption in 2010.

SNAP	Fuel	GHG	IEF
0101	Residual oil	CH_4	1.0
0101	Gas oil	CH_4	2.1
0101	Biogas	CH_4	427
0201	Biogas	CH_4	224
0203	Biogas	CH_4	255
03	Gas oil	CH_4	0.8
03	Biogas	CH_4	183
0101	Residual oil	N_2O	0.63
0101	Gas oil	N_2O	0.5
0101	Biogas	N_2O	1.6
0103	Refinery gas	N_2O	0.2
0201	Gas oil	N_2O	0.4
0201	Biogas	N_2O	0.9
0202	Gas oil	N_2O	0.6
0203	Biogas	N_2O	1
03	Gas oil	N_2O	0.45
03	Biogas	N_2O	0.7

2.4.2 Point sources

Plant-specific emission factors are not used for GHGs. Therefore, emission factors for the individual fuels/SNAP categories are used. Point sources are, with a few exceptions, plants under SNAP 010101/010102/010103. In addition, natural gas fuelled gas turbines and engines fuelled by natural gas or biogas have been included in the model as "point sources".

For gas turbines, the emission factors for SNAP 010104 are applied.

For natural gas fuelled engines, the emission factors for SNAP 010105 are applied. However, as a result of the increased NO_x tax from 2012 the engine settings will be changed leading to an increased CH_4 emission[1]. The increase of the CH_4 emission differs between engine types. A 12 % increase of CH_4 is included from 2013. This value is based on an average increase for 8 different engines with a reduced NO_x emission (Kvist, 2012).

2.5 Emissions

Emissions for the individual GHGs are calculated by means of Equation 2.1, where A_s is the activity (fuel consumption) for sector s for year t and $EF_s(t)$ is the aggregate emission factor for sector s.

$$Eq.\ 2.1 \quad E = \sum_s A_s(t) \cdot \overline{EF}_s(t)$$

The total emission in CO_2 equivalents for stationary combustion is shown in Table 2.4.

Table 2.4 Greenhouse gas emissions, Gg CO_2 equivalents.

Sector	1990	2000	2005	2010	'2010'*	2015	2020	2025	2030	2035
Public power	22 825	22 920	20 092	20 615	19 216	10 266	10 555	10 471	9 880	9 801
District heating plants	1 962	566	544	944	763	1 905	1 934	1 914	1 790	1 650
Petroleum refining plants	908	1 001	939	855	904	901	901	901	901	901
Oil/gas extraction	552	1 475	1 629	1 501	1 511	1 261	1 274	1 330	1 373	1 419
Commercial and institutional plants	1 423	927	861	958	843	713	693	677	660	655
Residential plants	5 049	4 089	3 762	3 172	2 982	2 423	2 294	2 165	2 043	1 934
Plants in agriculture, forestry and aquaculture	616	792	670	333	315	324	325	323	321	319
Combustion in industrial plants	4 595	5 143	4 558	3 402	3 465	2 981	2 821	2 648	2 498	2 302
Total	37 928	36 913	33 054	31 780	29 999	20 774	20 797	20 428	19 466	18 982

*Average of historical years 2008-2010 and projection for 2011-2012

The projected emissions in 2008-2012 ('2010') are approximately 7900 Gg (CO_2 eqv.) lower than the emissions in 1990. From 1990 to 2035, the total emission falls by approximately 18 900 Gg (CO_2 eqv.) or 50 % due to coal being partially replaced by renewable energy. The emission projections for the three GHGs are shown in Figures 2.5-2.10 and in Tables 2.5-2.7, together with the historic emissions for 1990, 2000, 2005 and 2010 (Nielsen et al. 2012).

[1] The CH_4 tax is low compared to the NO_x tax.

2.5.1 CO_2 emissions

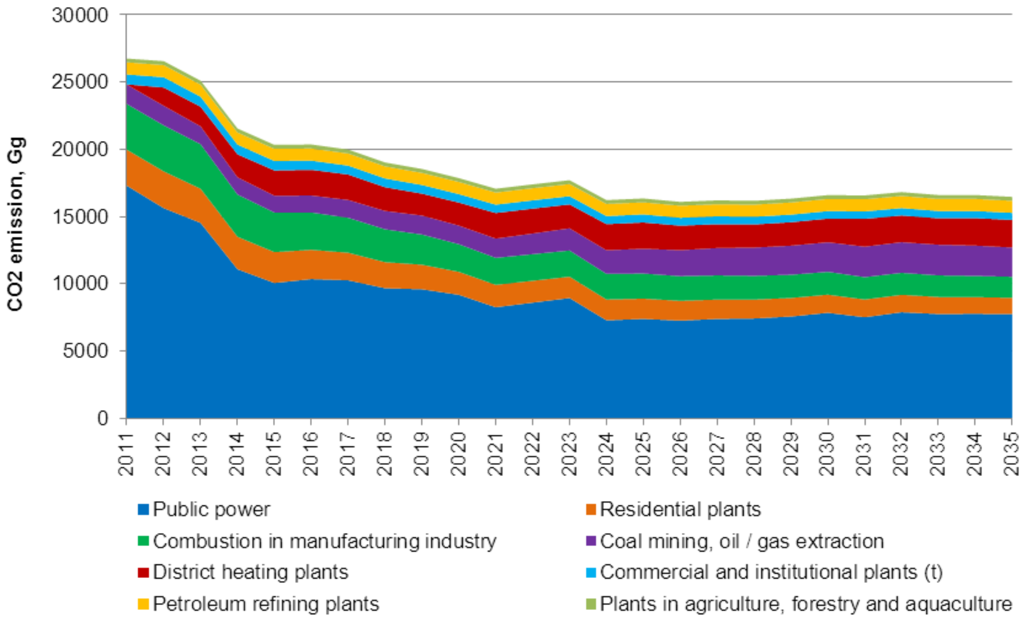


Figure 2.5 CO_2 emissions by sector.

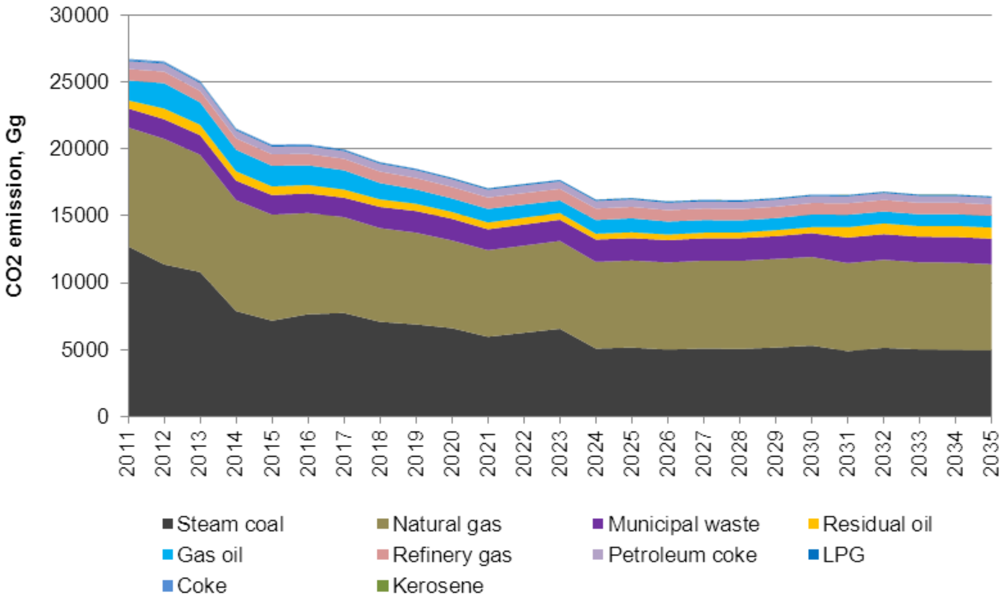


Figure 2.6 CO_2 emissions by fuel.

Table 2.5 CO_2 emissions, Gg.

Sector	1990	2000	2005	2010	'2010'*	2015	2020	2025	2030	2035
Public power	22 755	22 540	19 762	20 317	18 914	10 065	9 185	7 389	7 848	7 748
District heating plants	1 940	548	523	914	741	1 882	1 717	1 954	1 762	2 050
Petroleum refining plants	906	998	938	854	902	900	900	900	900	900
Oil/gas extraction	545	1 457	1 615	1 492	1 502	1 253	1 380	1 847	2 195	2 172
Commercial and institutional plants	1 413	900	836	933	824	701	629	595	559	527
Residential plants	4 944	3 960	3 602	2 997	2 819	2 295	1 709	1508	1 350	1 216
Plants in agriculture, forestry and aquaculture	586	734	618	300	287	299	286	286	287	289
Combustion in industrial plants	4 545	5 084	4 511	3 365	3 430	2 941	2 055	1 870	1 698	1 566
Total	37 634	36 222	32 404	31 172	29 420	20 335	17 862	16 350	16 600	16 468

*Average of historical years 2008-2010 and projection for 2011-2012.

CO_2 is the dominant GHG for stationary combustion and comprises, in 2011, approximately 98 % of total emissions in CO_2 equivalents. The most important CO_2 source is the public power sector, which contributes with about 64 % in '2010' to the total emissions from stationary combustion plants. Other important sources are combustion plants in industry, residential plants, district heating plants and oil/gas extraction. The emission of CO_2 decreases by 38 % from 2011 to 2035 due to lower fuel consumption and a fuel shift from coal and natural gas to wood and municipal waste.

2.5.2 CH_4 emissions

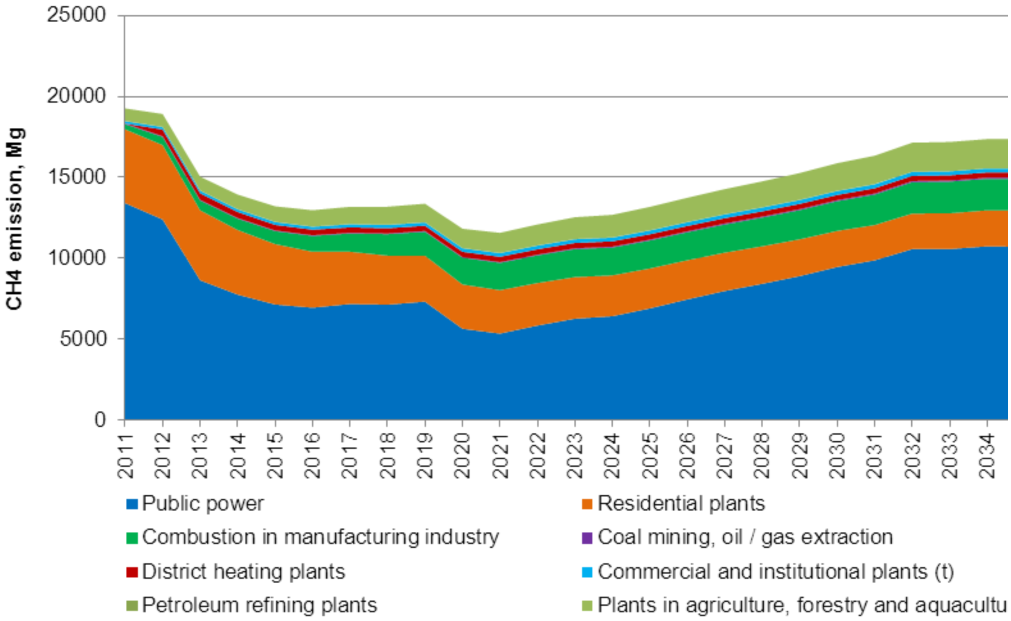


Figure 2.7 CH_4 emissions by sector.

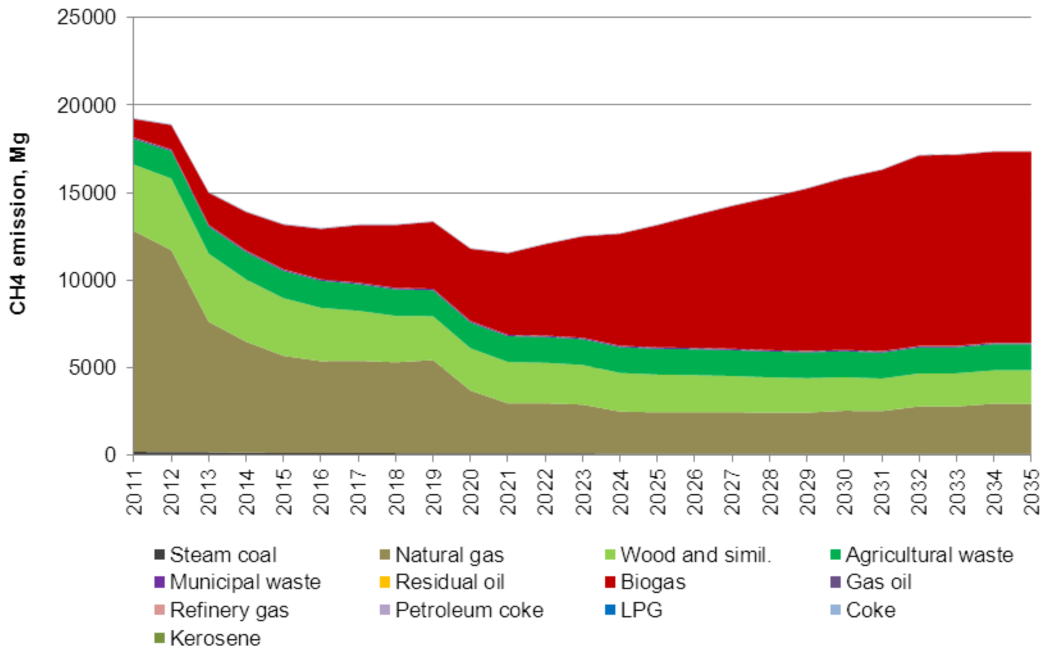


Figure 2.8 CH_4 emissions by fuel.

Table 2.6 CH_4 emissions, Mg.

Sector	1990	2000	2005	2010	'2010'*	2015	2020	2025	2030	2035
Public power	426	14 360	12 093	10 508	10 921	7 157	5 656	6 911	9 471	10 718
District heating plants	221	239	311	442	319	346	320	327	319	322
Petroleum refining plants	18	21	19	17	17	16	16	16	16	16
Oil/gas extraction	14	38	48	44	45	37	41	55	65	64
Commercial and institutional plants	114	920	822	662	473	175	220	232	243	247
Residential plants	3 654	4 754	5 634	5 796	5 351	3 728	2 738	2 470	2 227	2 241
Plants in agriculture, forestry and aquaculture	1 088	2 469	2 182	1 340	1 113	956	1 190	1 444	1 700	1 812
Combustion in industrial plants	304	1 125	919	624	536	804	1 652	1 729	1 837	1 959
Total	5 839	23 925	22 027	19 432	18 774	13 220	11 833	13 184	15 879	17 380

*Average of historical years 2008-2010 and projection for 2011-2012

The two largest sources of CH_4 emissions are public power and residential plants, which also fit well with the fact that natural gas, especially combusted in gas engines and biogas are the fuels contributing the most to the CH_4 emission. There is a significant increase in emissions from 1990 to 2000 due to the increased use of gas engines during the 1990s. Beginning around 2004, the natural gas consumption has begun to show a decreasing trend due to structural changes in the Danish electricity market. The very significant increase in CH_4 emission from biogas is due to the increasing use of biogas, combined with high emission factors when biogas is combusted in gas engines.

2.5.3 N_2O emissions

The contribution from the N_2O emission to the total GHG emission is small and the emissions stem from various combustion plants.

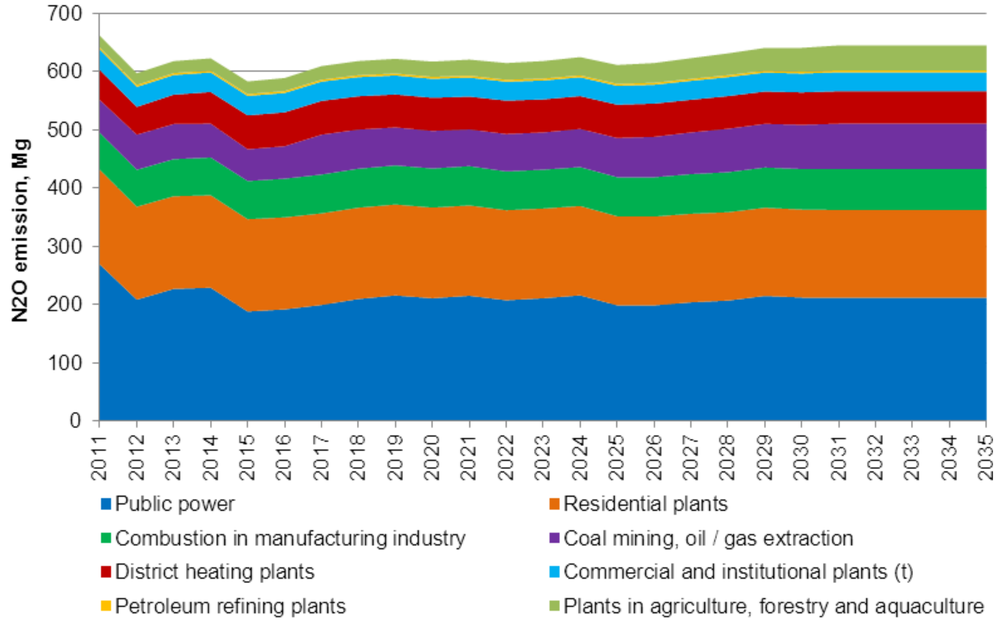


Figure 2.9 N_2O emissions by sector.

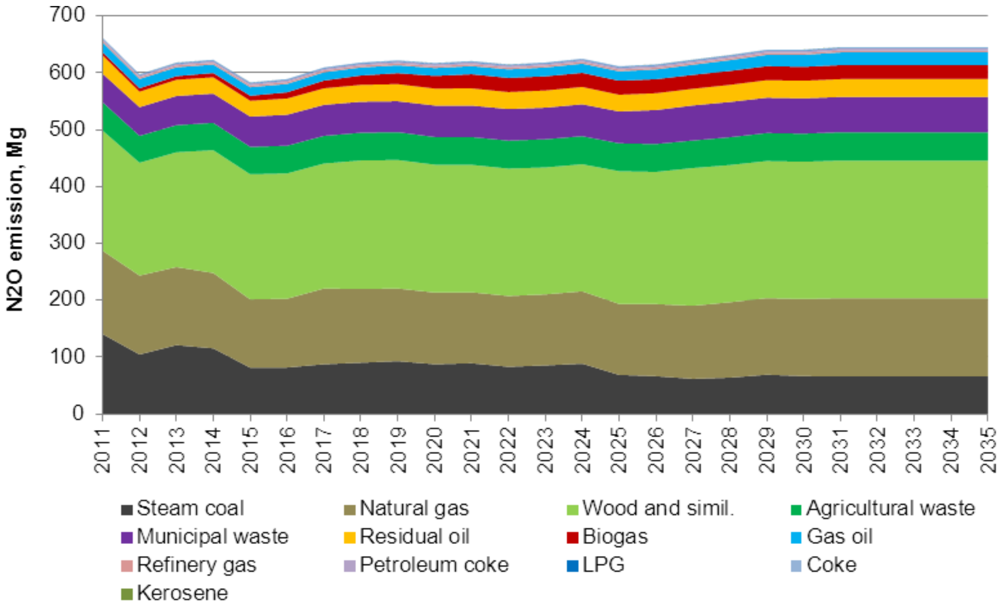


Figure 2.10 N_2O emissions by fuel.

Table 2.7 N_2O emissions, Mg.

Sector	1990	2000	2005	2010	'2010'*	2015	2020	2025	2030	2035
Public power	198	252	244	250	243	188	211	199	212	212
District heating plants	56	40	47	66	56	58	57	57	56	56
Petroleum refining plants	2	7	5	3	3	3	3	3	3	3
Oil/gas extraction	21	56	39	26	39	55	64	67	76	78
Commercial and institutional plants	25	25	26	34	33	33	33	32	32	33
Residential plants	90	93	136	172	164	159	156	153	151	151
Plants in agriculture, forestry and aquaculture	24	20	19	16	17	22	26	33	41	43
Combustion in industrial plants	138	114	89	78	73	66	67	67	69	70
Total	554	606	605	645	628	583	617	612	641	645

*Average of historical years 2008-2010 and projection for 2011-2012.

2.6 Model description

The software used for the energy model is Microsoft Access 2010, which is a Relational Database Management System (RDBMS) for creating databases. The database is called the 'Fremskrivning 2011-2035' and the overall construction of the database is shown in Figure 2.11.

The model consists of input data collected in tables containing data for fuel consumption and emission factors for combustion plants larger than 25 MW_e and combustion plants smaller than 25 MW_e. 'Area' and 'Point' in the model refer to small and large combustion plants, respectively. The names and the content of the tables are listed in Table 2.8.

Table 2.8. Tables in the 'Fremskrivning 2011-2035'.

Name	Content
tblEmfArea	Emission factors for small combustion plants
tblActArea	Fuel consumption for small combustion plants
tblEmfPoint	Emission factors for large combustion plants
tblActPoint	Fuel consumption for large combustion plants

From the data in these tables a number of calculations and unions are created by means of queries. The names and the functions of the queries used for calculating the total emissions are shown in Table 2.9.

Table 2.9. Queries for calculating the total emissions.

Name	Function
qEmission_Area	Calculation of the emissions from small combustion plants.
	Input: tbArea_act and tblEmfArea
qEmission_Point	Calculation of the emissions from large combustion plants.
	Input: tblPoint_act and tblEmfPoint
qEmission_All	Union of qEmission_Area and qEmission_Point

Based on some of the queries a large number of summation queries are available in the 'Fremskrivning 2011-2035' (Figure 2.12). The outputs from the summation queries are Excel tables.

Table 2.10 Summation queries.

Name	Output
qxls_Emission_All	Table containing emissions for SNAP groups, Years and Pollutants
qxls_Emission_Area	Table containing emissions for small combustion plants for SNAP groups, Years and Pollutants
qxls_Emission_Point	Table containing emissions for large combustion plants for SNAP groups, Years and Pollutants
qxlsActivityAll	Table containing fuel consumption for SNAP groups, Years and Pollutants
qxlsActivityPoint	Table containing fuel consumption for large combustion plants for SNAP groups, Years and Pollutants

All the tables and queries are connected and changes of one or some of the parameters in the tables result in changes in the output tables.

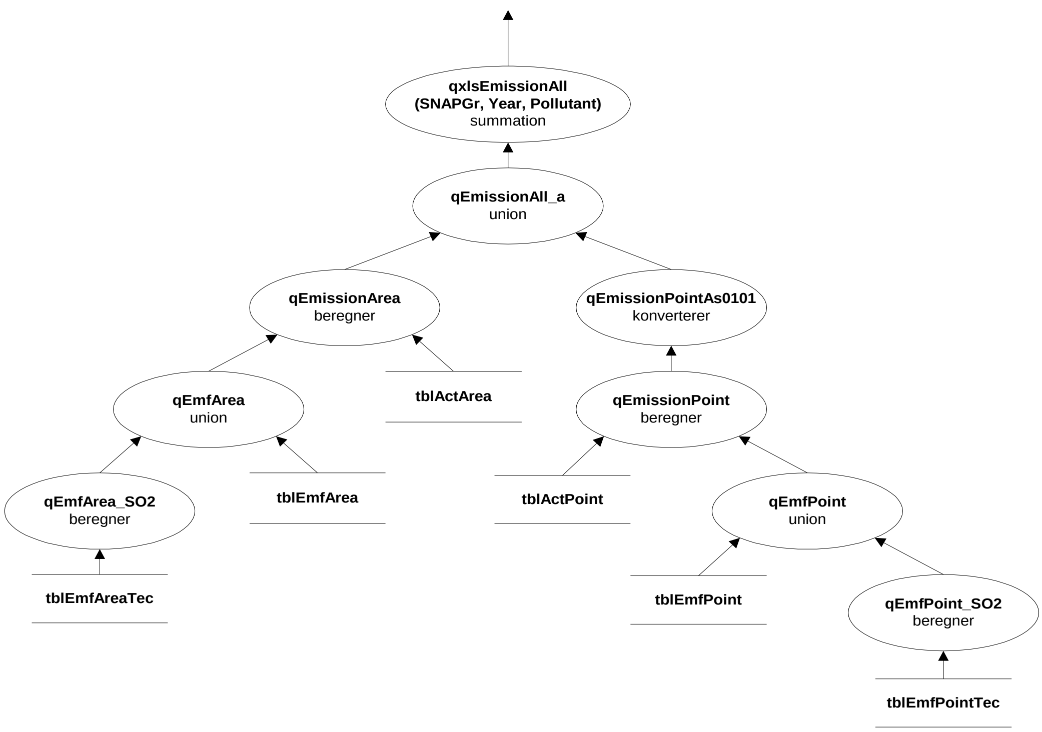


Figure 2.11 The overall construction of the database.

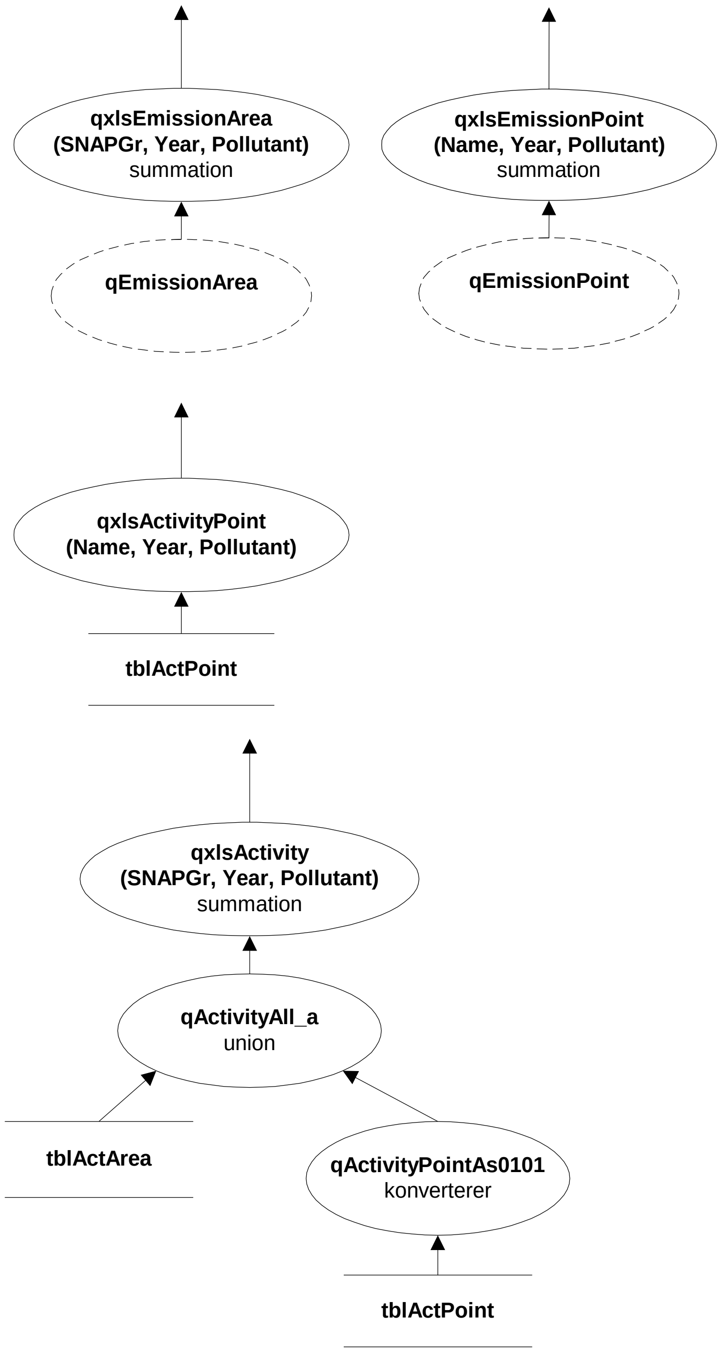


Figure 2.12 Summation queries.

2.7 Recalculations

2.7.1 Recalculations in fuel consumptions

Energy consumption in the model is based on the Danish Energy Agency's energy projections and energy projections for individual plants (Danish Energy Agency, 2012a and 2012b). All recalculations made in these projections are directly observable in the present submission.

The projected fuel consumptions are lower now than in last year's submission. The only exception is district heating, for which the consumption is 20 % to 46 % higher in this year's submission.

The largest decrease percentagewise is for plants in agriculture, forestry and aquaculture, which has decreased between 22 % (2012) and 51 % (2035). And the largest decrease measured in total energy consumption is for public power, where the decrease is between roughly 6000 TJ (2014) and 66000 TJ (2028).

Biogas fuelled engines smaller than 25 MW_e, are placed in the model as a point source.

2.7.2 Recalculations for emission factors

A few emission factors have been recalculated. Most important is the implementation of the improved CO_2 emission factor for waste incineration. The fossil waste emission factor 37 kg per GJ that is based on emission measurements from Danish waste incineration plants (Astrup et al. 2012) have been implemented[2].

An increase of the CH_4 emission factor for natural gas fuelled engines has been included. This increase is a result of the change of engine setting caused by the increased NO_x tax.

In addition, the CO_2 emission factor for natural gas has been updated and the EU ETS data for 2010 have been implemented.

2.8 References

Astrup, T., Larsen, A.W., Fuglsang, K. & Pedersen, N.H. 2012: PSO-0213, Biogenic Carbon in Danish Combustable Waste. DTU 2012. In press.

Danish Energy Agency, 2012a: Energy projections 2011-2035, September 2012.

Danish Energy Agency, 2012b: Energy projections 2011-2035 of individual plants, RAMSES, September 2012.

EMEP/CORINAIR, 2007: Emission Inventory Guidebook 3rd edition, prepared by the UNECE/EMEP Task Force on Emissions Inventories and Projections, 2007 update. Available at:
http://reports.eea.europa.eu/EMEPCORINAIR5/en/page002.html (19-09-2012)

IPCC, 1997: Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories. Available at:
http://www.ipcc-nggip.iges.or.jp/public/gl/invs6.htm (19-09-2012).

Nielsen, O.-K., Mikkelsen, M.H., Hoffmann, L., Gyldenkærne, S., Winther, M., Nielsen, M., Fauser, P., Thomsen, M., Plejdrup, M.S., Albrektsen, R., Hjelgaard, K., Bruun, H.G., Johannsen, V.K., Nord-Larsen, T., Bastrup-Birk, A., Vesterdal, L., Møller, I.S., Rasmussen, E., Arfaoui, K., Baunbæk, L. & Hansen, M.G. 2012: Denmark's National Inventory Report 2012. Emission Inventories 1990-2010 - Submitted under the United Nations Framework Convention on Climate Change and the Kyoto Protocol. Aarhus University, DCE – Danish Centre for Environment and Energy, 1168 pp. Scientific Report from DCE - Danish Centre for Environment and Energy No. 19. Available at http://www2.dmu.dk/pub/sr19.pdf

[2] The former factor was 32.5 kg per GJ

3 Oil and gas extraction (Fugitive emissions from fuels)

This chapter includes fugitive emissions in the CRF sector 1B. The sources included in the Danish emission inventory and in this projection are listed in Table 3. 1. The following chapters describe the methodology, activity data, emission factors and emissions in the projection. For a detailed description of the emission inventory for the historical years, please refer to Plejdrup et al. (2009).

Table 3.1 List of the IPCC sectors and corresponding SNAP codes for the categories included in the Danish emission inventory model for greenhouse gases.

IPCC sectors	SNAP code	SNAP name	Activity
	04	Production processes	
1 B 2 a 4	040101	Petroleum products processing	Oil
1 B 2 a 4	040103	Other	Oil
	05	Extraction and distribution of fossil fuels and geothermal energy	
1 B 2 a 2	050201	Land-based activities	Oil
1 B 2 a 2	050202 *	Off-shore activities	Oil
1 B 2 b/1 B 2 b 3	050601	Pipelines	Natural gas/Transmission
1 B 2 b/1 B 2 b 4	050603	Distribution networks	Natural gas/Distribution
	09	Waste treatment and disposal	
1 B 2 c 2 1	090203	Flaring in oil refinery	Venting and flaring
1 B 2 c 2 2	050699	Venting in gas storage	Venting and flaring
1 B 2 c 2 2	090206	Flaring in oil and gas extraction	Venting and flaring

*In the Danish inventory emissions from extraction of gas are united under "Extraction, 1st treatment and loading of liquid fossil fuels/off-shore activities" (IPCC 1B2a/SNAP 050202).

3.1 Methodology

The methodology for the emission projection corresponds to the methodology in the annual emission inventory, based on the EMEP/EEA Guidebook (EMEP-/EEA, 2009).

Activity data are based on official forecasts by the Danish Energy Agency on fuel consumption (the energy consumption prognosis) and on offshore production and flaring of oil and natural gas (the oil and gas prognosis).

Emission factors are based on either the EMEP/EEA guidelines (EMEP-/EEA, 2009) or are country-specific based on data for one or more of the historical years.

3.2 Activity data

The prognosis for the production of oil and gas (DEA, 2012b) is shown in Figure 3.1. The production is assumed to decrease over the projection period. The prognosis includes reserves (production at existing facilities and including justified projects for development), technological resources (estimated additional production due to new technological initiatives, e.g. CO_2 injection) and prospective resources (estimated production from new discoveries). Further, the production prognosis includes offshore flaring. The flaring amounts are expected to decrease over the projection period as well.

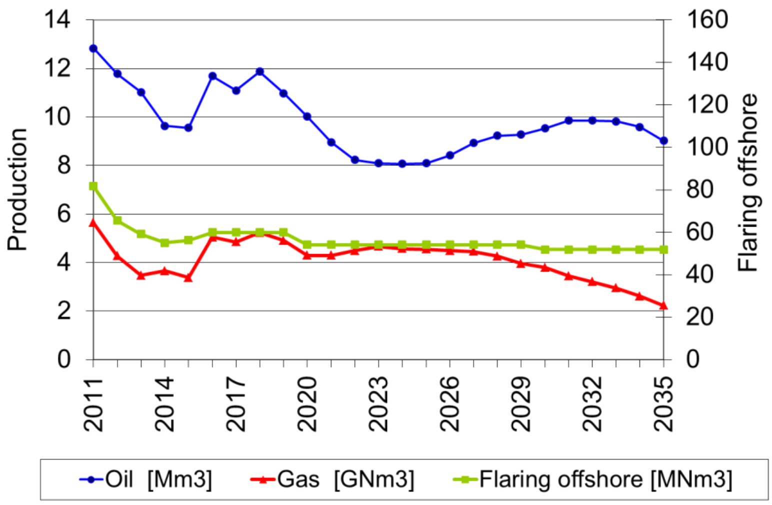


Figure 3.1 Prognosis for the production of oil and gas (DEA, 2012b).

The DEA prognosis of the production of oil and gas are used in projection of a number of sources: extraction of oil and natural gas, transport of oil in pipelines, onshore and offshore loading of ships and offshore flaring.

Data from the energy consumption prognosis by the DEA (2012a) are applied in the projection of fugitive emissions from fuels. Consumption of natural gas is used as proxy to project transmission of natural gas. Consumption of refinery gas and flaring in refineries are included in the energy consumption prognosis and applied in the projection.

3.3 Emission factors

For some sources the emission factors are based on the EMEP/EEA Guidebook (EMEP/EEA, 2009). This is the case for exploration, onshore and offshore loading and flaring. For loading of ships the guidebook provide emission factors for different countries and the Norwegian emission factors are applied in the Danish projection. The CH_4 emission factor for onshore loading given in the guidebook has been reduced by 21 % in the projection period due to introduction of new vapour recovery unit (VRU) at the Danish oil terminal in 2010 (Spectrasyne Ltd, 2010). Further, a new degassing system has been built and taken into use medio 2009, which reduced the CH_4 emissions from oil tanks by 53 % (Spectrasyne Ltd, 2010). An average emission factor for 2010-2011 has been applied for all years in the projection period, as 2010 and 2011 are the only years when the de-gassing system has operated during the whole year. The CH_4 emission factors for the projection years 2011 to 2035 are listed in Table 3.2.

Table 3.2 Emission factors for 2011-2035.

Source	CH_4	Unit	Ref.
Ships offshore	0.00005	Fraction of loaded	EMEP/EEA, 2009
Ships onshore	0.0000079	Fraction of loaded	EMEP/EEA, 2007 and Spectrasyne Ltd, 2010
Oil tanks	74.171	g per m^3	DONG Energy, 2010 and Spectrasyne Ltd, 2010

Emissions of CO_2 for flaring offshore and in refineries are based on EU-ETS. For flaring offshore the average emission factor based on EU-ETS data for 2007-2011 are applied. For flaring in refineries activity data, emission factors and emissions for the latest historical year are applied.

The CH_4 emission factor for flaring in refineries is based on detailed fuel data from one of the two refineries (Statoil, 2009).

N_2O emission factors are taken from the EMEP/EEA Guidelines (2009) for flaring offshore and in refineries.

The fuel consumption and flaring amounts for refineries in the DEA prognosis (DEA, 2012a) are constant for the projection period, and correspondingly the emissions for 2010 are applied for the projection years 2011-2035.

For sources where the emissions in historical years are given by the companies in annual or environmental reports the implied emission factors for one or the average of a number of historical years are applied for the projection years. This approach is applied for e.g. transmission and distribution of natural gas and town gas where five year averages have been applied.

3.4 Emissions

The majority of the emissions are calculated due to the standard formula (Equation 1) while the emissions in the last historical year, given in e.g. annual reports, are adopted for the remaining sources.

$$E_{s,t} = AD_{s,t} * EF_{s,t} \qquad \text{(Equation 1)}$$

where E is the emission, AD is the activity data and EF is the emission factor for the source s in the year t.

Table 3.3 include CH_4 emission on sub-sector level in selected historical years and projection years. Further the average emissions for the years 2008-2012 are included in the table ('2010'). The total fugitive CH_4 emission is expected to decrease in the projection period. The decrease is mainly caused by a decrease in extraction of oil and gas, which contribute to lower the CH_4 emissions. Emissions of CH_4 are also shown in Figure 3.2 for selected years in the time series 1990-2035.

Table 3.3 CH_4 emissions, Mg, in historical years (1990, 2000, 2005, 2010) and projection years (2015, 2020, 2025, 2030, 2035). '2010' refers to the average for the years 2008-2012.

	1990	2000	2005	2010		
Refining	37	188	716	2219		
Oil, onshore activities	817	1809	2225	842		
Oil, offshore activities	708	1566	1775	1781		
Gas, transmission and distribution	425	397	379	169		
Venting and flaring	86	144	114	89		
Total	2073	4104	5208	5101		
Continued	'2010'	2015	2020	2025	2030	2035
Refining	2209	2208	2208	2208	2208	2208
Oil, onshore activities	1146	652	743	546	628	649
Oil, offshore activities	1766	1719	1735	1722	1724	1712
Gas, transmission and distribution	168	105	95	94	93	92
Venting and flaring	121	110	110	110	109	109
Total	5413	4794	4891	4681	4762	4771

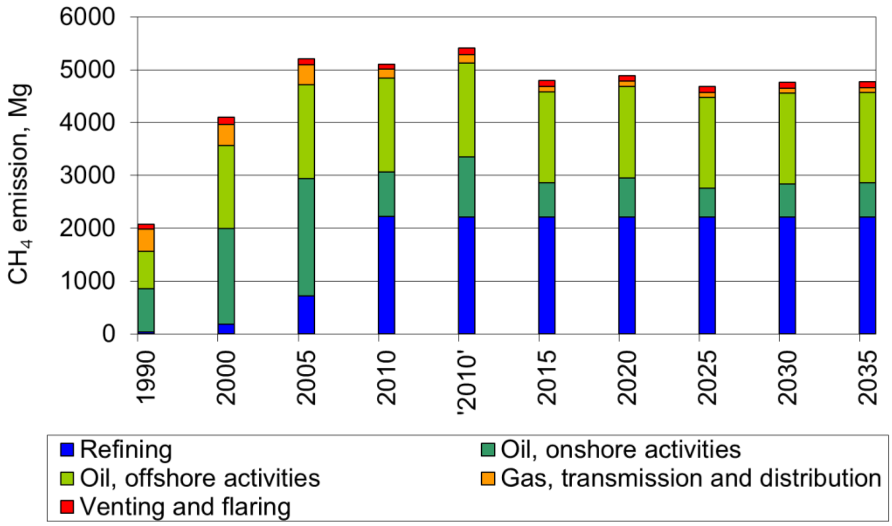


Figure 3.2 CH_4 emissions in the projection period by sector.

The summarised greenhouse gas emissions for selected historical years and projection years are shown in Figure 3.3 on sub-sector level. Further the average emission for the years 2008-2012 ('2010') are included in Figure 3.3. Transmission and distribution of gas and flaring and venting are the only source contributing fugitive emissions of CO_2 and N_2O.

The major contribution to the fugitive CH_4 emissions in the projection years are refining and oil and gas production. Emissions from onshore activities (storage of oil and loading of ships) have shown a large decrease from 2005 to 2010. The only source of N_2O emissions in the fugitive emission sector is flaring offshore, in refineries and in gas storage and treatment plants. The CO_2 emission mainly owe to offshore flaring. The N_2O emission is limited.

Emissions of CO_2 are shown in Figure 3.3 for selected historical years, projection years and the average of the years 2008-2012 ('2010').

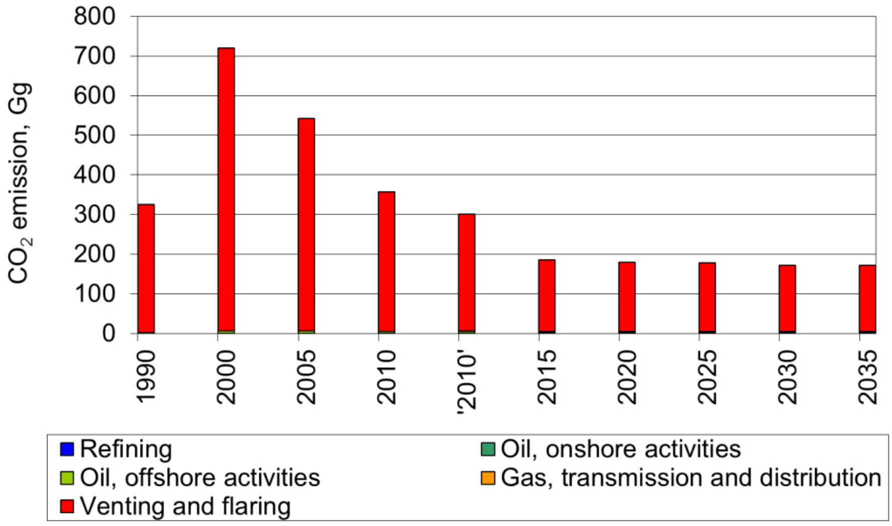


Figure 3.3 CO_2 emissions in the projection period by sector.

The GHG emissions from flaring and venting dominate the summarised GHG emissions. The GHG emissions reached a maximum around year 2000 and show a decreasing trend in the later historical years and in the projection years. The decrease owe to decreasing production amounts of oil and natural gas and to better technologies leading to less flaring on the offshore installations.

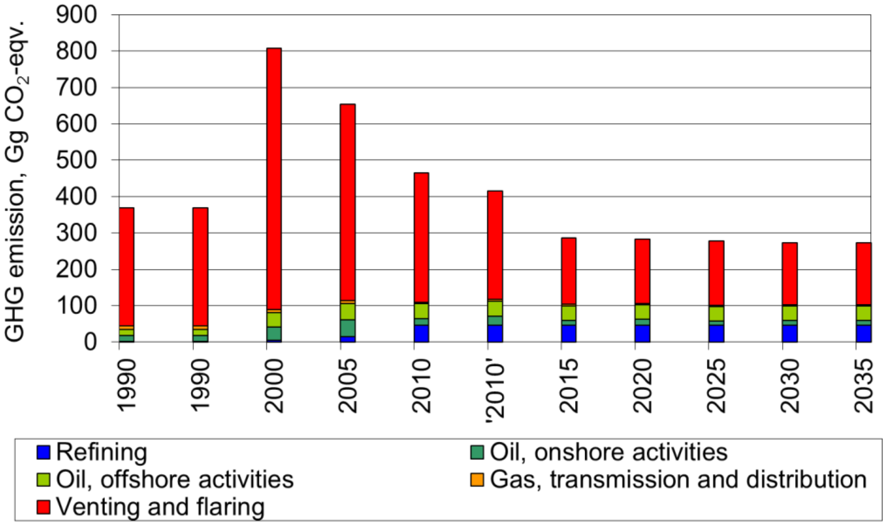


Figure 3.4 GHG emissions in selected historical and projection years.

3.5 Model description

The model for projection of fugitive emissions from fuels, the "Fugitive emissions projection model", is created in Microsoft Excel. The projection model is built in accordance with the model used in the national emission inventory system; the "Fugitive emission model". For sources where the historical emissions are used to estimate emissions in the projection years, the "Fugitive emissions projection model" links to the "Fugitive emission model". Historical emission from Refineries and transmission/distribution of gas are treated in separate workbook models ("Refineries" and "Gas losses"). The names and content of the sub models are listed in Table 3.4.

Table 3.4 Tables in the 'Fugitive emissions projection model'.

Name	Content
Fugitive emissions projection model	Activity data and emission factors for extraction of oil and gas, loading of ships and storage in oil tanks at the oil terminal for the historical years 1990 to 2010 plus prognosis and projected activity rates and emission factors for the projection years 2011 to 2035. Further, the resulting emission the projection years for all sources in the fugitive sector are stored in the worksheet "Projected emissions".
Refineries	Activity data and emission factors for refining and flaring in refineries for the historical years 1990-2010.
Gas losses	Activity data and emission factors for transmission and distribution of natural gas and town gas for the historical years 1990-2010.

Activity data, emission factors, calculations and results are kept in separate sheets in the sub models. Changing the data in the input data tables or emission factor tables will automatically update the projected emissions.

3.6 References

Danish Energy Agency, 2012a: Energy consumption prognosis 2011-2035, August 2012.

Danish Energy Agency, 2012b: Oil and gas production prognosis 2011-2035, September 2012.

EMEP/EEA, 2009: EMEP/EEA air pollutant emission inventory guidebook – 2009. Available at:
http://www.eea.europa.eu/publications/emep-eea-emission-inventory-guidebook-2009 (07-08-2012).

Plejdrup, M.S., Nielsen, O.-K. & Nielsen, M. 2009: Emission Inventory for Fugitive Emissions in Denmark. National Environmental Research Institute, Aarhus University, Denmark. 47 pp. – NERI Technical Report no. 739. Available at:
http://www.dmu.dk/pub/FR739.pdf.

Spectrasyne Ltd (2009): Fugitive Hydrocarbon Emission Survey of 8 Crude Oil Storage Tanks at DONG, Fredericia. Spectrasyne, Environmental Surveying, Sep/Oct 2009.

Statoil A/S, 2009: Personal communication. September 2009.

4 Industrial processes

4.1 Sources

A range of sources is covered in the projection of industrial process emissions 2011 to 2035 (see Table 4.1).

Table 4.1 Sources/processes included in the projection of process emissions.

IPCC code		Sources/processes	SNAP code
2A	Mineral products	2A1 Cement	04 06 12
		2A2 Lime production	04 06 14
		2A3 Limestone an dolomite use	
		- Flue gas cleaning	04 06 18
		- Mineral wool production	04 06 18
		2A5+6 Asphalt products	
		- Roof covering with asphalt products	04 06 10
		- Road surfacing with asphalt	04 06 11
		2A7 Other processes	
		- Brick production	04 06 14
		- Production of expanded clay products	04 06 14
		- Production of packaging glass	04 06 13
		- Glass wool production	04 06 13
2B	Chemical industry	Catalysts/fertilisers	04 04 16
2C	Metal production	Electro-steel works	04 02 07
2D	Food and drink	Refining of sugar	04 06 25
2G	Other	Consumption of lubricants	06 06 04

The projection of emissions from industrial processes is based on the national emissions inventory (Nielsen et al., 2012).

4.2 Projections

The results of projection of the GHG emission are presented in Table 4.3. The projections are based on energy and production value projections related to specific sectors (Danish Energy Agency, 2012a; 2012b); the applied extrapolation factors are presented in Table 4.2. The methodologies used within the different sectors - especially the estimate on 2011 activity for some of the sectors - are described below.

Cement production is the major CO_2 source within industrial processes. Information on the emission of CO_2 in 2011 is based on the company report to EU-ETS (Aalborg Portland, 2012). The emission for 2012-2035 is estimated by extrapolation with a factor based on projected production values (Danish Energy Agency, 2012b); see Table 4.2.

Production of building materials i.e. yellow bricks, expanded clay products, glass and stone wool contributes significantly to industrial process emissions. The emission for 2011-2035 is estimated by extrapolation with a factor based on expected production values within the sector "building and construction"; see Table 4.2.

Lime is used for a number of different applications. The emission for 2011-2035 is estimated by extrapolation with a factor based on expected production values within the sector "other production"; see Table 4.2.

Glass is mainly produced for packaging. The emission for 2011-2035 is estimated by extrapolation with a factor based on expected production values within the sector "glass industry"; see Table 4.2.

Consumption of lime for flue gas cleaning depends primarily on the consumption of coal (at CHP) and waste (at waste incineration plants). The activity in 2011 is assumed to be the same as in 2010. The emission for 2012-2035 is estimated by extrapolation with a factor based on expected consumption of "coal and coke" and "waste"; see Table 4.2 and Figure 4.1.

Table 4.2 Extrapolation factors for estimation of CO_2 emissions from industrial processes (based on energy and production value projections by (Danish Energy Agency (2012a; 2012b)).

	fxnf_emma	fxnk_emma	fxnq_emma	fxgl_emma	fxcm_emma	fxb_emma	Central plants	Decentral plants
	Food and beverage	Chemical industry	Other production	Glass industry	Cement industry	Building and construction	CHP/Coal & coke	Waste incineration
2010	1	1	1	1		1		
2011[1]	0.98	1.05	1.02	1.05	1	1.03	1	1
2012	1.00	1.06	1.04	1.06	1.01	1.05	0.89	1.02
2013	1.02	1.10	1.06	1.09	1.05	1.04	0.84	1.02
2014	1.07	1.11	1.08	1.10	1.06	1.07	0.60	1.01
2015	1.09	1.13	1.09	1.12	1.08	1.11	0.55	1.02
2016	1.16	1.16	1.10	1.14	1.11	1.14	0.59	1.02
2017	1.24	1.18	1.12	1.16	1.13	1.17	0.60	1.01
2018	1.31	1.21	1.14	1.19	1.15	1.21	0.55	1.11
2019	1.34	1.24	1.16	1.21	1.18	1.24	0.54	1.14
2020	1.39	1.27	1.18	1.24	1.20	1.28	0.52	1.14
2021	1.41	1.28	1.20	1.26	1.21	1.31	0.47	1.10
2022	1.43	1.30	1.21	1.27	1.23	1.33	0.49	1.10
2023	1.45	1.31	1.22	1.28	1.24	1.36	0.52	1.11
2024	1.47	1.32	1.22	1.29	1.24	1.39	0.39	1.18
2025	1.49	1.33	1.23	1.30	1.25	1.41	0.40	1.18
2026	1.51	1.34	1.24	1.31	1.26	1.43	0.39	1.18
2027	1.54	1.36	1.25	1.33	1.27	1.46	0.40	1.18
2028	1.56	1.36	1.26	1.33	1.28	1.48	0.39	1.21
2029	1.58	1.37	1.27	1.34	1.29	1.50	0.40	1.21
2030	1.61	1.40	1.29	1.37	1.31	1.53	0.41	1.27
2031	1.63	1.41	1.30	1.38	1.33	1.55	0.38	1.37
2032	1.66	1.43	1.32	1.40	1.34	1.57	0.40	1.37
2033	1.68	1.44	1.33	1.41	1.35	1.59	0.39	1.37
2034	1.70	1.45	1.34	1.42	1.36	1.60	0.39	1.37
2035	1.73	1.48	1.37	1.45	1.39	1.64	0.39	1.37

1) Emission in 2011 is based on EU-ETS reporting for cement (Aalborg Portland, 2012) and sector specific assumptions for consumption of limestone in CHP and waste incineration plants.

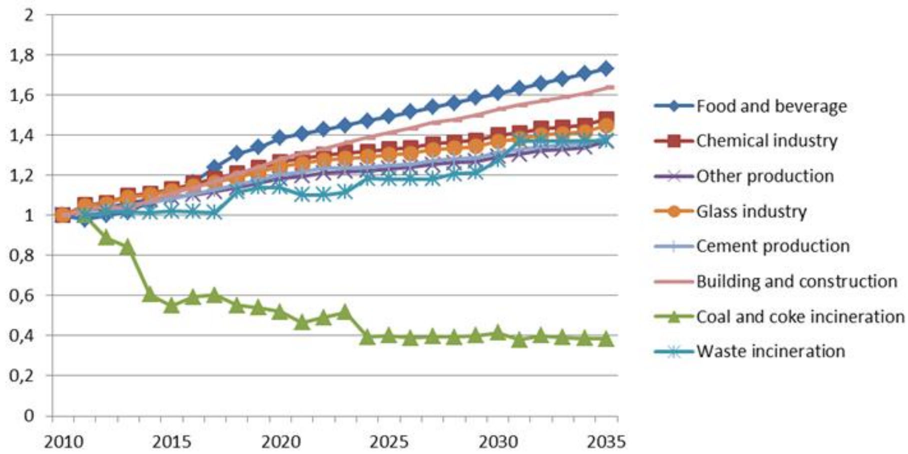


Figure 4.1 Extrapolation factors for estimation of CO_2 emissions from industrial processes (based on energy projections by (Danish Energy Agency (2012a; 2012b)).

For chemical processes, the emission in CO_2 equivalents declines sharply in 2004 as the production of nitric acid ceased in mid-2004 (http://www.kemira-growhow.com/dk; Kemira-Growhow, 2004). For the production of catalysts/fertilisers, the activity in 2010 is assumed to be at the average level for 2006-8. The emission for 2011-2030 is estimated by extrapolation with a factor based on expected energy consumption within chemical industry; see Table 4.2.

Emissions from steelworks are, in the years 2002-2004, stated as 0 as production ceased in spring 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 end of 2005, and in June 2006 DanScan Metal was taken over by Duferco; the future for the electro steelwork (DanScan Steel) is still uncertain.

The emission of CO_2 within the food and beverage industry for 2011-2035 is estimated by extrapolation with a factor based on expected production values within food and beverage industry; see Table 4.2.

The emission of CO_2 from consumption of lubricants for the years 2011-2035 is assumed to be constant at the 2010 level.

Table 4.3 Projection of CO_2 process emissions (kt CO_2).

	2A Mineral Products	2B Chemical Industry	2C Metal Production	2D Food and drink	2G Lubricants	Total
1990	1069	0.80	28.4	4.45	49.7	1152
1991	1246	0.80	28.4	4.49	48.9	1329
1992	1366	0.80	28.4	4.14	48.1	1447
1993	1383	0.80	31.0	4.26	47.6	1466
1994	1406	0.80	33.5	4.36	46.9	1492
1995	1405	0.80	38.6	3.91	48.8	1497
1996	1513	1.45	35.2	3.80	48.9	1603
1997	1681	0.87	35.0	4.29	47.1	1768
1998	1615	0.56	42.2	4.90	44.9	1707
1999	1595	0.58	43.0	4.71	42.7	1686
2000	1616	0.65	40.7	3.90	39.7	1701
2001	1612	0.83	46.7	4.95	38.5	1703
2002	1656	0.55	0	4.47	39.9	1701
2003	1527	1.05	0	4.49	37.0	1569
2004	1644	3.01	0	3.97	37.7	1688
2005	1544	3.01	15.6	4.46	37.6	1604
2006	1607	2.18	0	2.17	37.5	1649
2007	1606	2.16	0	1.72	37.9	1647
2008	1320	2.40	0	2.67	34.0	1360
2009	881	2.13	0	1.92	31.2	916
2010	796	2.12	0	1.56	33.2	833
2011	988	2.23	0	1.53	33.2	1025
2012	998	2.25	0	1.56	33.2	1035
2013	1027	2.32	0	1.58	33.2	1064
2014	1032	2.35	0	1.66	33.2	1069
2015	1049	2.40	0	1.70	33.2	1086
2016	1071	2.45	0	1.81	33.2	1109
2017	1092	2.50	0	1.93	33.2	1130
2018	1113	2.56	0	2.03	33.2	1151
2019	1137	2.62	0	2.08	33.2	1175
2020	1162	2.68	0	2.16	33.2	1200
2021	1172	2.71	0	2.19	33.2	1210
2022	1190	2.75	0	2.22	33.2	1228
2023	1195	2.78	0	2.25	33.2	1233
2024	1195	2.79	0	2.29	33.2	1233
2025	1203	2.81	0	2.32	33.2	1242
2026	1210	2.83	0	2.36	33.2	1248
2027	1226	2.87	0	2.39	33.2	1265
2028	1234	2.89	0	2.43	33.2	1272
2029	1241	2.91	0	2.46	33.2	1280
2030	1266	2.96	0	2.50	33.2	1305
2031	1277	2.99	0	2.54	33.2	1316
2032	1295	3.03	0	2.58	33.2	1333
2033	1301	3.04	0	2.62	33.2	1339
2034	1308	3.06	0	2.65	33.2	1347
2035	1340	3.14	0	2.69	33.2	1379

The results are summarised under the main IPCC groupings in Table 4.4.

Table 4.4 Summary of results of projection of CO_2 process emissions (kt CO_2).

		1990	2000	2005	2010	'2010'[1]	2015	2020	2025	2030	2035
2A	Mineral Products	1069	1616	1544	796	997	1049	1162	1203	1266	1340
2B	Chemical Industry	0.80	0.65	3.01	2.12	2.22	2.40	2.68	2.81	2.96	3.14
2C	Metal Production	28.4	40.7	15.6	0	0	0	0	0	0	0
2D	Food and drink	4.45	3.90	4.46	1.56	1.84	1.70	2.16	2.32	2.50	2.69
2G	Lubricants	49.7	39.7	37.6	33.2	32.9	33.2	33.2	33.2	33.2	33.2
	Total	1152	1701	1604	833	1034	1086	1200	1242	1305	1379

[1)] Average of the years 2008-2012.

4.3 References

Danish Energy Agency, 2012a: Energy projections 2011-2035, 31 August 2012.

Danish Energy Agency, 2012b: Production values for industry – 2008-2035. Personal communication, Anne Lund Bender, Danish Energy Agency, 6 July 2012.

Kemira GrowHow, 2004: Miljø & arbejdsmiljø. Grønt regnskab 2003; inkl. 1996-2002 (in Danish).

Nielsen, O.-K., Mikkelsen, M.H., Hoffmann, L., Gyldenkærne, S., Winther, M., Nielsen, M., Fauser, P., Thomsen, M., Plejdrup, M.S., Albrektsen, R., Hjelgaard, K., Bruun, H.G., Johannsen, V.K., Nord-Larsen, T., Bastrup-Birk, A., Vesterdal, L., Møller, I.S., Rasmussen, E., Arfaoui, K., Baunbæk, L. & Hansen, M.G. 2012. Denmark's National Inventory Report 2012. Emission Inventories 1990-2010 - Submitted under the United Nations Framework Convention on Climate Change and the Kyoto Protocol. Aarhus University, DCE – Danish Centre for Environment and Energy, 1167 pp. Scientific Report from DCE – Danish Centre for Environment and Energy No. 19. http://www.dmu.dk/Pub/SR19.pdf.

Aalborg Portland, 2012: CO_2-opgørelse og afrapportering 2011. Aalborg Portland A/S. Fremstilling af klinker (cement); including 2005-2010. Confidential.

5 Solvents and other product use

This category includes CO_2, N_2O and NMVOC emissions from solvents and other product use in industrial processes and households that are related the source categories Paint application (CRF sector 3A), Degreasing and dry cleaning (CRF sector 3B), Chemical products, manufacture and processing (CRF sector 3C) and Other (CRF sector 3D). NMVOCs are not considered direct greenhouse gases but once emitted in the atmosphere they will over a period of time oxidise to CO_2. Solvents are chemical compounds that are used on a global scale in industrial processes and as constituents in final products to dissolve e.g. paint, cosmetics, adhesives, ink, rubber, plastic, pesticides, aerosols or are used for cleaning purposes, i.e. degreasing. NMVOCs are main components in solvents - and solvent use in industries and households is typically the dominant source of anthropogenic NMVOC emissions. In industrial processes where solvents are produced or used NMVOC emissions to air and as liquid can be recaptured and either used or destroyed. Solvent containing products are used indoor and outdoor and the majority of solvent sooner or later evaporate. A small fraction of the solvent ends up in waste or as emissions to water and may finally also contribute to air pollution by evaporation from these compartments. Emission inventories for solvents are based on model estimates, as direct and continuous emissions are only measured from a limited number of pollutants and sources.

The methodology for the Danish NMVOC emission inventory for solvent use is done for the period 1995 – 2010 based on the detailed approach described in EMEP/CORINAIR (2004) and emissions are calculated for industrial sectors, households in the CRF categories mentioned above, as well as for individual chemicals and/or chemical groups. Further details on the inventory methodology can be seen in Nielsen et al. (2012).

5.1 Emission projections

Production, use, marketing and labelling of VOC containing products in Denmark are regulated by two Directives; BEK nr 350 af 29/05/2002 "Bekendtgørelse om begrænsning af emissionen af flygtige organiske forbindelser fra anvendelse af organiske opløsningsmidler i visse aktiviteter og anlæg" aka the VOC-directive, and its amendments BEK no. 817 of 25/08/2009, BEK no. 281 of 25/03/2010, BEK no. 282 of 25/03/2010 and BEK no. 283 of 25/03/2010. These are based on Directive 2004/42/CE. Further regulation follows BEK no. 1049 af 27/10/2005 "Bekendtgørelse om markedsføring og mærkning af flygtige organiske forbindelser i visse malinger og lakker samt produkter til autoreparationslakering" and its amendments BEK no. 1073 of 27/10/2009 and BEK no. 84 of 02/02/2011.

The directives supplement each other, as the VOC-directive regulates activities with VOC consumption above a certain limit value, and BEK 1049 regulates activities with VOC consumption below the limit value. Not all activities covered by the CRF3 are regulated by the two directives, e.g. only the small amount used in surface treatment of plastic products is covered in the plastic industry.

The 2010 NMVOC emissions from CRF 3 and its SNAP sub-categories are shown in Table 5.1. Sub-categories 060412 Other use: Other, 060408 Other use: Domestic solvent use and 060314 Chemical products, manufacturing and processing: Other, comprise 50 %, 14 % and 14 %, respectively, of the total CRF 3 NMVOC emissions. These sub-categories constitute highly diverse and diffuse activities and product uses, each comprising a number of chemicals.

Table 5.1 2010 NMVOC emission in Gg from CRF 3 Solvents and other product use and its sub-categories.

SNAP	Category description	NMVOC emission 2010 (Gg)	Fraction of total 2010 emission
060101	Manufacture of Automobiles	0.043	0.0016
060102	Car Repairing	0.26	0.0096
060103	Constructions and Buildings	0.60	0.022
060104	Domestic Use	0.25	0.0095
060105	Coil Coating	0.022	0.0008
060106	Boat Building	0.54	0.020
060107	Wood	0.075	0.0028
060108	Other Industrial Paint Applications	1.3	0.047
060109	Other Non-Industrial Paint Application	0.077	0.003
	Paint Application (sum of above SNAP sub-categories)	3.1	0.12
060201	Metal Degreasing	0	0
060202	Dry Cleaning	1.2E-05	5E-07
060203	Electronic Components Manufacturing	0	0
060204	Other Industrial Dry Cleaning	0	0
	Degreasing and Dry Cleaning (sum of above SNAP sub-categories)	1.2E-05	5E-07
060301	Polyester Processing	0	0
060302	Polyvinylchlorid Processing	0.00010	4E-09
060303	Polyurethan Foam Processing	0.14	0.0052
060304	Polystyrene Foam Processing	0.99	0.037
060305	Rubber Processing	0	0
060306	Pharmaceuticals Products Manufacturing	0	0
060307	Paints Manufacturing	0.00020	7E-06
060308	Inks Manufacturing	0.00021	8E-06
060309	Glues Manufacturing	0	0
060310	Asphalt Blowing	0	0
060311	Adhesive, Magnetic Tapes, Film & Photographs Manufacturing	3E-06	1E-07
060312	Textile Finishing	0	0
060313	Leather Tanning	0	0
060314	Other	3.8	0.14
	Chemical Products Manufacturing & Processing (sum of above SNAP sub-categories)	5.0	0.19
060401	Glass Wool Enduction	5.6E-06	2E-07
060402	Mineral Wool Enduction	0.00065	2E-05
060403	Printing Industry	0.0093	0.0003
060404	Fat, Edible and Non-Edible Oil Extraction	0	0
060405	Application of Glues and Adhesives	1.6	0.06
060406	Preservation of Wood	0	0
060407	Underseal Treatment and Conservation of Vehicles	0	0
060408	Domestic Solvent Use (Other Than Paint Application)	3.6	0.14
060409	Vehicles Dewaxing	0	0
060411	Domestic Use of Pharmaceutical Products	0	0
060412	Other (Preservation of Seeds a.o)	13.4	0.50
0606	Other (Use of fireworks, tobacco & charcoal for BBQs)	0.068	0.003
	Other use (sum of above SNAP sub-categories)	19	0.70
	Total	26.7	1.0

The processes and activities that are covered by BEK 350 and the associated fraction of the total 2010 NMVOC emissions are shown in Table 5.2. They cover 9.5 % of the total NMVOC emissions in CRF 3.

NMVOC emission threshold values that these categories must comply with refer to single installations. As the solvent consumption for any category is only known as a total, it is not known how big a fraction of the solvent use exceeds the emission threshold values. A worst-case assumption could be that the entire solvent consumption in a category must comply with the emission limit. However, this is not a realistic scenario as the emission values, for the solvent fraction that exceeds the thresholds in BEK 350, are considerably lower than the emission factors that are used in the inventory. Furthermore BEK 350 only covers industrial installations, and adhesive coating, which constitutes the largest fraction of the emissions covered by BEK 350, also includes diffuse use.

The predominant emissions in the inventory thus represent diffuse uses, which cannot be attributed to an industrial sector or trade organisation and it is not feasible to perform projections according to the above directives. The emission projection of all categories will be based on extrapolation of historic 1995-2010 emissions.

For N_2O historic emissions from N_2O as anaesthetic are available for 2005 to 2010 and are approximately constant during 2006 to 2010 with a mean value of 0.037 Gg N_2O per year. The emission factor is 1 for use. During production the emissions are negligible and as there are no estimates on changes in sale the projected emissions are assumed equal to the average historic 2006 to 2010 emissions. In addition there are N_2O emissions from use of fireworks, tobacco and charcoal in BBQs. The projected emissions are, with minor fluctuations, equal to the 2010 emissions of 0.011 Gg N_2O per year.

Table 5.2 Processes and activities (categories) that are covered by BEK 350, associated SNAP sub-categories, NMVOC emissions in 2010 and fraction of 2010 emissions from BEK 350 category.

Categories in BEK 350	Corresponding SNAP categories	NMVOC emission 2010 (Gg)	Fraction of total 2010 emission
Adhesive coating	060405	1.61	0.06 (also includes diffuse use)
Coating activity and vehicle refinishing	060101, 060102, 060106, 060107	0.91	0.034
Coil coating and winding wire coating	060105	0.022	0.0008
Dry cleaning	060202	0.000012	0.0000004
Footwear manufacture	nd	nd	nd
Manufacturing of coating preparations, varnishes, inks and adhesives	060307, 060308, 060309, 060311	0.00041	0.00002
Manufacture of pharmaceutical products	060306	0	0
Printing	060403	0.0093	0.0003
Rubber conversion	060305	0	0
Surface cleaning	nd	nd	nd
Vegetable oil and animal fat extraction and vegetable oil refining activities	060404	0	0
Wood impregnation	060406	0	0
Wood and plastic lamination	nd	nd	nd
Total covered by BEK 350		2.6	0.095

nd: Not defined in SNAP and may be a fraction of different SNAP categories.
0: Some of the emissions that are reported as zero, e.g. rubber conversion, may have a NMVOC use and emissions. The ca-tegories in Statistics Denmark (2012) and SPIN (2012) that include rubber may cover more materials than rubber and the use therefore falls under a different SNAP category, e.g. softeners in plastic and rubber products enters SNAP 060302 Polyvinylchloride processing.

Table 5.3 shows the extrapolation of the historic NMVOC emissions from 1990 to 2010 for the four CRF 3 categories; CRF 3A Paint application, CRF 3B Degreasing and dry cleaning, CRF 3C Chemical products, manufacture and processing and CRF 3D Other. An exponential fit gives the best approximation with R^2 values of 0.82, 0.75, 0.72 and 0.92, respectively. All projected CRF 3 categories show a decrease in NMVOC emissions, however, a decrease in use and emissions is only realistic to a certain point in time, either because the use becomes zero or because a minimum of solvent use has been reached. There is stagnation in the latest four years of the historic emissions; i.e. the four CRF categories show approximately constant emissions during the latest three years (2007 to 2010). The most realistic projection is assumed to represent the mean of the exponential fit and constant estimates. In Table 5.4, the projected CO_2 eqv. emissions are shown.

Table 5.3 Projected NMVOC and N_2O emissions from CRF 3 Solvent and Other Product Use. NMVOC projections are mean values of exponential fit of historic 1990 to 2010 emissions, and constant mean historic 2007 to 2010 emissions. N_2O projections are constant mean historic 2006 to 2010 emissions.

	Unit	1990	2000	2005	2010	'2010'[1)]	2015	2020	2025	2030	2035
NMVOC emissions											
3A Paint Application	Gg	6.02	7.44	4.89	3.11	3.29	2.87	2.54	2.30	2.13	2.00
3B Degreasing and Dry Cleaning	Gg	7.05E-05	2.93E-05	1.83E-05	1.24E-05	1.3E-05	1.1E-05	9.6E-06	8.8E-06	8.4E-06	8.1E-06
3C Chemical Products, Manufacturing and Processing	Gg	7.96	6.74	6.12	4.96	5.16	4.76	4.43	4.15	3.91	3.72
3D Other Use	Gg	23.7	26.6	20.0	18.7	18.1	16.4	15.1	14.1	13.3	12.6
Total NMVOC	Gg	37.6	40.7	31.1	26.8	26.6	24.0	22.1	20.6	19.4	18.3
N_2O emissions											
3D Use of N_2O and other products	Gg	0.0034[2)]	0.010[2)]	0.042	0.046	0.049	0.049	0.049	0.049	0.049	0.049

[1)] Mean emission (2008 – 2012).

[2)] Fireworks, tobacco and BBQ. Other uses are NA.

Table 5.4 Projected CO_2 eqv. emissions from CRF 3 Solvent and Other Product Use. CO_2 eqv. emissions are derived from NMVOC and NO_2 emissions in Table 5.3 and CO_2 conversion factors.

	Unit	1990	2000	2005	2010	'2010'[1)]	2015	2020	2025	2030	2035
CO_2 eqv. emissions											
3A Paint Application	Gg	15.9	19.3	12.4	7.96	8.41	7.32	6.47	5.85	5.41	5.09
3B Degreasing and Dry Cleaning	Gg	3,7E-05	1,6E-05	9,7E-06	6,6E-06	6.9E-06	5,8E-06	5,1E-06	4,7E-06	4,4E-06	4,3E-06
3C Chemical Products, Manufacturing and Processing	Gg	18.9	16.3	15.2	12.3	12.8	11.8	11.0	10.3	9.70	9.22
3D Other Use	Gg	57.4	63.2	46.8	41.7	41.1	37.4	34.6	32.2	30.2	28.6
Total CO_2 eqv. emissions from NMVOC	Gg	92.2	98.8	74.4	62.0	62.3	56.5	52.0	48.3	45.3	42.9
CO_2 eqv. emissions											
3D Use of N_2O and other products	Gg	1.1[2)]	3.4[2)]	13.3	14.4	15.2	15.4	15.4	15.3	15.3	15.3
Total CO_2 eqv. emissions	Gg	93.3	42.2	87.7	76.4	77.5	71.9	67.4	63.6	60.6	58.2

[1)] Mean emission (2008 – 2012).

[2)] Fireworks, tobacco and BBQ. Other uses are NA.

Previously emission projections (Nielsen et al., 2010) of four industrial sectors were elaborated in more detail: Auto paint and repair, plastic industry, graphic industry and lacquer and paint industry. Their emissions are not directly derivable from the above tables, but an estimate is that they represent 1 %, 4 %, <1 % and <1 % of the 2010 emissions. Their considerable decrease compared to the previous assessment is caused by an alteration and improvement in the source allocation calculation. This means that the emissions are still included in the inventory but are assigned to other categories, predominantly to use.

The plastic industry covers three main activities; production of expanded polystyrene products (EPS), production of fibreglass-reinforced polyester products (composite) and production of polyurethane products (PUR). Production of plastic materials does not take place in Denmark, only manufacturing and processing of plastic containing products are relevant. Emission reducing measures have already been implemented; i.e. a general shift from open to closed processes, replacing solvent-based with water-based cleaning agents, instalment of coal filters and combustion of solvent waste. Polystyrene products are manufactured from imported polystyrene pellets, which contain 6 % pentane. To comply with limit values in Luftvejledningen (EPA, 2001) and NEC directive there has been focus on reducing the pentane emissions during the EPS manufacturing and processing phase. However, due to technical barriers these initiatives will not be implemented. Other pentane reducing initiatives are reducing the pentane content in the polystyrene pellets from 6 % to 5.3 % or 3.5-4 %. This will probably be introduced in the future. For composite and PUR there are on-going initiatives on reducing the use of styrene, mainly due to exposure in the work place. However, it is not possible to quantify their effect on styrene emissions.

For the Auto paint and repair sector the emission limit values are identical in the two directives and are also reached by fulfilling a reduction program outlined in the VOC-directive. No new emission reducing initiatives are planned in the near future or have been implemented since 2007, where a general shift to water soluble and high solid products was made.

In conclusion Table 5.3 and Table 5.4 show the projected NMVOC, NO_2 and CO_2 emissions for 2011 to 2035 for the UNFCCC source categories Paint application (CRF sector 3A), Degreasing and dry cleaning (CRF sector 3B), Chemical products, manufacture and processing (CRF sector 3C) and Other (CRF sector 3D). The projections show a 32 % decrease in total NMVOC emissions from 2010 (Table 5.1) to 2035. CFR 3A, 3C and 3D5 show a 36 %, 25 % and 33 % decrease, respectively. CRF 3B emissions are negligible. CO_2 decreases are approximately the same with small variations due to different conversion factors for the NMVOCs. N_2O emissions are constant.

5.2 References

BEK nr. 350 af 29/05/2002 Bekendtgørelse om begrænsning af emissionen af flygtige organiske forbindelser fra anvendelse af organiske opløsningsmidler i visse aktiviteter og anlæg, aka the VOC directive.

BEK no. 1049 af 27/10/2005 Bekendtgørelse om markedsføring og mærkning af flygtige organiske forbindelser i visse malinger og lakker samt produkter til autoreparationslakering.

Directive no 350 on Limitation of Emissions of Volatile Organic Compounds from use of Organic Solvents in Certain Activities, aka VOC directive.

Directive no 1049 on Marketing and Labelling of Volatile Organic Compounds in Certain Paints and Lacquers and Products for Auto Repair Lacquering, aka Directive 1049.

EMEP/CORINAIR, 2004: Emission Inventory Guidebook 3rd edition, prepared by the UNECE/EMEP Task Force on Emissions Inventories and Projections, 2004 update. Available at:
http://reports.eea.eu.int/EMEPCORINAIR4/en.

EPA, 2001. Luftvejledningen - Begrænsning af luftforurening fra virksomheder, Vejledning fra miljøstyrelsen Nr. 2 2001 (in Danish).

Nielsen, O., Winther, M., Mikkelsen, M. H., Gyldenkærne, S., Lyck, E., Plejdrup, M. S., Hoffmann, L., Thomsen, M., Hjelgaard, K. & Fauser, P. 2010. Projection of Greenhouse Gas Emissions 2009 to 2030. National Environmental Research Institute, Aarhus University. 143 s. Available at:
http://www2.dmu.dk/Pub/FR793.pdf

Nielsen, O.-K., Lyck, E., Mikkelsen, M.H., Hoffmann, L., Gyldenkærne, S., Winther, M., Nielsen, M., Fauser, P., Thomsen, M., Plejdrup, M.S., Albrektsen, R., Hjelgaard, K., Johannsen, V.K., Vesterdal, L., Rasmussen, E., Arfaoui, K. & Baunbæk, L. 2011: Denmark's National Inventory Report 2011 - Emission Inventories 1990-2009 - Submitted under the United Nations Framework Convention on Climate Change. National Environmental Research Institute, Aarhus University. Available at:
http://www2.dmu.dk/Pub/FR827.pdf

SPIN, 2012: Substances in Preparations in Nordic Countries. Available at:
http://www.spin2000.net/spin.html

Statistics Denmark, 2012: Statistics Denmark. Available at:
http://www.statistikbanken.dk/statbank5a/default.asp?w=1024

6 Transport and other mobile sources

In the forecast model all activity rates and emissions are defined in SNAP sector categories (Selected Nomenclature for Air Pollution) according to the CORINAIR system. 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 6.1 (mobile sources only).

Table 6.1 SNAP – CRF correspondence table for transport.

SNAP classification	CRF classification
07 Road transport	1A3b Transport-Road
0801 Military	1A5 Other
0802 Railways	1A3c Railways
0803 Inland waterways	1A3d Transport-Navigation
080402 National sea traffic	1A3d Transport-Navigation
080403 National fishing	1A4c Agriculture/forestry/fisheries
080404 International sea traffic	1A3d Transport-Navigation (international)
080501 Dom. airport traffic (LTO < 1000 m)	1A3a Transport-Civil aviation
080502 Int. airport traffic (LTO < 1000 m)	1A3a Transport-Civil aviation (international)
080503 Dom. cruise traffic (> 1000 m)	1A3a Transport-Civil aviation
080504 Int. cruise traffic (> 1000 m)	1A3a Transport-Civil aviation (international)
0806 Agriculture	1A4c Agriculture/forestry/fisheries
0807 Forestry	1A4c Agriculture/forestry/fisheries
0808 Industry	1A2f Industry-Other
0809 Household and gardening	1A4b Residential
0811 Commercial and institutional	1A4a Commercial and institutional

Military transport activities (land and air) refer to the CRF sector Other (1A5), while the Transport-Navigation sector (1A3d) comprises national sea transport (ship movements between two Danish ports) and recreational craft. The working machinery and materiel in industry is grouped in Industry-Other (1A2f), while agricultural and forestry machinery is accounted for in the Agriculture/forestry/fisheries (1A4c) sector together with fishing activities. For aviation, LTO (Landing and Take Off)[3] refers to the part of flying, which is below 1000 m. According to UNFCCC the national emissions for aviation comprise the emissions from domestic LTO (0805010) and domestic cruise (080503) and flights between Denmark and Greenland or the Faroe Islands are regarded as domestic flights. 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.

6.1 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 Emission Inventory Guidebook (EMEP/EEA, 2009). The actual calculations are made with a model developed by DCE, using the European COPERT IV model methodology. The latter model approach is explained in (EMEP/EEA, 2009). In COPERT, fuel consumption and emission simulations can be made for

[3] 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.

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.

6.1.1 Vehicle fleet and mileage data

Corresponding to the COPERT fleet classification, all present and future vehicles in the Danish traffic 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 6.2 gives an overview of the different model classes and sub-classes and the layer level with implementation years are shown in Annex 5.I.

Table 6.2 Model vehicle classes and sub-classes, trip speeds and mileage split.

Vehicle classes	Fuel type	Engine size/weight
PC	Gasoline	< 1.4 l.
PC	Gasoline	1.4 – 2 l.
PC	Gasoline	> 2 l.
PC	Diesel	< 2 l.
PC	Diesel	> 2 l.
PC	LPG	
PC	2-stroke	
LDV	Gasoline	
LDV	Diesel	
LDV	LPG	
Trucks	Gasoline	
Trucks	Diesel	Diesel RT 3,5 - 7,5t
Trucks	Diesel	Diesel RT 7,5 - 12t
Trucks	Diesel	Diesel RT 12 - 14 t
Trucks	Diesel	Diesel RT 14 - 20t
Trucks	Diesel	Diesel RT 20 - 26t
Trucks	Diesel	Diesel RT 26 - 28t
Trucks	Diesel	Diesel RT 28 - 32t
Trucks	Diesel	Diesel RT >32t
Trucks	Diesel	Diesel TT/AT 14 - 20t
Trucks	Diesel	Diesel TT/AT 20 - 28t
Trucks	Diesel	Diesel TT/AT 28 - 34t
Trucks	Diesel	Diesel TT/AT 34 - 40t
Trucks	Diesel	Diesel TT/AT 40 - 50t
Trucks	Diesel	Diesel TT/AT 50 - 60t
Trucks	Diesel	Diesel TT/AT >60t
Buses	Gasoline	Gasoline Urban Buses
Buses	Diesel	Diesel Urban Buses <15t
Buses	Diesel	Diesel Urban Buses 15 - 18t
Buses	Diesel	Diesel Urban Buses >18t
Buses	Gasoline	Gasoline Coaches
Buses	Diesel	Diesel Coaches <15t
Buses	Diesel	Diesel Coaches 15 - 18t
Buses	Diesel	Diesel Coaches >18t
Mopeds	Gasoline	
Motorcycles	Gasoline	2 stroke
Motorcycles	Gasoline	< 250 cc.
Motorcycles	Gasoline	250 – 750 cc.
Motorcycles	Gasoline	> 750 cc.

To support the emission projections a project has been carried out by DTU Transport in order to provide fleet and annual mileage data for the vehicle categories present in COPERT IV (Jensen and Kveiborg, 2011). For information on the historical vehicle stock and annual mileage, please refer to Nielsen et al. (2012).

In addition data from a survey made by the Danish Road Directorate (Hansen, 2010) has information on 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 mileages have been backcasted to 1985 and forecasted to 2035.

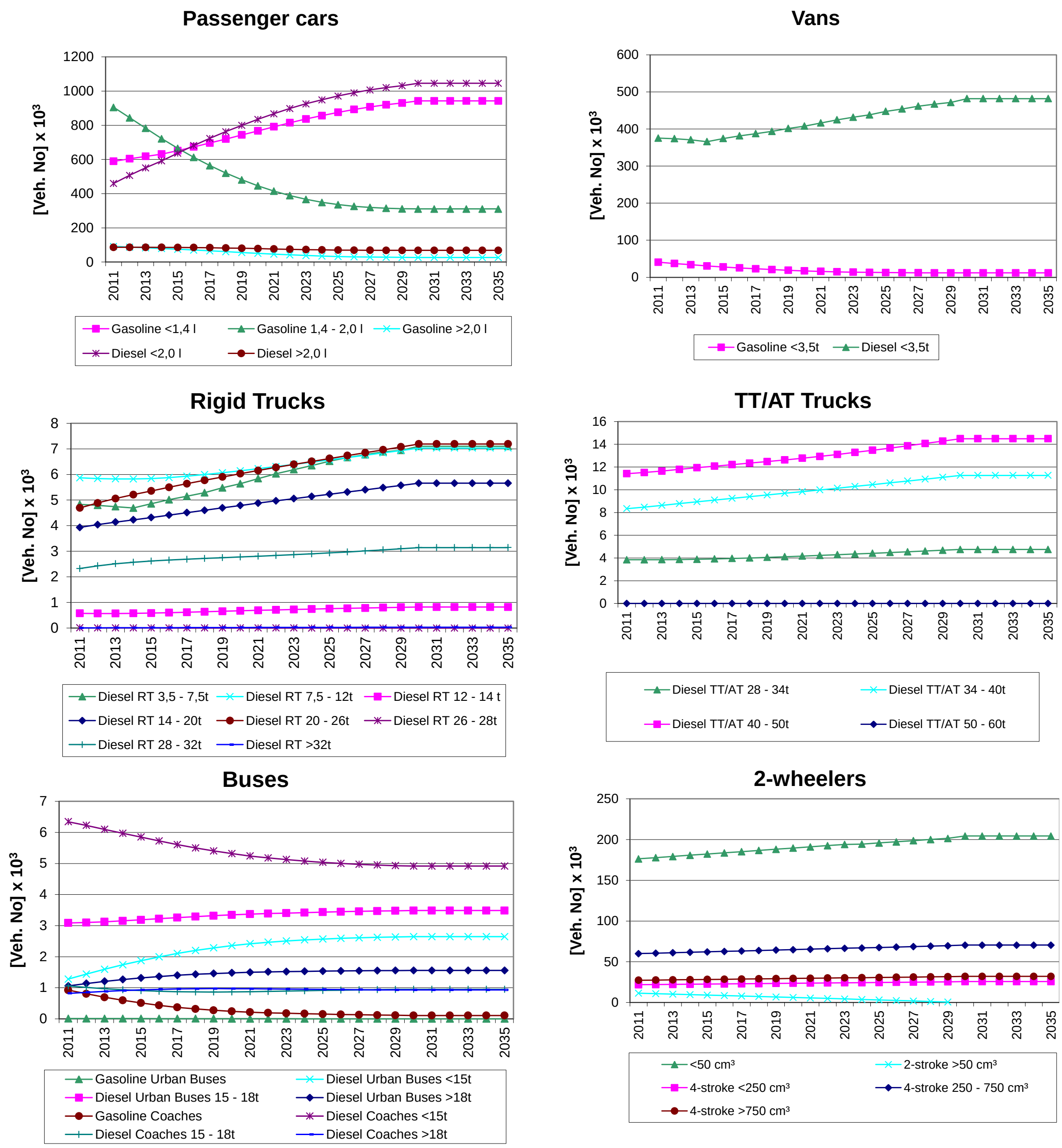


Figure 6.1 Number of vehicles in sub-classes from 2011-2035.

The vehicle numbers per sub-class are shown in Figure 6.1. The engine size differentiation is associated with some uncertainty.

The vehicle numbers are summed up in layers for each year (Figure 6.2) by using the correspondence between layers and first registration year:

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

where N = number of vehicles, j = layer, y = year, i = first registration year.

Weighted annual mileages per layer are calculated as the sum of all mileage driven per first registration year divided with the total number of vehicles in the specific layer.

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

Vehicle numbers and weighted annual mileages per layer are shown in Annex 5.1 for 2011-2035. The trends in vehicle numbers per EU layer are also shown in Figure 6.2 for the 2011-2035 periods. The latter figure clearly shows how vehicles complying with the gradually stricter EU emission levels (EURO IV, V and VI) are introduced into the Danish motor fleet in the forecast period.

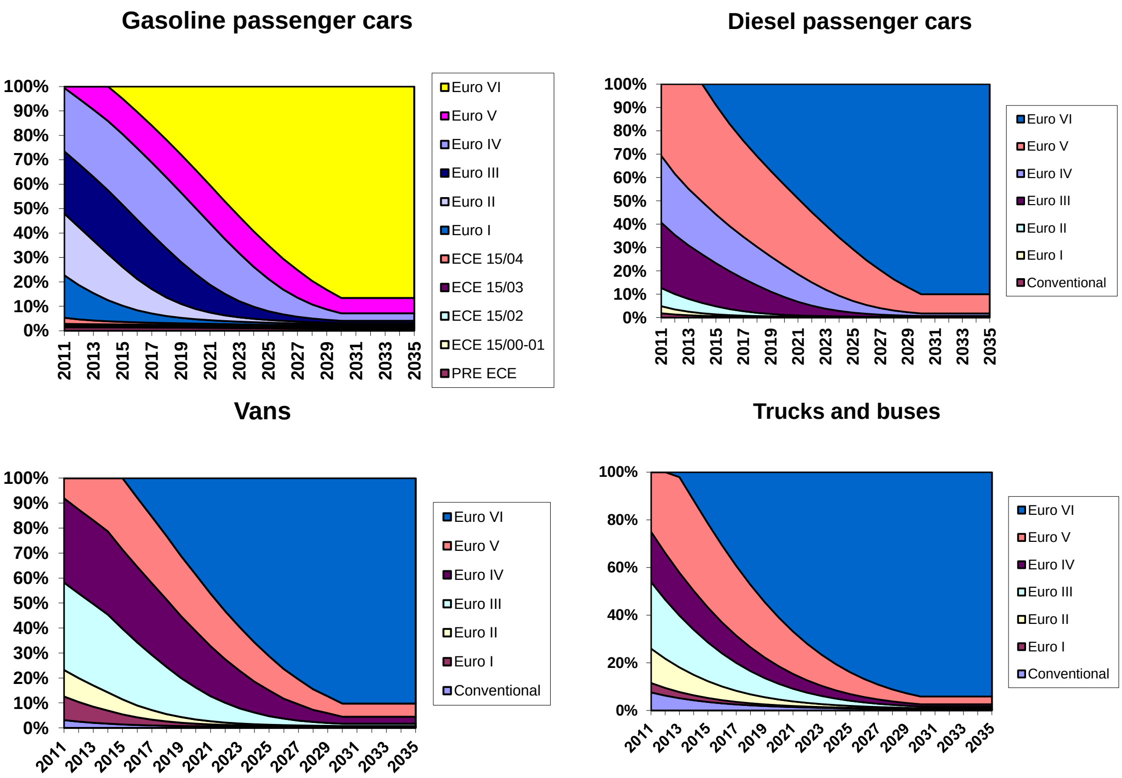


Figure 6.2 Layer distribution of vehicle numbers per vehicle type in 2011-2035.

6.1.2 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. The modalities for reaching this target and the aspects of its implementation including the excess emissions premium will have to be defined in a review to be completed no later than the beginning of 2013.
- **Eco-innovations:** because the test procedure used for vehicle type approval is outdated, certain innovative technologies cannot demonstrate their CO_2 reducing effects under the type approval test. As an interim procedure until the test procedure is reviewed by 2014, manufacturers can be granted a maximum of 7g per km of emission credits on average for their fleet if they equip vehicles with innovative technologies, based on independently verified data.

The EU 510/2011 regulation sets new emission performance standards for new light commercial vehicles (vans). Some key elements of the regulation are as follows:

- **Target dates:** The EU fleet average of 175 g CO_2 per km will be phased in between 2014 and 2017. In 2014 an average of 70 %of each manufacturer's newly registered vans must comply with the limit value curve set by the legislation. This proportion will rise to 75 % in 2015, 80 % in 2016, and 100% from 2017 onwards.
- **Limit value curve:** emissions limits are set according to the mass of vehicle, using a limit value curve. The curve is set in such a way that a fleet average of 175 grams of CO_2 per kilometre is achieved. A so-called limit value curve of 100 % implies that heavier vans are allowed higher emissions than lighter vans while preserving the overall fleet average. Only the fleet average is regulated, so manufacturers will still be able to make vehicles with emissions above the limit value curve provided these are balanced by other vehicles which are below the curve.
- **Vehicles affected:** the vehicles affected by the legislation are vans, which account for around 12 % of the market for light-duty vehicles. This in-

cludes 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. This needs to be confirmed in a review of the vans Regulation, based on an updated assessment of its costs and benefits that is to be completed no later than the beginning of 2013. The modalities for reaching this target and aspects of its implementation, including the excess emissions premium, will also be defined as part of the review.
- **Excess emissions premium for small excess emissions until 2018:** If the average CO_2 emissions of a manufacturer's fleet exceed its limit value in any year from 2014, the manufacturer has to pay an excess emissions premium for each van registered. This premium amounts to €5 for the first g per km of exceedance, €15 for the second g per km, €25 for the third g per km, and €95 for each subsequent g per km. From 2019, the first g per km of exceedance will cost €95. This value is equivalent to the premium for passenger cars.
- **Super-credits:** vehicles with extremely low emissions (below 50g per km) will be given additional incentives whereby each low-emitting van will be counted as 3.5 vehicles in 2014 and 2015, 2.5 in 2016 and 1.5 vehicles in 2017.
- **Eco-innovations:** because the test procedure used for vehicle type approval is outdated, certain innovative technologies cannot demonstrate their CO_2 reducing effects under the type approval test. As an interim procedure until the test procedure is reviewed by 2014, manufacturers can be granted a maximum of 7g per km of emission credits on average for their fleet if they equip vehicles with innovative technologies, based on independently verified data.
- **Other flexibilities:** manufacturers may group together to form a pool and act jointly in meeting the specific emissions targets. Independent manufacturers who sell fewer than 22,000 vehicles per year can also apply to the Commission for an individual target instead.

The test cycle used in the EU for measuring fuel is the New European Driving Cycle (NEDC) used also for emission testing. The NEDC cycle consists of two parts, the first part being a 4-times repetition (driving length: four km) of the ECE test cycle - the so-called urban driving cycle (average speed: 19 km per h). The second part of the test is the Extra Urban Driving Cycle (EUDC) test driving segment, simulating the fuel consumption under rural and highway driving conditions. The driving length in the EUDC is seven 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.

For NO_x, VOC (NMVOC + CH_4), CO and PM, the emissions from road transport vehicles have to comply with the different EU directives listed in Table 6 .3. In the latter table, EU directive starting dates for vehicles new registrations are also listed. The specific emission limits can be seen in Winther (2012).

For heavy duty trucks, specific information from the Danish Car Importers Association (Danske Bilimportører, DBI) of the Euro level for the trucks sold in Denmark between 2001 and 2007, are used to estimate a percentage new sales per Euro level matrix for truck engines for these inventory years. A full new sales matrix covering all relevant inventory years is subsequently made based on a broader view of the 2001-2007 DBI data and taking into account the actual starting dates for Euro 0-6 engines, see Annex 5.1.

Table 6.3 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	1.1.2011
	Euro VI	715/2007	1.9.2015
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	1.1.2011
	Euro VI	715/2007	1.9.2015
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
Heavy duty vehicles	Euro 0	88/77	1.10.1990
	Euro I	91/542	1.10.1993
	Euro II	91/542	1.10.1996
	Euro III	1999/96	1.10.2001
	Euro IV	1999/96	1.10.2006
	Euro V	1999/96	1.10.2009
	Euro VI	595/2009	1.10.2013
Mopeds	Conventional	-	-
	Euro I	97/24	2000
	Euro II	2002/51	2004
Motor cycles	Conventional	-	-
	Euro I	97/24	2000
	Euro II	2002/51	2004
	Euro III	2002/51	2007

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).

For passenger cars and light duty vehicles the emission approval tests are made on a chassis dynamometer, and for Euro I-IV vehicles the EU NEDC test cycle is used (see Nørgaard & Hansen, 2004). The emission directives distinguish between three vehicle classes: passenger cars and light duty vehicles (<1 305 kg), light duty vehicles (1 305-1 760 kg) and light duty vehicles (>1 760 kg).

In practice the emissions from vehicles in traffic are different from the legislation limit values and, therefore, the latter figures are considered to be too inaccurate for total emission calculations. A major constraint is that the emission approval test conditions only in a minor way reflect the large variety of emission influencing factors in real traffic situations, such as cumulated mileage driven, engine and exhaust after treatment maintenance levels, and driving behaviour.

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

For heavy duty vehicles (trucks and buses) the emission limits are given in g per kWh. The measurements are carried out for engines in a test bench, using the EU European Stationary Cycle (ESC) and European Transient Cycle (ETC) test cycles, depending on the Euro norm and the exhaust gas after instalment of treatment system. A description of the test cycles are given by Nørgaard & Hansen (2004). Measurement results in g per kWh from emission approval tests cannot be directly used for inventory work. Instead, emission factors used for national estimates must be transformed into g per km and derived from a sufficient number of measurements, which represent the different vehicle size classes, Euro engine levels and real world variations in driving behaviour.

6.1.3 Fuel legislation

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 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.

6.1.4 Fuel consumption and emission factors

Trip speed dependent basis factors for fuel consumption and emissions are taken from the COPERT IV model, for trip speeds related to urban, rural and highway driving. The scientific basis for COPERT IV is fuel consumption and emission information from various European measurement programmes, transformed into trip speed dependent fuel consumption and emission factors for all vehicle categories and layers.

Real measurement data lies behind the emission factors for passenger cars (Euro 4 and prior), vans (Euro 1 and prior), trucks and buses (Euro V and prior), and for mopeds and motorcycles (all technologies).

The emission factors for later engine technologies are produced by using reduction factors (see Winther, 2012). 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.

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.

An aggregated CO_2 emission factor (g pr km) for new registered passenger cars in the years 2009 and 2010 have been calculated from 1) type approval fuel economy values incorporated in the DTU Transport fleet and mileage statistics and 2) fuel specific CO_2 emission factors. The aggregated CO_2 emission factor for 2010 is used in combination with the overall EU target of 130 g CO_2 per km in 2015 and 95 g CO_2 per km in 2020 in order to calculate an interpolated time series of type approval related CO_2 emission factors for the years 2011-2014 and 2016-2019 (year specific CO_2 emission factors).

By assuming that the fuel type/engine size specific COPERT IV fuel consumption factors for Euro 4 cars relate to cars from 2009, Euro 5 and 6 COPERT corresponding factors for each fuel type/engine size combination are calculated for each year in the forecast period by multiplying the Euro 4 factor with the ratio between the year specific aggregated CO_2 emission factor and the aggregated CO_2 emission factor for 2009. The fuel specific CO_2 emission factors (g pr MJ) for gasoline and diesel are finally used to transform the km related CO_2 emission factors into fuel consumption factors.

6.1.5 Fuel consumption and emission calculations

The fuel consumption and emissions are calculated for operationally hot engines and for engines during cold start. A final fuel balance adjustment is made in order to account for the statistical fuel sold according to Danish energy statistics. It must be noted that a certain amount of gasoline fuel – the difference between bottom-up estimates and fuel sales statistics for non-road machinery - is subtracted from the road transport fuel input data prior to inventory calculations in order to maintain the overall national statistical fuel balance. This is explained in more details in section 6.2 below.

The calculation procedure for hot engines is to combine basis fuel consumption and emission factors, number of vehicles and annual mileage numbers (Annex 5.1) and mileage road type shares (from Table 5.2). For additional description of the hot and cold start calculations and fuel balance approach, please refer to Winther (2012).

Fuel consumption and emission results per layer and vehicle type, respectively, are shown in Annex 5.1 from 2011-2035. The layer specific emission factors (km based) for CO_2, CH_4 and N_2O derived from the basis input data are also shown in Annex 5.1.

6.2 Other mobile sources

Other mobile sources are divided into several sub-sectors: sea transport, fishery, air traffic, railways, military, and working machinery and equipment in the sectors agriculture, forestry, industry and residential. The emission calculations are made using the detailed method as described in the EMEP/EEA Emission Inventory Guidebook (EMEP/EEA, 2009) for air traffic, off-road working machinery and equipment, and ferries, while for the remaining sectors the simple method is used.

6.2.1 Activity data

Air traffic

For historical years, the activity data for air traffic consists of air traffic statistics provided by the Danish Civil Aviation Agency (CAA-DK) and Copenhagen Airport. For 2001-2010, records are given per flight by CAA-DK as data for aircraft type and origin and destination airports. For inventory years prior to 2001 detailed LTO/aircraft type statistics are obtained from Copenhagen Airport (for this airport only) while information of total take-off numbers for other Danish airports is provided by CAA-DK. Fuel statistics for jet fuel consumption and aviation gasoline are obtained from the Danish energy projections (DEA, 2010).

Prior to emission calculations for historical years, the aircraft types are grouped into a smaller number of representative aircraft for which fuel consumption and emission data exist in the EMEP/CORINAIR databank. In this procedure the actual aircraft types are classified according to their overall aircraft type (jets, turbo props, helicopters and piston engine). Secondly, information on the aircraft Maximum Take-Off Mass (MTOM) and number of engines are used to append a representative aircraft to the aircraft type in question. A more thorough explanation is given in Winther (2001a, b).

No forecast of air traffic movements is available as input to the emission projection calculations. Instead, the official Danish national fuel consumption projections from the DEA (2012) are used as activity data in the projection period.

Non road working machinery

Non road working machinery and equipment are used in agriculture, forestry and industry, for household/gardening purposes and inland waterways (recreational craft). The specific machinery types comprised in the Danish inventory are shown in Table 6.4.

Table 6.4 Machinery types comprised in the Danish non road inventory.

Sector	Diesel	Gasoline/LPG
Agriculture	Tractors, harvesters, machine pool, other	ATV's (All Terrain Vehicles), other
Forestry	Silvicultural tractors, harvesters, forwarders, chippers	-
Industry	Construction machinery, fork lifts, building and construction, Airport GSE, other	Fork lifts (LPG), building and construction, other
Residential and Commercial/ institutional	-	Riders, lawn movers, chain saws, cultivators, shrub clearers, hedge cutters, trimmers, other

A Danish research project has provided information of the number of different types of machines, their load factors, engine sizes and annual working hours for non-road machinery for historical years as well as methodology descriptions of how to forecast stock data for emission projection purposes (Winther et al., 2006). The most recent update of the historical data can be seen in Winther (2012).

The statistical fuel sales and energy projections from DEA for the sector "Agriculture (gasoline/diesel/LPG)" are used as an input for the fuel balance for the DCE sectors "Agriculture (gasoline/diesel/LPG)" and "Forestry (gasoline/diesel/LPG)". The DEA fuel data for "Manufacturing industries (gasoline/diesel/LPG)" and "Building and Construction (gasoline/diesel/-LPG)" are used as an input for the fuel balance for the DCE sector "Industry (gasoline/diesel/LPG)". In cases for industrial non road where DCE bottom-up estimates are smaller than DEA reported values, the fuel difference is transferred to industrial stationary sources.

The total DCE fuel estimate for gasoline working machinery used in the agriculture, forestry, industry, residential and commercial/institutional sectors is considerably larger than the statistical fuel sales reported by DEA in the DEA sectors "Agriculture", "Industry", "Building and Construction" and "Residential". The fuel difference is subtracted from the road transport fuel input data prior to inventory calculations for this sector in order to maintain the overall national statistical fuel balance.

National sea transport

An internal DCE model is used to estimate the fuel consumption figures for national sea transport based on fleet activity estimates for regional ferries, local ferries, sailing activities between Denmark and Greenland/Faroe Islands, and other national sea transport (Winther, 2008; Nielsen et al., 2012).

Further, the statistical fuel sales and energy projections from DEA for the sectors "National sea transport" and "Greenland/Faroe Islands maritime" are used as an input for the fuel balance made in the subsequent emission calculations.

Table 6.5 lists the most important domestic ferry routes in Denmark in the period 1990-2010. 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 2006-2010, the above mentioned traffic and technical data for specific ferries have been provided by Kristensen (2011) in the case of Mols-Linien (Sjællands Odde-Ebeltoft, Sjællands Odde-Århus, Kalundborg-Århus), by Hjortberg (2011) for Bornholmstrafikken (Køge-Rønne) and by Simonsen (2011) for Langelandstrafikken A/S (Tårs-Spodsbjerg). For Esbjerg-Torshavn and Hanstholm-Torshavn traffic and technical data have been provided by Dávastovu (2011) for Smyril Line.

Table 6.5 Ferry routes comprised in the Danish inventory.

Ferry service	Service period
Esbjerg-Torshavn	1990-1995, 2009+
Halsskov-Knudshoved	1990-1999
Hanstholm-Torshavn	1991-1992, 1999+
Hirtshals-Torshavn	2010
Hundested-Grenaa	1990-1996
Kalundborg-Juelsminde	1990-1996
Kalundborg-Samsø	1990+
Kalundborg-Århus	1990+
Korsør-Nyborg, DSB	1990-1997
Korsør-Nyborg, Vognmandsruten	1990-1999
København-Rønne	1990-2004
Køge-Rønne	2004+
Sjællands Odde-Ebeltoft	1990+
Sjællands Odde-Århus	1999+
Tårs-Spodsbjerg	1990+

Other sectors

The activity data for military, railways, international sea transport and fishery consists of fuel consumption information from DEA (2012). For international sea transport, the basis is expected fuel sold in Danish ports for vessels with a foreign destination, as prescribed by the IPCC guidelines.

For all other mobile sectors, fuel consumption figures are given in Annex 5.2 for the years 2011-2035 in both CollectER and CRF formats.

6.2.2 Emission legislation

For the engines used by other mobile sources, no legislation limits exist for specific fuel consumption or the directly fuel dependent emissions of CO_2. The engine emissions, however, have to comply with the general emission legislation limits agreed by the EU and, except for ships (no VOC exhaust emission regulation), the VOC emission limits influence the emissions of CH_4, the latter emissions being a part of total VOC.

For non-road working machinery and equipment, 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 relate to non-road machinery other than agricultural and forestry tractors and the directives have different implementation dates for machinery operating under transient and constant loads. The latter directive also comprises emission limits for railway machinery. For tractors the relevant directives are 2000/25 and 2005/13. For gasoline, Directive 2002/88 distinguishes between handheld (SH) and non-handheld (NS) types of machinery.

For engine type approval, the emissions (and fuel consumption) are measured using various test cycles (ISO 8178). Each test cycle consists of a number of measurement points for specific engine loads during constant operation. The specific test cycle used depends on the machinery type in question and the test cycles are described in more detail in the directives.

Table 6.6 Overview of EU emission directives relevant for diesel fuelled non road machinery.

Stage/Engine size [kW]	CO	VOC	NO_X	VOC+NO_X	PM	Diesel machinery			Tractors	
	[g per kWh]					EU directive	Implement. date Transient	Implement. date Constant	EU directive	Imple-ment. date
Stage I										
37<=P<75	6.5	1.3	9.2	-	0.85	97/68	1/4 1999	-	2000/25	1/7 2001
Stage II										
130<=P<560	3.5	1	6	-	0.2	97/68	1/1 2002	1/1 2007	2000/25	1/7 2002
75<=P<130	5	1	6	-	0.3		1/1 2003	1/1 2007		1/7 2003
37<=P<75	5	1.3	7	-	0.4		1/1 2004	1/1 2007		1/1 2004
18<=P<37	5.5	1.5	8	-	0.8		1/1 2001	1/1 2007		1/1 2002
Stage IIIA										
130<=P<560	3.5	-	-	4	0.2	2004/26	1/1 2006	1/1 2011	2005/13	1/1 2006
75<=P<130	5	-	-	4	0.3		1/1 2007	1/1 2011		1/1 2007
37<=P<75	5	-	-	4.7	0.4		1/1 2008	1/1 2012		1/1 2008
19<=P<37	5.5	-	-	7.5	0.6		1/1 2007	1/1 2011		1/1 2007
Stage IIIB										
130<=P<560	3.5	0.19	2	-	0.025	2004/26	1/1 2011	-	2005/13	1/1 2011
75<=P<130	5	0.19	3.3	-	0.025		1/1 2012	-		1/1 2012
56<=P<75	5	0.19	3.3	-	0.025		1/1 2012	-		1/1 2012
37<=P<56	5	-	-	4.7	0.025		1/1 2013	-		1/1 2013
Stage IV										
130<=P<560	3.5	0.19	0.4	-	0.025	2004/26	1/1 2014		2005/13	1/1 2014
56<=P<130	5	0.19	0.4	-	0.025		1/10 2014			1/10 2014

Table 6.7 Overview of the EU emission directive 2002/88 for gasoline fuelled non road machinery.

	Category	Engine size [ccm]	CO [g per kWh]	HC [g per kWh]	NO_X [g per kWh]	HC+NO_X [g per kWh]	Implementation date
	Stage I						
Hand held	SH1	S<20	805	295	5.36	-	1/2 2005
	SH2	20=<S<50	805	241	5.36	-	1/2 2005
	SH3	50=<S	603	161	5.36	-	1/2 2005
Not hand held	SN3	100=<S<225	519	-	-	16.1	1/2 2005
	SN4	225=<S	519	-	-	13.4	1/2 2005
	Stage II						
Hand held	SH1	S<20	805	-	-	50	1/2 2008
	SH2	20=<S<50	805	-	-	50	1/2 2008
	SH3	50=<S	603	-	-	72	1/2 2009
Not hand held	SN1	S<66	610	-	-	50	1/2 2005
	SN2	66=<S<100	610	-	-	40	1/2 2005
	SN3	100=<S<225	610	-	-	16.1	1/2 2008
	SN4	225=<S	610	-	-	12.1	1/2 2007

For recreational craft, Directive 2003/44 comprises the emission legislation limits for diesel 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 given in the calculation formulae in Table 6.8. 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.

Table 6.8 Overview of the EU emission directive 2003/44 for recreational craft.

Engine type	Impl. date	CO=A+B/Pn			HC=A+B/Pn			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 6.9 Overview of the EU emission directive 2004/26 for railway locomotives and motor cars.

	Engine size [kW]		CO [g per kWh]	HC [g per kWh]	NO_X [g per kWh]	HC+NO_X [g per kWh]	PM [g per kWh]	Implementation date
Locomotives	Stage IIIA							
	130<=P<560	RL A	3.5	-	-	4	0.2	1/1 2007
	560<P	RH A	3.5	0.5	6	-	0.2	1/1 2009
	2000<=P and piston displacement >= 5 l/cyl.	RH A	3.5	0.4	7.4	-	0.2	1/1 2009
	Stage IIIB	RB	3.5	-	-	4	0.025	1/1 2012
Motor cars	Stage IIIA							
	130<P	RC A	3.5	-	-	4	0.2	1/1 2006
	Stage IIIB							
	130<P	RC B	3.5	0.19	2	-	0.025	1/1 2012

Aircraft engine emissions of NO_x, CO, VOC and smoke are regulated by the International Civil Aviation Organization (ICAO). 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, 1993). 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 must 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 four categories:

For engines of a type or model for which the date of manufacture of the first individual production model is on or before 31 December 1995 and for which the production date of the individual engine is on or before 31 December 1999.

For engines of a type or model for which the date of manufacture of the first individual production model is after 31 December 1995, or for individual engines with a production date after 31 December 1999.

For engines of a type or model for which the date of manufacture of the first individual production model is after 31 December 2003.

For engines of a type or model for which the date of manufacture of the first individual production model is after 31 December 2007.

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 6.10.

Table 6.10 Current certification limits for NO_x for turbo jet and turbo fan engines.

	Engines first produced before 31.12.1995 & for engines manufac-tured up to 31.12.1999	Engines first produced after 31.12.1995 & for engines manufac-tured after 31.12.1999	Engines for which the date of manufacture of the first individual production model was after 31 December 2003	Engines for which the date of manufacture of the first individual production model was after 31 December 2007
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			$Dp/F_{oo} = 19 + 1.6\pi_{oo}$	$Dp/F_{oo} = 16.72 + 1.4080\pi_{oo}$
Thrust between 26.7 kN and not more than 89 kN			$Dp/F_{oo} = 37.572 + 1.6\pi_{oo} - 0.208F_{oo}$	$Dp/F_{oo} = 38.54862 + (1.6823\pi_{oo}) - (0.2453F_{oo}) - (0.00308\pi_{oo}F_{oo})$
Engines of pressure ratio more than 30 and less than 62.5				
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 82.6 or more			$Dp/F_{oo} = 32+1.6\pi_{oo}$	$Dp/F_{oo} = 32+1.6\pi_{oo}$

Source: International Standards and Recommended Practices, Environmental Protection, ICAO Annex 16 Volume II Part III Paragraph 2.3.2, 2nd edition July 1993, plus amendments: Amendment 3 (20 March 1997),Amendment 4 (4 November 1999),Amendment 5 (24 November 2005).
where:
D_p = the sum of emissions in the LTO cycle in g.
F_{oo} = thrust at sea level take-off (100 %).
π_{oo} = pressure ratio at sea level take-off thrust point (100 %).

The equivalent limits for HC and CO are D_p/F_{oo} = 19.6 for HC and D_p/F_{oo} = 118 for CO (ICAO Annex 16 Vol. II paragraph 2.2.2). Smoke is limited to a regulatory smoke number = 83 $(F_{oo})^{-0.274}$ or a value of 50, whichever is the lower.

A further description of the technical definitions in relation to engine certification as well as actual engine exhaust emission measurement data can be found in the ICAO Engine Exhaust Emission Database. The latter database is accessible from http://www.caa.co.uk, hosted by the UK Civil Aviation Authority.

For seagoing vessels, NO_x emissions are regulated as explained in Marpol 73/78 Annex VI, formulated by the International Maritime Organisation (IMO). The legislation is relevant 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 NO_x emission limits for ship engines in relation to their rated engine speed (n) given in Revolutions Per Minute (RPM) are the following:

- 17 g per kWh, n < 130 RPM
- 45 x n-0.2 g per kWh, 130 ≤ n < 2000 RPM
- 9.8 g per kWh, n ≥ 2000 RPM

Further, the Marine Environment Protection Committee (MEPC) of IMO has approved proposed amendments to the MARPOL Annex in order to strengthen the emission standards for NO_x and the sulphur contents of heavy fuel oil used by ship engines.

For NO_x emission regulations, a three tiered approach is considered, which 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.
- Tier II: Diesel engines (> 130 kW) installed on a ship constructed on or after 1 January 2011.
- Tier III[4]: Diesel engines (> 130 kW) installed on a ship constructed on or after 1 January 2016.

As for the existing NO_x emission limits, the new Tier I-III NO_x legislation values rely on the rated engine speeds. The emission limit equations are shown in Table 6.11.

Table 6.11 Tier I-III NO_x emission limits for ship engines (amendments to MARPOL Annex VI).

	NO_x limit - g per kWh	RPM (n)
Tier I	17	n < 130
	45 x n-0.2	130 ≤ n < 2000
	9,8	n ≥ 2000
Tier II	14.4	n < 130
	44 x n-0.23	130 ≤ n < 2000
	7.7	n ≥ 2000
Tier III	*3.4*	*n < 130*
	9 x n-0.	*130 ≤ n < 2000*
	2	*n ≥ 2000*

The Tier I emission limits are identical with the existing emission limits from MARPOL Annex VI.

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.

[4] For ships operating in a designated Emission Control Area. Outside a designated Emission Control Area, Tier II limits apply.

In relation to the sulphur content in heavy fuel and marine gas oil used by ship engines, Table 6.12 shows the current legislation in force.

Table 6.12 Current legislation in relation to marine fuel quality.

Legislation		Heavy fuel oil		Gas oil	
		S- %	Implem. date (day/month/year)	S- %	Implem. date
EU-directive 93/12		None		0.2[1]	1.10.1994
EU-directive 1999/32		None		0.2	1.1.2000
EU-directive 2005/33[2]	SECA - Baltic sea	1.5	11.08.2006	0.1	1.1.2008
	SECA - North sea	1.5	11.08.2007	0.1	1.1.2008
	Outside SECA's	None		0.1	1.1.2008
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.

For non-road machinery, the EU directive 2003/17/EC gives a limit value of 50 ppm sulphur in diesel (from 2005).

6.2.3 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, 2009). For military machinery aggregated CH_4 emission factors for gasoline and diesel are derived from the road traffic emission simulations. The CH_4 emission factors for railways are derived from specific Danish VOC measurements from the Danish State Railways (Delvig, 2011) and a NMVOC/CH_4 split based on own judgment.

For agriculture, forestry, industry, household gardening and inland waterways, the VOC emission factors are derived from various European measurement programmes; see IFEU (2004) and Winther et al. (2006). The NMVOC/CH_4 split is taken from USEPA (2004).

For the ferries used by Mols_Linien (Sjællands Odde-Ebeltoft, Sjællands Odde-Århus, Kalundborg-Århus) the VOC emission factors provided by Kristensen (2008) are from measurements made by Hansen et al. (2004), Wismann (1999) and PHP (1996). For the remaining domestic ferries, other national and international sea transport and fisheries, the VOC emission factors come from the Danish TEMA2000 model. The NMVOC/CH_4 split comes from the EMEP/EEA guidebook (EMEP/EEA, 2009). The latter source also provides CH_4 emission factors for the remaining sectors.

Emission factors are given in CollectER and CRF formats in Annex 5.2 for the years 2011-2035.

6.2.4 Calculation method

Air traffic

For aviation the estimates are made separately for landing and take-off (LTOs < 3000 ft), and cruise (> 3000 ft). The calculations furthermore distinguish between national and international flights. For more details regarding the calculation procedure please refer to Winther (2001a, 2001b and 2012).

Non-road working machinery and recreational craft

The fuel consumption and emissions are calculated as the product of the number of engines, annual working hours, average rated engine size, load factor and fuel consumption/emission factors. For diesel and gasoline engines, the deterioration effects (due to engine ageing) are included in the emission calculation equation by using deterioration factors according to engine type, size, age, lifetime and emission level. For diesel engines before Stage IIIB and IV, transient operational effects are also considered by using average transient factors. For more details regarding the calculation procedure, please refer to Winther et al. (2006).

National sea transport

The fuel consumption and emissions for Danish regional ferries are calculated as the product of the number of round trips, sailing time per round trip, engine size, load factor, and fuel consumption/emission factors. For local ferries and other ships, simple fuel based calculations are made using fuel-related emission factors and fuel consumption estimates from Winther (2008a). Please refer to the latter report for more details regarding this calculation procedure.

Other sectors

The emissions for fishing vessels, military and railways are estimated with the simple method using fuel-related emission factors and fuel consumption from DEA (2012).

6.3 Fuel consumption and emission results

An overview of the fuel consumption and emission results is given in Table 6.13 for all mobile sources in Denmark. The '2010' results are the average figures for the years 2008-2012.

Table 6.13 Summary table of fuel consumption and emissions for mobile sources in Denmark.

		1990	2000	2005	2010	"2010"	2015	2020	2025	2030	2035
Energy, PJ	Industry-Other (1A2f)	11.5	12.0	13.0	14.2	12.7	10.7	9.8	10.4	11.0	11.6
	Civil Aviation (1A3a)	3.4	2.1	1.9	2.2	2.1	2.0	2.1	2.1	2.1	2.1
	Road (1A3b)	126.3	152.5	166.1	165.6	167.7	170.1	174.6	180.4	191.8	205.8
	Railways (1A3c)	4.0	3.1	3.1	3.3	2.9	1.4	1.4	1.4	1.4	1.4
	Navigation (1A3d)	10.5	7.9	7.8	7.9	8.2	8.8	8.8	8.8	8.8	8.8
	Commercial/Institutional (1A4a)	1.0	1.2	2.2	2.4	2.4	2.3	2.3	2.3	2.3	2.3
	Residential (1A4b)	0.5	0.6	0.8	0.9	1.0	1.2	1.2	1.2	1.2	1.2
	Ag./for./fish. (1A4c)	25.7	21.8	23.8	25.2	23.5	21.4	20.4	20.2	20.1	20.2
	Military (1A5)	1.6	1.5	3.7	1.5	2.0	2.1	2.1	2.1	2.1	2.1
	Navigation int. (1A3d)	39.1	54.6	30.7	27.2	28.4	29.4	29.4	29.4	29.4	29.4
	Civil Aviation int. (1A3a)	24.1	32.6	35.7	33.6	34.7	38.1	43.6	45.1	42.2	42.2
		1990	2000	2005	2010	"2010"	2015	2020	2025	2030	2035
CO_2, Gg	Industry-Other (1A2f)	839	877	948	1037	928	784	716	761	805	851
	Civil Aviation (1A3a)	243	154	135	156	152	148	153	155	152	152
	Road (1A3b)	9282	11203	12214	12108	12098	11793	11575	11964	12715	13648
	Railways (1A3c)	297	228	232	242	213	106	106	106	106	106
	Navigation (1A3d)	796	588	585	593	614	660	660	660	660	660
	Commercial/Institutional (1A4a)	74	87	162	173	171	164	154	154	154	154
	Residential (1A4b)	39	43	59	63	72	82	77	77	77	77
	Ag./for./fish. (1A4c)	1899	1615	1758	1865	1734	1582	1501	1489	1482	1486
	Military (1A5)	119	111	271	107	144	153	153	153	153	153
	Navigation int. (1A3d)	3005	4168	2352	2073	2176	2255	2255	2255	2255	2255
	Civil Aviation int. (1A3a)	1736	2350	2574	2421	2498	2746	3137	3248	3042	3042
		1990	2000	2005	2010	"2010"	2015	2020	2025	2030	2035
CH_4, Mg	Industry-Other (1A2f)	60	50	45	37	35	31	28	28	28	28
	Civil Aviation (1A3a)	7	5	7	4	4	2	2	2	2	2
	Road (1A3b)	2518	1783	1237	644	683	451	356	334	329	357
	Railways (1A3c)	12	10	9	7	6	1	0	0	0	0
	Navigation (1A3d)	32	33	35	35	27	16	16	16	16	16
	Commercial/Institutional (1A4a)	99	92	157	160	161	147	147	147	147	147
	Residential (1A4b)	51	45	62	65	74	82	81	81	81	81
	Ag./for./fish. (1A4c)	139	88	90	113	110	103	102	103	105	108
	Military (1A5)	5	6	12	4	5	4	3	3	3	3
	Navigation int. (1A3d)	64	94	55	51	53	57	58	60	60	60
	Civil Aviation int. (1A3a)	31	42	48	39	29	9	10	11	10	10
		1990	2000	2005	2010	"2010"	2015	2020	2025	2030	2035
N_2O, Mg	Industry-Other (1A2f)	34	37	40	44	39	34	31	33	35	37
	Civil Aviation (1A3a)	10	8	8	8	7	5	5	5	5	5
	Road (1A3b)	299	449	428	385	392	384	401	437	474	508
	Railways (1A3c)	8	6	6	7	6	3	3	3	3	3
	Navigation (1A3d)	48	34	34	35	36	40	40	40	39	39
	Commercial/Institutional (1A4a)	1	1	2	3	3	3	3	3	3	3
	Residential (1A4b)	1	1	1	1	1	2	2	2	2	2
	Ag./for./fish. (1A4c)	87	78	87	91	84	78	77	78	80	83
	Military (1A5)	4	3	9	4	5	5	6	6	6	6
	Navigation int. (1A3d)	189	262	148	130	137	142	142	142	142	142
	Civil Aviation int. (1A3a)	59	82	89	83	95	119	136	140	131	131
		1990	2000	2005	2010	"2010"	2015	2020	2025	2030	2035
GHG eq., Gg	Industry-Other (1A2f)	851	890	961	1051	941	795	726	772	817	863
	Civil Aviation (1A3a)	246	157	138	158	154	149	155	156	153	153
	Road (1A3b)	9427	11379	12372	12241	12234	11922	11707	12107	12869	13813
	Railways (1A3c)	300	230	234	244	215	107	107	107	107	107
	Navigation (1A3d)	811	600	597	605	626	672	672	672	672	672
	Commercial/Institutional (1A4a)	76	89	166	177	175	167	158	158	158	158

Continued

Residential (1A4b)	40	44	60	64	74	84	79	79	79	79
Ag./for./fish. (1A4c)	1929	1641	1787	1895	1763	1608	1527	1516	1509	1514
Military (1A5)	120	112	274	108	146	155	155	155	155	155
Navigation int. (1A3d)	3065	4251	2400	2115	2219	2300	2300	2300	2300	2300
Civil Aviation int. (1A3a)	1755	2376	2602	2448	2528	2783	3179	3292	3083	3083

6.3.1 Road transport

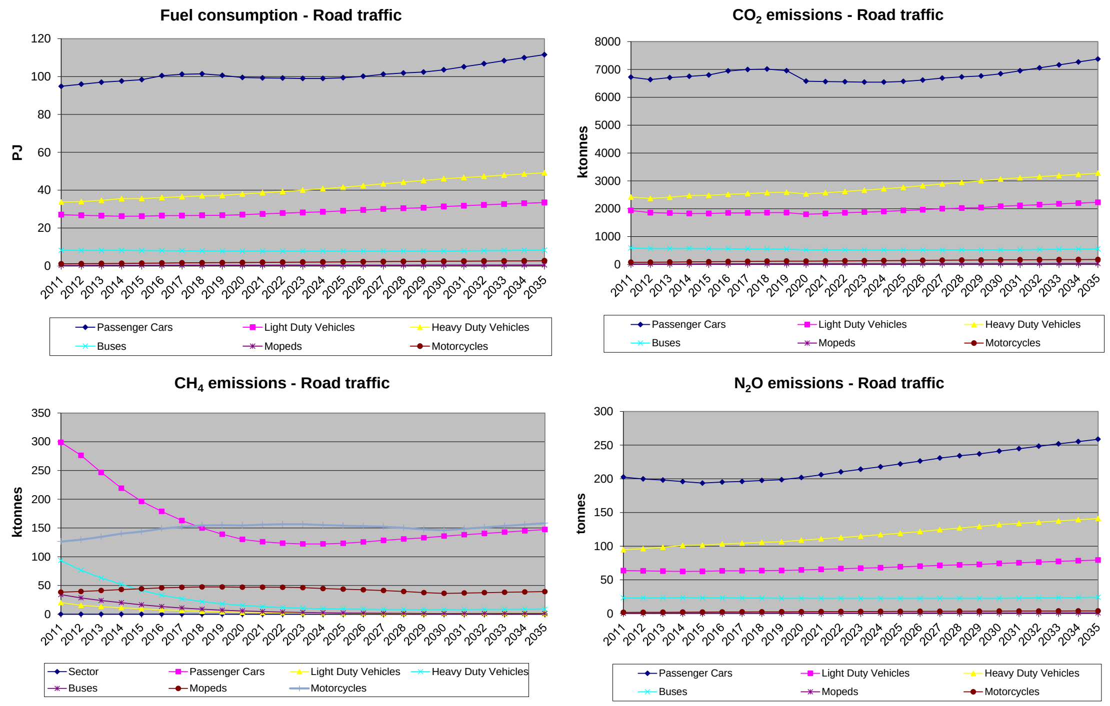


Figure 6.3 Fuel consumption, CO_2, CH_4 and N_2O emissions from 2010-2030 for road traffic.

The total fuel consumption for road traffic increases by 25 % from 2011 to 2035. Passenger cars have the largest fuel consumption share followed by heavy duty vehicles, light duty vehicles, buses and 2-wheelers in decreasing order.

The CO_2 emissions directly depend of the fuel consumption and the percentage amount of biofuels used in the Danish road transportation sector. From 2012 onwards, the DEA (2011) assumes this percentage to be 5.75, (clearly visible from Figure 5.3 and following the EU directive 2003/30). The total CO_2 emissions increase is expected to be 16 % from 2011-2035.

The majority of the CH_4 and N_2O emissions from road transport come from gasoline passenger cars (Figure 5.3). The CH_4 emission decrease of 42 % from 2011 to 2035 is explained by the introduction of gradually more efficient catalytic converters for gasoline cars. 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 during the projection period until the number of Euro 1 cars are only insignificant.

6.3.2 Other mobile sources

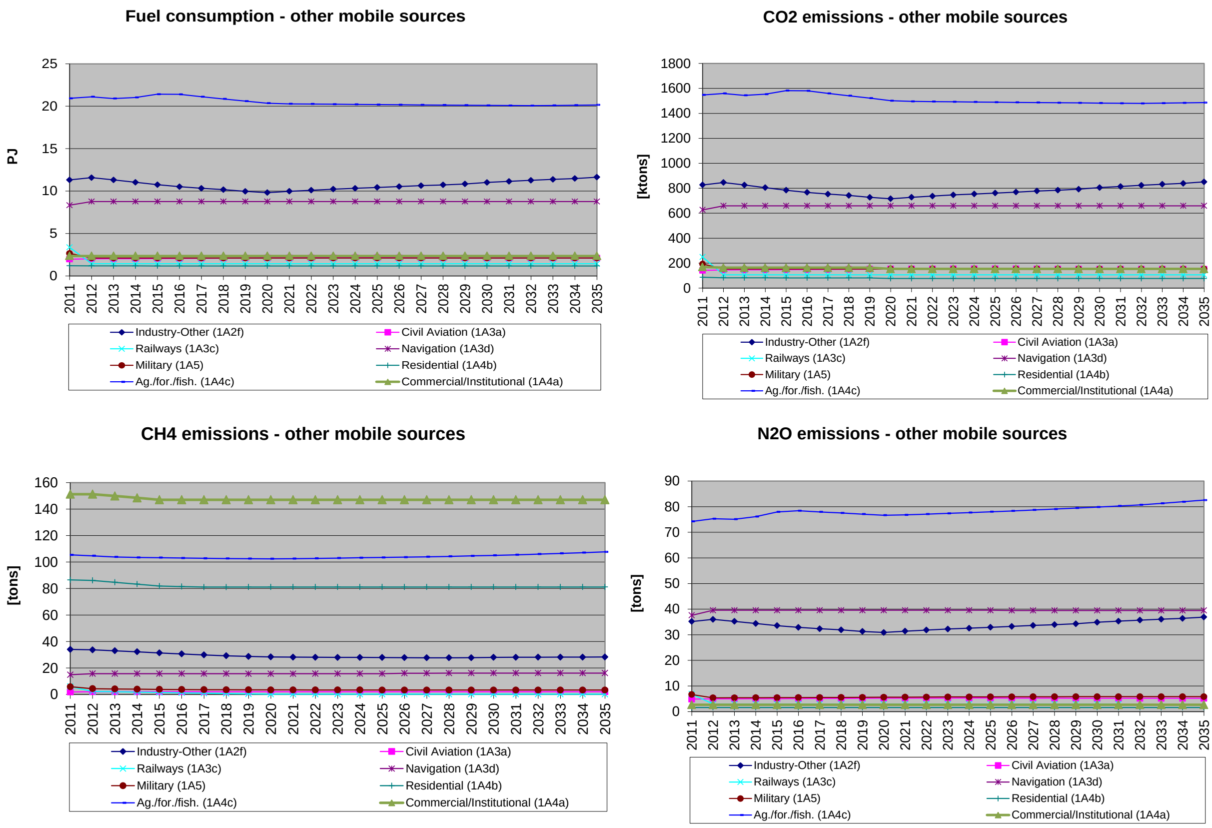


Figure 6.4 Fuel consumption, CO_2, CH_4 and N_2O emissions from 2011-2035 for other mobile sources.

The development in CO_2 emissions for other mobile sources corresponds with the development in fuel consumption forecasted by the DEA (2011). Agriculture/forestry/fisheries (1A4c) is by far the largest source of CO_2 emissions followed by Industry (1A2f), Navigation (1A3d), Commercial/institutional (1A4a), Military (1A5), Domestic aviation (1A3a), Railways (1A3c) and Residential (1A4b) in this consecutive order.

Agriculture/forestry/fisheries (1A4c) is the most important source of N_2O emissions, followed by Industry (1A2f) and Navigation (1A3d). The emission contributions from Railways (1A3c), Domestic aviation (1A3a) and Military (1A5) are small compared to the overall N_2O total for other mobile sources.

The majority of the CH_4 emission comes, by far, from gasoline gardening machinery in Commercial/institutional (1A4a) and Residential (1A4b), whereas for the railway, domestic air traffic and military categories only small emission contributions are noted. The CH_4 emission reduction for the residential category is due to the introduction of the cleaner gasoline stage II emission technology. Also for Agriculture/forestry/fisheries (1A4c) and Industry (1A2f), the gradually stricter emission standards for diesel engines cause the CH_4 emissions to decrease over the forecast period.

6.4 Model structure for DCE transport models

More detailed emission models for transport comprising road transport, air traffic, non-road machinery and sea transport have been developed by DCE. The emission models are organised in databases. The basis is input data tables for fleet and operational data as well as fuel sale figures. Output fuel consumption and emission results are obtained through linked database queries. A thorough documentation of the database input data side and data manipulation queries will be given in a later DCE report, along with flow-chart diagrams.

6.5 References

Danish Energy Agency, 2011: The Danish energy statistics, Available at: http://www.ens.dk/da-DK/Info/TalOgKort/Statistik_og_noegletal/Aarsstatistik/Documents/Energistatistik_2010.pdf (04-01-2012).

Danish Energy Agency, 2012: Energy projections 2011-2035, August 2012.

Dávastovu, Jógvan í (2011): Unpublished data material from Smyril Line.

EMEP/EEA, 2009: EMEP/EEA air pollutant emission inventory guidebook, prepared by the UNECE/EMEP Task Force on Emissions Inventories and Projections (TFEIP). Available at: http://www.eea.europa.eu/publications/emep-eea-emission-inventory-guidebook-2009 (02-02-2010).

Hansen, K.F., Jensen, M.G. 2004: MÅLING AF EMISSIONER FRA FREMDRIVNINGSANLÆG PÅ MADS MOLS. Ruston 20RK270, Sagsnr.: 1076868, Documentation note, 5 pages (in Danish).

Hjortberg, F.K. 2011: Unpublished data material from Bornholmstrafikken.

ICAO Annex 16: 'International standards and recommended practices', Volume II 'Aircraft Engine Emissions', 2nd ed. (1993), plus amendments: Amendment 3 March 20 1997 and amendment 4 November 4 1999.

IFEU, 2004: Entwicklung eines Modells zur Berechnung der Luftschadstoffemissionen und des Kraftstoffverbrauchs von Verbrennungs-motoren in mobilen Geräten und Maschinen - Endbericht, UFOPLAN Nr. 299 45 113, pp. 122, Heidelberg.

Jensen, T.C. & Kveiborg, O. 2011: Dokumentation af konvertering af trafiktal til emissionsopgørelser, arbejdsnotat, 22 pp. DTU Transport, 2011.

Kristensen, F. 2011: Unpublished data material from Mols-Linjen.

Markamp, H. 2011: Personal communication, Henrik Markamp, The National Motorcycle Association.

Nielsen, O.-K., Mikkelsen, M.H., Hoffmann, L., Gyldenkærne, S., Winther, M., Nielsen, M., Fauser, P., Thomsen, M., Plejdrup, M.S., Albrektsen, R., Hjelgaard, K., Bruun, H.G., Johannsen, V.K., Nord-Larsen, T., Bastrup-Birk, A., Vesterdal, L., Møller, I.S., Rasmussen, E., Arfaoui, K., Baunbæk, L. & Hansen, M.G. 2012a: Denmark's National Inventory Report 2012. Emission Inventories 1990-2010 - Submitted under the United Nations Framework Convention on Climate Change and the Kyoto Protocol. Aarhus University, DCE – Danish Centre for Environment and Energy, 1168 pp. Scientific Report from DCE – Danish Centre for Environment and Energy No. 19. Available at http://www2.dmu.dk/Pub/SR19.pdf

Ntziachristos, L. & Samaras, Z. 2000: COPERT III Computer Programme to Calculate Emissions from Road Transport - Methodology and Emission Factors (Version 2.1). Technical report No 49. European Environment Agency, November 2000, Copenhagen. Available at:
http://re-ports.eea.eu.int/Technical_report_No_49/en (June 13, 2003).

Delvig, P. 2011: Unpublished data material from the Danish State Railways.

Nørgaard, T. & Hansen, K.F. 2004: Chiptuning af køretøjer - miljømæssig effekt, Miljøprojekt nr. 888, Miljøstyrelsen.

PHP, 1996: Research Report – Emission tests at Alpha, Mols 2 and Mols 4, 9L25MC mk6 engines #35031 and #35033, 22-23/10 1995 and 16/1 1996, DOK, PHP Basic Research, October 1996, 20 pages.

USEPA 2004: Conversion Factors for Hydrocarbon Emission Components. EPA420-P-04-001, US Environmental Protection Agency, 5 pp.

Winther, M. 2001a: 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, Denmark. Available at:
http://www.mst.dk/udgiv/Publications/2001/87-7944-661-2/html/

Winther, M. 2001b: Improving fuel statistics for Danish aviation. National Environmental Research Institute, Denmark. 56 p – NERI Technical Report No. 387. Available at:
http://www2.dmu.dk/1_viden/2_Publikationer/3_fagrapporter/rapporter/FR387.pdf

Winther, M. & Nielsen O. 2006: Fuel use and emissions from non road machinery in Denmark from 1985-2004 - and projections from 2005-2030. Environmental Project 1092. The Danish Environmental Protection Agency. 238 pp. Available at:
http://www.mst.dk/udgiv/Publica-tions/2006/87-7052-085-2/pdf/87-7052-086-0.pdf

Winther, M. 2008: Fuel consumption and emissions from navigation in Denmark from 1990-2005 - and projections from 2006-2030. Technical Report from NERI no. 650. 109 pp. Available at:
http://www2.dmu.dk/Pub/FR650.pdf

Winther, M. 2012: Danish emission inventories for road transport and other mobile sources. Inventories until the year 2010. National Environmental Research Institute, University of Aarhus. 219 pp. – NERI Technical Report No. 686. Available at: http://www.dmu.dk/Pub/FR686.pdf

Wismann, T. 1999: MOLS-LINIEN, Mai Mols - Måling af emissioner fra hovedturbiner, dk-RAPPORT 14.901, 9 pages (in Danish).

7 The fluorinated gases (F-gases)

The fluorinated gases (F-gases) comprise HFCs, PFCs and SF_6. They all contain fluorine, hence the name F-gases, which is the international name.

None of the F-gases are produced in Denmark. The emission of these gases is therefore associated with their use alone.

An account of the annual consumption and emission of F-gases is prepared by a consultant on behalf of the Danish Environmental Protection Agency (DEPA) (Poulsen & Werge, 2012). In this connection, projections to 2020 are also prepared. Annual reports that contain both consumption and emission data are available. The present report extends the projection with projections from 2020 to 2035.

F-gases are powerful GHGs with GWP between 140 and 23 900. F-gases, therefore, receive a great deal of attention in connection with GHG emission inventories. For many F-gas applications, the gases can be controlled and/or replaced, which has been, and continues to be, the case in Denmark. Data for the projections mentioned here take this into consideration, but the projections do not take the potential influence of new EU legislation in this field into consideration. The EU legislation will, however, only have a lowering effect on emissions from mobile air conditioning equipment. As for the remaining application areas the legislation are already covered by different existing Danish legislation. Exemptions from the Danish bans on e.g. refrigeration equipment have been taken into account in the projections. In the 2010 emission inventories the total contribution from F-gases, converted into CO_2 equivalents, constituted 1.1 % of the Danish total without CO_2 from LULUCF. Of this contribution the HFCs dominate with 94 %.

HFCs comprise a range of substances, of which the following, relevant for Denmark, are approved for inventory under the Climate Convention and the Kyoto Protocol (KP) with stated and approved GWP values:

Substance:	GWP CO_2 eqv.
HFC-32	650
HFC-125	2800
HFC-134a	1300
HFC-143a	3800
HFC-152a	140
HFC-227ea	2900

However, HFCs in Denmark are estimated in accordance with the trade names for HFC mixtures, which are put together from the "pure" HFCs listed in Table 7.1.

Table 7.1 Relationship (percentage weight) between HFCs, as calculated for the Climate Convention ("'pure" HFCs) and the HFC mixtures used under trade names in Denmark.

Pure HFCs: HFC mixtures	HFC-32	HFC-125	HFC-134a	HFC-143a	HFC-152a	HFC-227ea
HFC-365						8
HFC-401a					13	
HFC-402a		60				
HFC-404a		44	4	52		
HFC-407a	23	25	52			
HFC-410a	50	50				
HFC-507a		50		50		

HFCs are mostly used as refrigerants in stationary and mobile air-conditioning and refrigeration systems. A minor application is in insulation foams and foams of other types.

With regard to PFCs, only C_3F_8 is considered to be relevant for Denmark and approved for inventory under the Climate Convention and KP, with a GWP of 7 000. The use of C_3F_8, mostly as a refrigerant, is limited.

SF_6 is used in Denmark and is estimated under the Climate Convention and KP, with a GWP value of 23 900. It is primarily used in high voltage equipment, in double-glazing and to a lesser degree in laboratories, for shoe soles and a limited number of other minor applications.

7.1 Emissions model

Emissions are calculated with a model for the individual substance's life-cycle over the years, taking the emissions associated with the actual processes into consideration. The processes for refrigeration and high voltage equipment are filling up/topping up, operation and destruction. For foam, the processes are production of the products in which the substances are used as well as use and destruction of the product. The model has been developed and used in connection with the annual historic emission inventories for the Climate Convention, see NIR, 2010 (Nielsen et al., 2012). As a result, the model corresponds with the guidelines produced for this purpose. The model is built in Microsoft Excel, combining an Excel spread sheet file for each year. For details of the model and the calculation methodologies, refer also to the DEPA's annual reports produced as a basis for the F-gas inventories.

7.2 Emissions of the F-gases HFCs, PFCs and SF_6 1993-2020

Data is available for historic values for F-gas emissions for the period 1995-2010, as well as projected values for the period 2011-2020 as calculated for DEPA (Poulsen & Werge, 2012). As mentioned, the calculations are based on the trade names for HFC mixtures and the inventories and projections are at this level of detail. The total F-gas emission in CO_2 equivalents agrees almost entirely with the historic values reported to the EU and the Climate Convention, where the mixtures are converted to pure HFCs. Where agreement is not total, this is due to lack of complete correspondence between the GWP values for mixtures and for the pure HFCs, as well as the minor rounding, which takes place in the databases and formats (CRF) used for the reporting. These differences are not of any significant importance.

The reference for the data in the tables below is therefore the 2010 report prepared for DEPA (Poulsen & Werge, 2012). Moreover, these data has been based on detailed spread sheets, prepared in connection with the consultant's work on the F-gas inventories for DEPA.

Furthermore, the report and the data collected in this connection indicate that, with regard to projection of the emissions, the data are based on 'steady state' consumption with 2006 as the reference year. Also, cut-off dates in relation to the phasing out of individual substances, in connection with Danish regulation concerning the phasing out of powerful GHGs, are taken into account. HFCs used in foaming agents in flexible foam plastic were phased out from of January 1, 2006. Furthermore, a tax effect has been introduced for relevant applications and, as far as possible, expected increases in the use of these substances will be taken into consideration in a number of application areas – as will reductions expected. Projection of the use of HFC-404A is based on a balancing exercise, as the development of the used of HCFC-22 refrigeration systems can, on the one hand, be expected to lead to higher than predicted increases in consumption of HFC-404A in commercial refrigeration plant, as HFC-404A together with CO_2 systems are the most obvious potential substitutes. On the other hand, from January 1 2000, building new HCFC-22-based systems has not been permitted and from January 1 2002 substitution with HCFC-22 in existing systems has been banned. For SF_6, use in connection with double-glazing was banned in 2002, but throughout the period there will be emission of SF_6 in connection with the disposal of double-glazing panes where SF_6 has been used.

The available historic and projected data are presented first at the CRF category level equivalent to the Summary 2 table in the CRF reporting format, Table 7.2. This level is equivalent to the sum of the emissions for all HFCs, PFCs and SF_6, respectively.

It should be noted that the basic data for the years before 1995 is not entirely adequate with regard to coverage, in relation to actual emissions. Under the Kyoto Protocol, it is possible to choose 1995 as base year for F-gases. Due to the lack of coverage prior to 1995 this option is used in Denmark. Therefore, the projection on the '5-year level' for F-gases summarised in Table 7.3 starts from 1995. For 2020 and onwards the emission of F gases are divided up in application areas and the tendencies seen in a graphical presentation has been continued until 2035; see Figure 7.1.

Table 7.2 Total F-gas emissions in Gg CO_2 eqv. Historic data: 1995-2010. Projections: 2011-2035.

Year	Sum HFCs	PFCs	SF_6	Total F-gases
1995	218	0.50	107	326
1996	329	1.66	61.0	392
1997	324	4.12	73.1	401
1998	411	9.10	59.4	480
1999	504	12.5	64.9	581
2000	607	17.9	58.8	683
2001	650	22.1	30.0	703
2002	676	22.2	24.6	723
2003	701	19.3	30.9	751
2004	755	15.9	32.7	804
2005	802	13.9	21.3	838
2006	823	15.7	35.6	875
2007	850	15.4	29.9	895
2008	853	12.8	31.2	897
2009	799	14.2	36.3	849
2010	800	13.3	37.9	851
2011	741	12.5	70.9	825
2012	667	11.9	117	796
2013	613	11.3	127	751
2014	522	10.8	139	672
2015	438	10.3	125	573
2016	346	9.91	97.1	453
2017	265	9.54	82.2	357
2018	184	9.21	82.6	276
2019	141	8.92	81.7	232
2020	72.5	8.65	61.2	142
2021	71.0	8.40	41.0	120
2022	65.1	8.00	31.0	104
2023	63.3	7.60	24.0	94.9
2024	62.8	7.20	18.0	88.0
2025	62.2	6.80	14.0	83.0
2026	61.6	6.40	12.0	80.0
2027	61.4	6.20	10.0	77.6
2028	61.2	6.20	9.00	76.4
2029	61.1	6.20	8.00	75.3
2030	61.1	6.20	8.00	75.3
2031	61.2	6.20	8.00	75.4
2032	61.2	6.20	8.00	75.4
2033	61.2	6.20	8.00	75.4
2034	61.3	6.20	8.00	75.5
3035	61.3	6.20	8.00	75.5

Note: Emissions 1995-2020 are taken from Poulsen & Werge (2012).

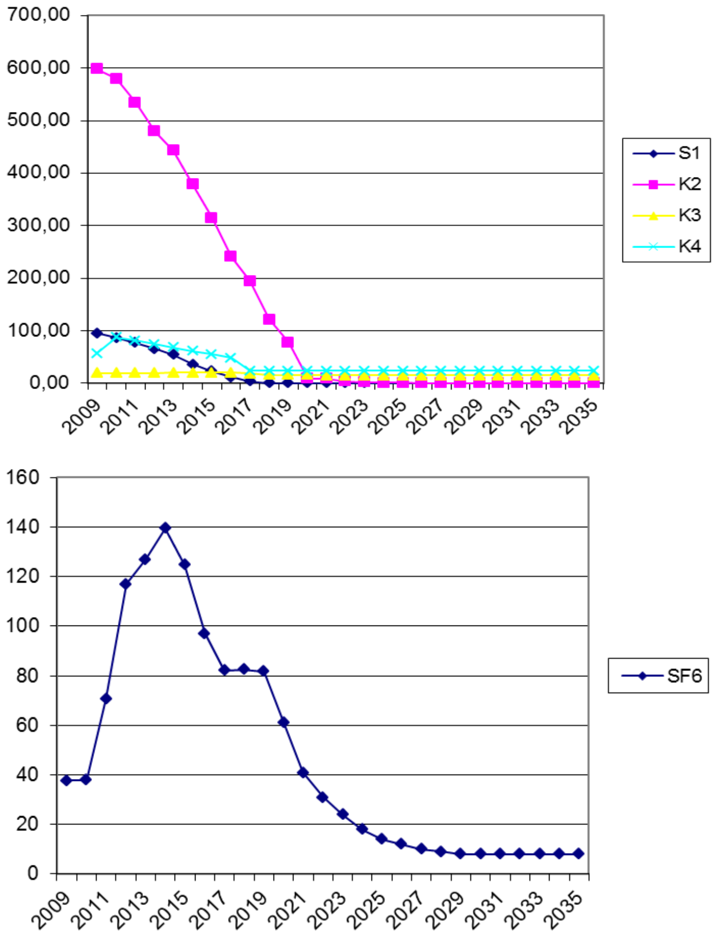


Figure 7.1 Projected F-gas emissions for the years 2011 to 2035 (Gg CO_2 eqv.). A: S1 Foam blowing, K2 Commercial refrigerant, K3 Transport refrigerant, K4 Mobile A/C. B SF_6

Table 7.3 Summary of results of projection of F gases (Gg CO_2 eqv.).

		1995	2000	2005	2010	'2010'[1]	2015	2020	2025	2030	2035
2F	HFC	218	607	802	800	772	438	72.5	62.2	61.1	61.3
2F	PFC	0.50	17.9	13.9	13.3	12.9	10.3	8.65	6.80	6.20	6.20
2F	SF_6	107	58.8	21.3	37.9	58.6	125	61.2	14.0	8.00	8.00
2F	F-gas total	326	683	838	851	844	573	142	83.0	75.3	75.5

1) Average of the years 2008-2012.

In Figure 7.2, the data from Table 7.2 are illustrated. The apparent increase within historic data for the total F-gas emission runs from 1995 to the most recent historic inventory for 2010. In 2001, legislation began to be adopted to control F-gases in Denmark. From 2001, the legislation involves a tax on use of F-gases. In 2002 bans were introduced, of which the majority first come into force in 2006 and 2007. In the projections, the regulation in this area translates into decreasing emissions after 2007. The figure shows that F-gas emissions are dominated by HFCs, whereas PFCs comprise only a very small share. At the beginning of the historic inventory period, SF_6 comprises a considerable share, falling thereafter due to the gradual phasing out of the use of SF_6 in metal works. The projection for SF_6 shows a rise and then a reduction towards the end of the period; this path reflects the expected emission from the destruction of double-glazing in which SF_6 is used.

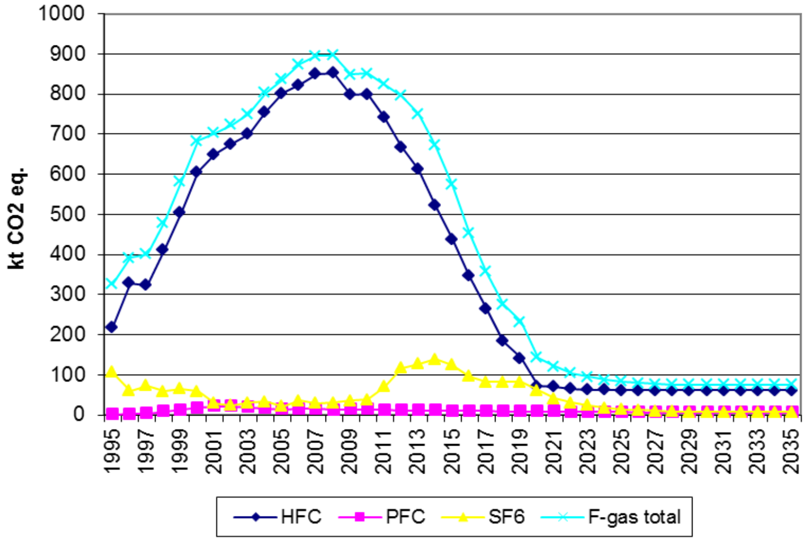


Figure 7.2 Time series for F-gas emissions, divided into HFCs, PFCs and SF_6.

7.3 References

Nielsen, O.-K., Mikkelsen, M.H., Hoffmann, L., Gyldenkærne, S., Winther, M., Nielsen, M., Fauser, P., Thomsen, M., Plejdrup, M.S., Albrektsen, R., Hjelgaard, K., Bruun, H.G., Johannsen, V.K., Nord-Larsen, T., Bastrup-Birk, A., Vesterdal, L., Møller, I.S., Rasmussen, E., Arfaoui, K., Baunbæk, L. & Hansen, M.G. 2012. Denmark's National Inventory Report 2012. Emission Inventories 1990-2010 - Submitted under the United Nations Framework Convention on Climate Change and the Kyoto Protocol. Aarhus University, DCE – Danish Centre for Environment and Energy, 1167 pp. Scientific Report from DCE – Danish Centre for Environment and Energy No. 19. http://www.dmu.dk/Pub/SR19.pdf

Poulsen, T.S. & Werge, M. 2012: The greenhouse gases HFCs, PFCs and SF_6. Danish consumption and emissions, 2010. Danish Environmental Protection Agency. Environmental project No. 1402.

8 Agriculture

The emission of greenhouse gases from the agricultural sector includes the emission of methane (CH_4) and nitrous oxide (N_2O). The emission is mainly related to the livestock production and includes CH_4 emission from enteric fermentation and manure management and N_2O emission from manure management and agricultural soils. Furthermore, a minor CH_4 and N_2O emission is estimated from burning of straw on field. The effect of lower emission from biogas treated slurry is also taken into account.

In this projection, the latest official reporting from Denmark includes emission until 2010. Thus, the projection comprises an assessment of the greenhouse gas emissions from the agricultural sector from 2011 to 2035.

It must be noted that CO_2 removals/emissions from agricultural soils are not included in the agricultural sector. According to the IPCC guidelines this removal/emission should be included in the LULUCF sector (Land-Use, Land-Use Change and Forestry). The same comment applies to the emission related to agricultural machinery (tractors, harvesters and other non-road machinery), these emissions are included in the energy sector.

8.1 Projected agricultural emission 2011 - 2035

Projection of greenhouse gas emissions is regularly updated in line with new scientific knowledge, which also includes changes in the historical emission inventory. Therefore, some deviations are apparent in comparison with the projection scenarios published in previous reports. Present projection of greenhouse gases replaces the latest basic projection published in NERI Technical Report No. 841 (Nielsen et al., 2011).

The expectations to the future framework conditions for the agricultural production includes establishment of ammonia reducing technologies. Increasing demands to reduce unintended environmental effects of the livestock production has led to more legislation in connection with approvals and establishment of new animal houses. This projection includes several objectives formulated in the Agreement on Green Growth (2009 and 2010) such as expansion of the biogas production and establishment of non-cultivated area along water streams and lakes. Furthermore implementation of technologies to achieve reductions in N-loss to the aquatic environment is taken into account. The most important assumptions are expected change in number of produced animals, change in nitrogen excretion as a consequence of efficiency for dairy cattle and sows and expected change in housing system.

The emission of greenhouse gases has decreased from 12.46 million tonnes CO_2 equivalents in 1990 to 9.52 million tonnes CO_2 equivalents in 2010, which correspond to a 24 % reduction. Based on the given assumptions the projected emission is expected to decrease further by 8 % in 2035, corresponding to 8.86 million tonnes CO_2 equivalents (Table 8.1). The decreased emission is mainly a result of decrease in emission from manure management and N_2O emission from synthetic fertiliser (included in direct soil emission).

The decreased emission from synthetic fertiliser is due to a reduction in agricultural area and implementation of ammonia reduction technology. Reduction of ammonia emission in animal housing leads to higher nitrogen content in manure resulting in less need for synthetic fertiliser.

The decrease in both CH_4- and N_2O emission from manure management is in particularly due to the increasing amount of biogas treated slurry.

Table 8.1 Projected emission from the agricultural sector, given in CO_2 equivalents.

Gg CO_2 equivalents	2011	2015	2020	2025	2030	2035
Enteric fermentation	2 826	2 795	2 853	2 935	3 017	3 098
Manure management	1 665	1 536	1 354	1 293	1 232	1 161
Direct soil emission[a]	3 066	2 966	2 888	2 855	2 822	2 794
Pasture, range and paddock manure	211	207	205	206	208	209
Indirect emissions[b]	1 715	1 649	1 600	1 596	1 593	1 593
Field burning of agricultural residue	4	4	4	4	4	4
Total	9 487	9 156	8 903	8 889	8 876	8 859

[a] Direct soil emission includes emissions from: Synthetic fertilizers, Animal manure applied to soils, N-fixing crops, crops residue, cultivation of histosols and other direct emissions.
[b] Indirect emissions includes emissions from: Atmospheric deposition and Nitrogen leaching and run-off.

Figure 8.1 and 8.2 below, shows the projected emission of CH_4 and N_2O emission 2011 – 2035 distributed on different emissions sources.

The CH_4 emission is nearly unchanged from 2011 to 2035. The decreased emission from manure compensates an increase in emission from enteric fermentation. This is a consequence of higher feed intake for dairy cattle to obtain higher milk yield.

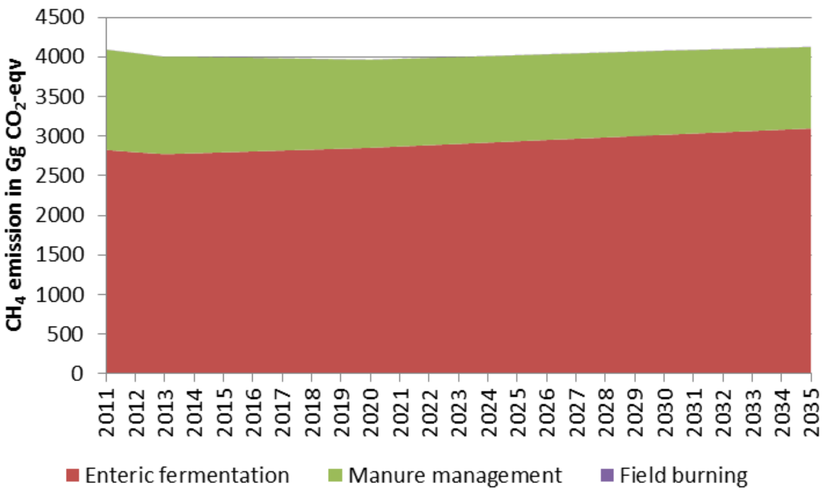


Figure 8.1 Projected CH4 emission from the agricultural sector, given CO_2 equivalents.

The expected development for N_2O emission, given in million tonnes CO_2 equivalents, is a decrease from 5.41 in 2011 to 4.73 in 2035, which leads to a 14 % reduction. The fall is mainly driven by the decrease in emission from manure and the decrease in use of fertiliser. Furthermore, the reduced emission is also affected by a decrease from N-leaching and a decrease in area of cultivated organic soils. Data used in Figure 8.2 are available in Section 8.6, see Table 8.12.

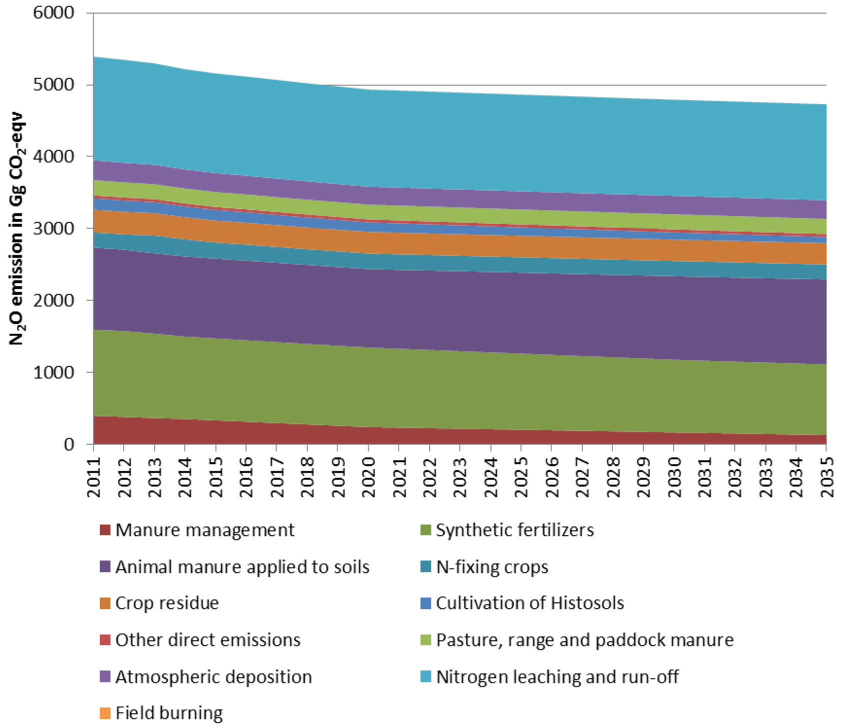


Figure 8.2 Projected N_2O emission from the agricultural sector, given in CO_2 equivalents.

8.2 Comparison with previous projection

The present projection of greenhouse gases replaces the latest basic projection published in NERI Technical Report No. 841 (Nielsen et al., 2011). Compared to the previous projection some changes has been implemented, which is a consequence of the annual update of agricultural data and adjustment of certain assumptions. Compared with previous projection, these changes have resulted in an increase of the total agricultural emissions by 0-1 % from 2011 to 2030.

The most important changes, compared with the previous projection (2011-projection), are mentioned below.

The livestock production is based on the latest historical inventory, which is year 2010. According to Statistics Denmark, the number of dairy cattle is higher than presumed in the previous projection (2011-projection). This means that the present projections assume a larger cattle production for all years 2011 to 2030.

The 2012-projection calculates with a higher agricultural area than presumed in the 2011-projection. The historical data show a fall in the agricultural area, which is expected to continue. Basically the same trend as in 1995-2010, is used for the decrease in area.

Other changes compared to 2011-projection:

- Higher implementation rate for biogas treated slurry based on new assessment from the Danish Energy Agency.
- Lower nitrogen excretion for dairy cattle and sows.
- Change in data regarding the sewage sludge applied to soils.
- Lower area of cultivation of organic soils based on new assessment from the Danish Centre for Food and Agriculture.

Some changes have lowered the emission, while other changes have resulted in higher emission. Given in total emissions, no significant changes is seen compared to the 2011-projection.

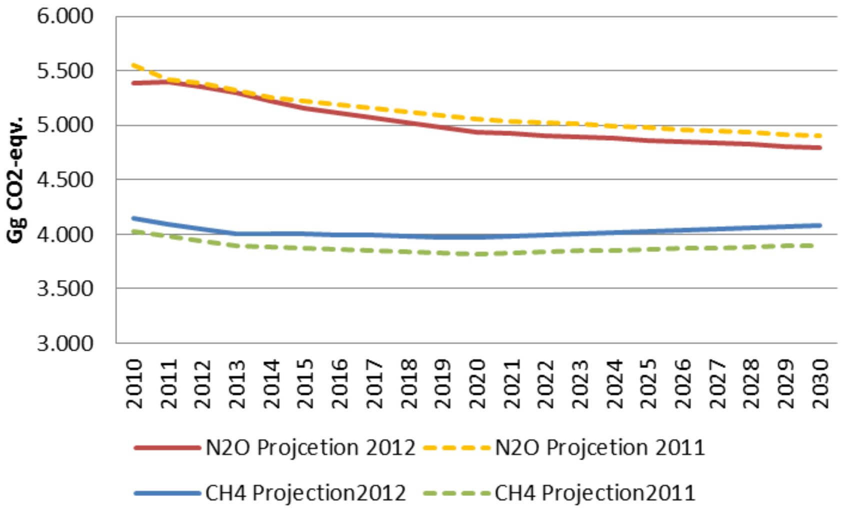


Figure 8.3 Projection 2012 compared to projection 2011.

8.3 Assumptions for the livestock production

The main part of the greenhouse gas emission is related to the livestock production and particularly the production of pigs and dairy cattle. All other livestock categories have a minor effect of the total emission and the population are therefore until 2035, kept at a level equivalent to average production conditions in 2006-2010.

The given assumptions for the cattle and pig production are discussed with the Knowledge Centre for Agriculture.

8.3.1 Cattle

The total cattle production is mainly depending on the production of dairy cattle, and thus decided by the average milk yield and the total milk production. The milk production is fixed by the EU milk quota scheme until 2013. After 2013 the EU milk quota system will be replaced by free competition on the world marked. It is uncertain how Danish milk production will adjust to the competition, but due to the highly intensive production form it is expected that the number of dairy cattle could be maintained.

Therefore, a total milk production is assumed to stay at the same level until 2013, which mean a reduction in the number of dairy cattle due to an increase in the milk yield. From 2013 to 2035 the number of dairy cattle is kept constant, while the assumption of increased efficiency will give rise to an increased milk production.

8.3.2 Dairy cattle

In the projection continuing increase in production efficiency is expected in the form of improved milk yield per cow. From 2010 to 2020 an increase of dairy yield of 1.5 % per year is assumed, which is based on an assessment provided by the Knowledge Centre for Agriculture (Aaes, 2012). From 2021 to 2035, the rate of increase is not expected to be as high, and thus assumed to be 1.25 % dairy yield per year. The increase in the efficiency gives an average dairy yield of approximately 10 400 kg milk per cow per year in 2020 and 12 600 kg milk per cow per year in 2035.

Table 8.2 Number of dairy cattle and milk yield - figures used in the projection to 2035.

	2011	2015	2020	2025	2030	2035
Dairy cattle, 1000 unit	563	549	549	549	549	549
Milk yield, kg milk per cow per year	9 178	9 704	10 437	11 150	11 862	12 575

8.3.3 N-excretion – dairy cattle

The N-excretion is closely related to the level of milk yield. According to the default values, N-excretion in 2010 for dairy cattle (large breed) was 141.4 kg N per animal per year (Poulsen, 2012). An increase of milk yield to 10 400 kg milk per cow in 2020 assumed to result in an N-excretion of 143 kg N per animal per year (large breed) and 156 kg N per animal per year in 2035 based on an assessment provided by the Knowledge Centre for Agriculture (Aaes, 2012). The N-excretion for the years between 2010-2020 and 2020-2035 is interpolated.

It is assumed that the relationships between N ex Animal/N ex Housing and N ex Animal/N ex Storage are the same as in 2010. Table 8.3 shows the N-excretion figures used in the projection.

Table 8.3 N-excretion for dairy cattle – figures used in the projection to 2035.

N-excretion dairy cattle	2011	2015	2020	2025	2030	2035
	kg N per animal per year					
Large breed	141.4	142.1	143.3	147.4	151.6	155.7
Jersey	120.2	120.8	121.8	125.3	128.8	132.3

8.3.4 Non-dairy cattle

The production of non-dairy cattle is based on the number of dairy cattle. No significant change in the allocation of the subcategories of non-dairy cattle; heifers, bulls and suckling cattle, is expected until 2035. Thus, the changes in number of dairy cattle reflect the number of non-dairy cattle. The allocation of sub-categories is based on an average of 2006-2010 distribution.

The historic normative data for N-excretion for all cattle sub-categories shows few changes until 2005. From 2005 is seen an increase in N-excretion for heifers, bulls and suckling cattle, which are kept steady from 2007-2010. In the projection no significant changes in N-excretion is expected and therefore kept at the same level as in 2010.

8.3.5 Housing system

In 2010, according to Statistics Denmark, there were 568 000 dairy cows and 573 000 heifers > ½ year, of which around 80 % of the dairy cattle and 30 % of the heifers are estimated to be housed in housing systems with cubicles. The assumed development in housing for dairy cattle is a phasing out of both tethering and deep litter housing and it is estimated that all dairy cattle will be housed in systems with cubicles in 2020. For heifers the same development is assumed but over a longer period. Tethering housing is assumed to be phased out in 2030 and around 15 % of the heifers are housed in deep litter systems, the rest of the heifers are assumed to be housed in systems with cubicles. Based on these developments in distribution of housing types it is assumed that all manure from dairy cattle in 2020 is handled as slurry.

8.3.6 Pigs

It is assessed that the agricultural structural development against larger farm units will contribute to additional growth in pig production. However, at the same time the development is strongly influenced by the present economic crises and stricter environmental regulations in e.g. the Agreement of Green Growth (2009 and 2010), the Water Framework Directive and the Nitrate Directive. In the projection, the number of sows is assumed to stay at the same level as the production during the last four years, which correspond to 1.1 million sows. However, the production of weaners and fattening pigs will increase as a consequence of production efficiency in form of more produced weaners per sow.

8.3.7 Sows

During the period 1990-2010 a constant increase in the number of weaners per sow of 0.3 piglets per year in average is observed, with no appreciable changes from year to year. In the projection this development rate is expected to continue until 2020. This is confirmed by the Knowledge Centre for Agriculture as a realistic estimate (Tybirk, 2011). A more conservative estimate is assumed for 2020-2035 equalling to 0.1 piglets per sow per year. This results in an average production of approximately 30 piglets per sow in 2035.

8.3.8 Weaners and fattening pigs

The number of sows and the production efficiency calculated as number produced weaners per sow affects the production of weaners and fattening pigs. At the same time export data from Statistics Denmark shows a significant increase in the export of weaners from 2004. This trend is expected continue and thus the export is assumed to increase from 8 million weaners in 2010 to 12 million in 2020/2035. This result in a rise in produced number of weaners from 28.5 million in 2010 to 31.8 in 2020 and 33.5 in 2035, which corresponds to an increase of 18 % from 2010 to 2035. Because of the rising export of weaners, the production level for fattening pigs is assumed to increase around 3 %.

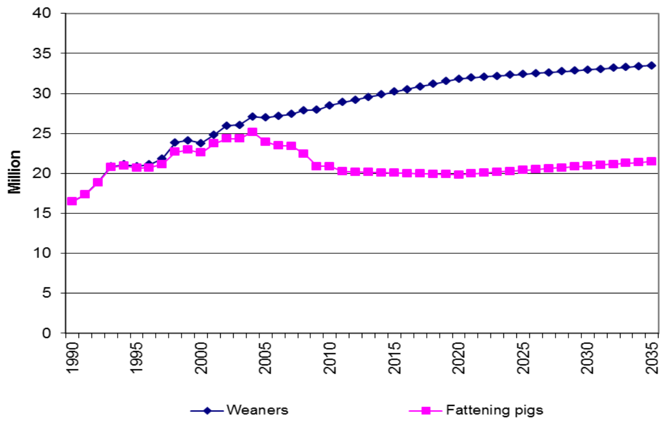


Figure 8.4 Number of produced weaners and fattening pigs.

Table 8.4. Number of produced sows, weaners and fattening pigs.

Pigs, million produced	2011	2015	2020	2025	2030	2035
Sows	1.1	1.1	1.1	1.1	1.1	1.1
Weaners	28.9	30.2	31.8	32.4	32.9	33.5
Fattening pigs	20.2	20.1	19.8	20.4	20.9	21.5

8.3.9 N-excretion - pigs

Due to improvements of feed efficiency a decrease in nitrogen excretion is expected. The assumptions applied in the projection are based on results from research provided by the Faculty of Agricultural Science (DEPA, 2006).

According to the Ammonia report the N-excretion for sows in 2020 expects to be 22.81 kg N per sow per year, which corresponds to 9 % reduction compared to 2010. For fattening pigs, N-excretion is expected to decrease from 2.82 to 2.70 kg N per pig produced per year, implying a reduction of 4 %. For weaners an N-excretion is assumed at the same level as in 2010.

In Table 8.5, the figures for N-excretion used in the projection are given.

Table 8.5 N-excretion for pigs – figures used in the projection to 2035.

N-excretion for swine	2011	2015	2020	2025	2030	2035
			kg N per pig per year			
Sows	24.90	23.97	22.81	22.81	22.81	22.81
Weaners	0.49	0.49	0.49	0.49	0.49	0.49
Fattening pigs	2.81	2.76	2.70	2.70	2.70	2.70

8.3.10 Housing system

In 2010 more than 50 % of the fattening pigs were housed in systems with fully slatted floor. In the projection is it assumed that these systems are phased out for fattening pigs in 2020. Also systems with solid floor and with deep layer of bedding are assumed to be phased out. Thus, all fattening pigs are expected to be housed in systems with partially slatted or drained floor in 2020. For sows, a phasing out of systems with fully slatted floor is expected, with all phased out in 2030. But a system with deep layer of bedding is assumed to continue at almost the same level as in 2010.

8.4 Assumptions for the technology implementation

In Denmark most of the environmental requirements regarding the agricultural production have focused on reducing nitrogen loss to the aquatic environment, protection of nitrogen exposed areas and reduction of the ammonia emission. These have no direct impact on greenhouse gas emissions. They do, however, have an indirect impact because the N_2O emission is closely linked with the nitrogen cycle. National and international decisions and agreements force the agricultural sector to further reduction not only for air pollutants but also the reduction of greenhouse gases have a high priority.

Concerning the air pollutants the most important decisions, which can be considered as driving forces to implementation of further environmental requirements are; the national agreement of Green Growth formulated in 2009 and followed up in 2010, the NEC Directive (Directive 2001/81/EC) and the Danish Law on environmental approval of animal holdings (LBK No. 1486 of 04/12/2009). Another decision, which concerns the greenhouse gases is the Kyoto Protocol, but also the EU Decision No 406/2009/EC is relevant. In sectors which are not included in the EU Emission Trading System all Member States have individual greenhouse gas emission targets expressed as a percentage in 2020 compared to the 2005. For Denmark this target is stated as minus 20 % and covers sectors such as transport, buildings, agriculture and waste.

The present projection includes the effect of lower emission from biogas treated slurry, based on the Energy Statistics provided by the Danish Energy Agency. Furthermore, implementation of ammonia emission reducing technologies in animal housings has been taken into account and cover air cleaning and slurry acidification systems. At present, the reduction technology is still used to a limited extent. Biogas treated slurry, air cleaning and slurry acidification seems to be the most common reduction technologies.

However, it has to be mentioned that other technologies with greater reduction potentials can be brought into use later on, or other technologies with less economic or practical efforts.

8.4.1 Emission reducing technologies in animal housings

Until now, reduction of nitrogen losses has been pursued through requirements to handling of manure during storage and application to the field. In future, application of technology to further additional decreases will obviously take place in animal housings. It is chosen to include reducing technology in form of air cleaning in housings and slurry acidification systems to adjust the pH value of the slurry. Based on contact to different technology suppliers these technologies seem to be the two most used systems. Furthermore, these technologies are described and the reduction effect is quantified in Best Available Techniques (BAT):

BAT 1: Sulphuric acid treatment of slurry in housings for fattening pigs.

BAT 2: Sulphuric acid treatment of cattle slurry.

BAT 3: Air cleaning with acid.

The main object for both technologies is to reduce the emission of ammonia besides a reduction in odour for the air cleaning. However, these technologies indirectly impact the emission of N_2O. New research indicates a reduction of CH_4 emission as a result of acidification of slurry, but no reduction is taken into account in the projection. Thus, a reducing effect is expected, but is not quantified in BAT 1 and BAT 2 and therefore not included.

In the projection, it has been decided to include the effects from emission reducing technologies for dairy cattle, heifers > ½ year, sows, fattening pigs and broilers, these being the most important for total livestock production.

8.4.2 Acidification of slurry

Acidification of slurry will mean that a greater proportion of the nitrogen in the slurry will be retained in ammonium-form, which is far less volatile than ammonia. This means that ammonia evaporation is also reduced under storage and under application of animal manure.

Acidification of slurry equipment for pig slurry in housing systems with partially slatted floors is predicted to be able to reduce ammonia evaporation in housings by 65-70 % (BAT 1). Acidification of slurry equipment for cattle slurry in housing systems with cubicles is predicted to be able to reduce ammonia evaporation in housings by 50 % (BAT 2). In the projection, an average reduction factor of 60 % is used for cattle and pigs.

Acidification of slurry is in the projection implemented for dairy cattle, heifers > ½ year, sows and fattening pigs.

8.4.3 Cleaning of air output

Air cleaning in pig housing is predicted to reduce the ammonia evaporation up to 90 %, depending on the selected air cleaning system and capacity of the ventilation system. 90 % reduction is expected when assuming all air in the housing is cleaned (BAT 3). In the projection an average reduction factor of 70 % is used.

In housing for poultry air cleaning technologies are not yet implemented, but it is under development and therefore this technology is included in the projection. The same reducing factor as for pigs is used.

In the projection, cleaning of air is implemented for sows, fattening pigs and broilers.

8.4.4 Estimation of technology

In the Agreement of Green Growth is established a requirement of 30 % reduction of the ammonia emission, when new animal housing is established or existing housing is restored. The requirement is specified in Law on environmental approval of animal holdings (LBK No. 1486 of 04/12/2009 + BEK No 294 of 31/03/2009). Due to the structural development, it is assumed that nearly all housing system have to meet the reduction requirements in 2020.

The requirement of 30 % reduction of ammonia emission relates to the best reference housing system, which means housing system with the lowest ammonia emission. In this projection is used the norm data 2011 (Poulsen et al., 2012).

Some of the 30 % ammonia reduction is assumed to be reached due to improvements of feed efficiency and change in the distribution of housing types. Thus, estimations for dairy cattle and fattening pigs indicate that agricultural practice can reduce the ammonia emission around 5 % and 3 %, respectively. To achieve a total reduction of 30 % it is assumed that the remaining 25 % and 27 %, respectively, is reduced by implementation of ammonia reducing technologies.

To reach the 30 % ammonia reduction in 2020, the dairy cattle needs to implement slurry acidification in approximately 40 % of the production in 2020. For the pig production two technologies are applicable; acidification of slurry and air cleaning. The average reduction factors for these technologies are 60 % and 70 %, respectively – in average 65 %. The technology implementation needed in 2020 is calculated to around 40% for the production of fattening pigs.

Same approach is used to calculate need of technology implementation for heifers, sows and broilers.

The implementation rate for 2035 has to be considered as a first estimate. The possibility and limitation for implementation very much depend on the technology development and the economic cost.

Table 8.6 Predictions regarding establishment of ammonia reducing technology in housings.

	2020 Share of production with reducing technology, %	2035 Share of production with reducing technology, %
Dairy cattle (60 % reduction)	40	70
Heifers > ½ year (60 % reduction)	60	70
Sows (65 % reduction)	50	60
Fattening pigs (65 % reduction)	40	80
Broilers (70 % reduction)	20	20

8.4.5 Biogas production

The use of liquid slurry in the biogas production will cause a reduction in emission of CH_4 and N_2O. No description on how to include biogas treated slurry in the inventories is provided in the IPCC guidelines. Therefore, the Danish inventory uses data based on a Danish study (Sommer et al., 2001).

In 2010, approximately 2.4 million tonnes slurry was treated in biogas plants which are equivalent to approximately 7 % of all slurry and an energy production of 2.9 PJ.

In the Agreement of Green Growth an aim of 50 % biogas treated animal husbandry is specified. A series of different actions is provided to promote the extension of the biogas production e.g. adjustment of settlement prices and financial support to biogas projects. However, large economic costs are related to establishments of biogas plants.

Assessment from the Danish Energy Agency shows an expected energy production from biogas plant by 16.8 PJ in 2020 and 35.0 PJ in 2035. The major part of the energy production origins from biogas treated slurry - 95 % is assumed. The calculation of the amount of biogas treated slurry is based on a conversion factor of 0.83 million tonnes slurry per PJ (DEA, 2012). Thus, in 2020 approximately 13 tonnes slurry is expected to be biogas treated, which correspond to around 35 % of the total amount of slurry and further extended to around 75 % in 2035 (28 tonnes slurry).

As a result of the slurry used in the biogas production the emission of CH_4 and N_2O, a reduction is calculated of 0.24 million CO_2 eqv. in 2020 and 0.49 CO_2 eqv. in 2035 (Table 8.7).

Table 8.7 Expected development in biogas treated slurry.

	Pct. of biogas treated slurry	Million tonnes slurry biogas treated	Reduced emission Gg CH_4	Gg N_2O	Million tonnes CO_2 eqv.
2011	9	3	1.41	0.08	0.05
1015	18	6	2.96	0.17	0.11
2020	36	13	6.13	0.35	0.24
2025	49	18	8.35	0.47	0.32
2030	61	23	10.57	0.60	0.41
2035	74	28	12.78	0.72	0.49

8.5 Assumptions for other agricultural sources

Besides the assumptions for the livestock production, many other variables influence the greenhouse gas emission. The most important ones are the agricultural area, use of synthetic fertiliser, nitrogen leaching and field burning of agricultural residue.

8.5.1 Agricultural area

Developments from 1995 to 2010 show a total reduction in the agricultural land area of 86 000 ha, which correspond to a reduction of 0.2 % annually. The decrease in area is a result of urban development and infrastructure, but also due to removal of marginal land areas in order to meet the objectives in the Action Plan on the Aquatic Environment, and directives such as the Nitrates Directive and the Habitats directive. In future, this trend is expected to continue. In the projection the agricultural area is assumed to continuously fall 0.2 % per year 2011-2020, which corresponds to 58 500 ha in total or 6 500 ha per year. From 2020-2035 a lower reduction rate is assumed; 3 500 ha per year or 0.17 % per year.

More agricultural area is expected to be set aside from cultivation as a result of the Agreement on Green Growth adopted in 2009 and followed up in a second version Green Growth 2.0 in April 2010. One of the measures described in the plan, is to remove 50 000 ha near water streams with the purpose to reduce the nitrogen loss to the aquatic environment. It is expected to be implemented in 2013 and 2014.

<u>Assumptions for 2010-2020:</u>

- Reduction of around 6 500 ha per year = 58 500 ha.
- Agreement on Green Growth = 50 000 ha.

<u>Assumption for 2020-2030:</u>

- Reduction of around 3 500 ha per year = 52 500 ha.

In the projection no significant changes in the division of different crop types are expected. Changes in climatic conditions can affect the choice of crop type, which probably means implementation of new species in the future production. However, global supply and demand also play an important role. The most important variable concerning the total greenhouse gas emission is whether the areas are cultivated or not, while the crop type is less important.

Table 8.8 Agricultural land area in the projection.

	2011	2015	2020	2025	2030	2035
Agricultural land area, 1 000 ha	2 640	2 564	2 531	2 514	2 496	2 479

8.5.2 Use of synthetic fertilisers

Consumption of synthetic fertilisers depends on the amount of nitrogen in animal manure, requirements for N-utilisation and area under agricultural cultivation. It is assumed that there is no significant change in the allocation of different crops types compared to the conditions in 2010.

The agricultural conditions 2006-2010 indicate an average nitrogen requirement in crops of 130 kg N per ha. Based on knowledge of the agricultural area and nitrogen content in manure (N ex Storage), the need for nitrogen in synthetic fertiliser can be calculated (see Table 8.9).

Table 8.9 Consumption of synthetic fertilisers.

	2011	2015	2020	2025	2030	2035
			Gg N			
N in animal manure (N ex storage)	203	197	193	199	205	209
N which is included in the farmers' fertiliser accounts	138	138	139	145	151	153
N in synthetic fertilisers	199	190	184	176	168	164

The use of nitrogen in synthetic fertilisers is assumed to decrease from 199 Gg in 2011 to 164 Gg in 2035, which is an 18 % reduction. The two main reasons for this fall, is a decrease in the agricultural area and implementation of ammonia reduction technology. The technology reduces the ammonia emission from the housings and thereby increases the content of N in the animal manure (N ex storage).

8.5.3 N-leaching

Nitrogen which is transported through the soil profile and aquatic environments can be transformed to N_2O. In the emission inventory the emission is calculated as the sum emission from three different parts; emission from leaching to groundwater, from transport to watercourses and from transport to sea. Nitrogen leaching in these three parts is based on results from the NOVANA programme.

In the projection only the nitrogen leached to the groundwater is known, which under Danish conditions corresponds to 33 % of N content in animal manure (given as N ex Animal), N content in synthetic fertiliser and N content in sewage sludge and industrial waste used as fertiliser. Thus, the N_2O emission from N-leaching in the projection is calculated based on a weighted N_2O emission factor. The weighted emission factor is based on the proportion between N leached to the groundwater and total emission, estimated as an average from 2006-2010. The weighted N_2O emission factor is estimated to 0.02 %kg N_2O-N per Kg N and the same factor is used for all years 2011 - 2035.

The N-leaching to the ground water is expected to decrease from 150 Gg N in 2010 to approx. 140 Gg N in 2020 and 139 Gg N in 2035 and this is mainly due to reduction of nitrogen in synthetic fertiliser. This impacts the N_2O emission, which decrease from 4.57 Gg N_2O in 2010 to 4.35 Gg N_2O in 2020 and further to 4.30 Gg N_2O in 2035, corresponding to a reduction of 6 % until 2035.

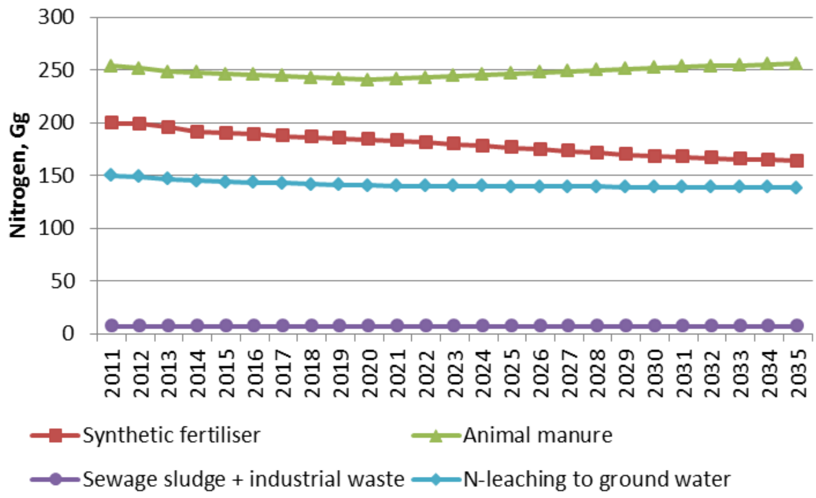


Figure 8.5 Nitrogen from synthetic fertiliser, animal excretions, N-leaching and sewage sludge + industrial waste.

8.5.4 Field burning of agricultural residue

There are two different sources of field burning of agricultural residue; straw from grass seed production and straw from wet or broken bales.

No significant change in area with repeated grass seed production is assumed. Thus, an average of the area 2006 to 2010 is used in the projection and same area is used for all years until 2035. The amount of burned straw from the grass seed production is assumed to be at the same level (15 %) as in the historical years.

The amount of straw burned from wet or broken bales of straw is assumed to be 0.1 % of the total amount of straw, similar to the historical years. The total amount of straw is presumed to vary concurrently with the area of agricultural land.

8.6 Results

In Table 8.10-8.12 is listed the historical greenhouse gas emission 1990-2010 followed by the projected emissions 2011-2035. The greenhouse gas emission is expected to decrease from 9.52 million tonnes CO_2 equivalents in 2010 to 8.90 million tonnes CO_2 equivalents in 2020. Until 2035 a further reduction to 8.86 million tonnes CO_2 equivalents is assumed. Thus, the projection indicates a reduced emission by 8 % from 2010 to 2035. The decreased emission is mainly a result of a decrease in the N_2O emission.

Table 8.10 Total historical (1990-2010) and projected (2011-2035) emission, given in CO_2 eqv.

CO_2 equivalents, million tonnes	1990	2000	2010	2011	2015	2020	2025	2030	2035	Average 2008/12
CH_4	4.24	4.05	4.15	4.09	4.00	3.97	4.02	4.08	4.13	4.09
N_2O	8.22	6.35	5.37	5.39	5.16	4.94	4.86	4.79	4.73	5.47
Agriculture, total	12.46	10.39	9.52	9.49	9.16	8.90	8.89	8.88	8.86	9.56

8.6.1 CH_4 emission

The overall CH_4 emission has decreased slightly from 202 Gg CH_4 in 1990 to 197 Gg CH_4 in 2035 and thus indicates no significant change (Table 8.11).

The decrease in emission from enteric fermentation 1990–2013 is due to a fall in number of dairy cattle, as a consequence of higher milk yield. Because the EU milk quota system does not continue from 2013, the number of dairy cattle is expected to be unaltered from 2013 – 2035. Continued increase in milk yield and feed intake leads to an increase of the enteric emission.

The CH_4 emission from manure management has increased from 1990- 2010, which is a result of change in housing system towards more slurry based systems. In future no considerable change is assumed, and thus the emission is presumed to be almost stable until 2035.

The reduced emission, as a result of biogas treated slurry, is assumed to have a substantial impact. In 2035, approximately 75 % of slurry is presumed to be biogas treated, which reduce the total CH_4 emission by 12.8 Gg CH_4. In case of a lower biogas expansion than assumed in this projection, the CH_4 emission could probably increase in 2035.

Table 8.11 Historical (1990-2010) and projected (2011-2035) CH_4 emission.

CH_4 emission, Gg	1990	2000	2010	2011	2015	2020	2025	2030	2035	Average 2008/12
Enteric fermentation	154.6	136.2	136.0	134.6	133.1	135.9	139.8	143.7	147.5	134.6
Manure management	47.4	56.9	62.4	61.7	60.1	59.1	60.1	61.1	61.7	61.5
Biogas treated slurry	-0.1	-0.5	-1.1	-1.4	-3.0	-6.1	-8.4	-10.6	-12.8	-1.3
Field burning	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Total CH_4, Gg	202.0	192.8	197.4	195.0	190.4	188.9	191.6	194.4	196.6	194.9

8.6.2 N_2O emission

The reduction of the N_2O emission from 1990 to 2010 continues until 2035 though with a lower reduction rate. The emission from 2011 to 2035 is assumed to be reduced from 17.33 Gg N_2O to 15.26 Gg N_2O, respectively, and this corresponds to a 12 % reduction (Table 8.12).

The emission decrease is mainly related to the greater part of the biogas treated slurry and also a fall of the emission from use of synthetic fertiliser, nitrogen leaching and cultivation of organic soils.

The decline in emission from the use of synthetic fertiliser from 3.86 Gg N_2O in 2011 to 3.16 Gg N_2O in 2035 is mainly caused by a decrease in the agricultural land. Another important explanation is implementation of the ammonia reducing technology. The reduced ammonia emission in livestock houses leads to a higher nitrogen content in manure, which increases the fertiliser potential. Given that the nitrogen is kept in the manure during the storage process, the nitrogen can be used as fertiliser. This will lower the demand of synthetic fertiliser. The decrease in use of synthetic fertiliser is also the reason for the fall in emission from N leaching from 4.64 Gg N_2O in 2011 to 4.30 Gg N_2O in 2035.

The emission from cultivation of organic soils expects to decrease significantly from 0.52 Gg N_2O in 2011 to 0.28 Gg N_2O in 2035. A new assessment from the Danish Centre for Food and Agriculture shows a decrease of 800 ha per year and this development is assumed to continue until 2035.

Table 8.12 Historical (1990-2010) and projected (2011-2035) N_2O emission.

N_2O emission, Gg	1990	2000	2010	2011	2015	2020	2025	2030	2035	Average 2008/12
Manure management	1.94	1.76	1.42	1.37	1.25	1.13	1.14	1.14	1.15	1.42
Biogas treated slurry	-0.01	-0.03	-0.06	-0.08	-0.17	-0.35	-0.47	-0.6	-0.72	-0.07
Synthetic fertiliser	7.76	4.88	3.68	3.86	3.67	3.56	3.41	3.25	3.16	3.91
Animal manure applied	3.59	3.42	3.72	3.68	3.58	3.52	3.63	3.75	3.81	3.73
N-fixing crops	0.87	0.75	0.77	0.68	0.72	0.70	0.69	0.68	0.68	0.72
Crop residues	1.17	1.09	1.02	1.01	0.99	0.97	0.97	0.96	0.95	1.01
Cultivation of histosols	0.73	0.63	0.53	0.52	0.48	0.43	0.38	0.33	0.28	0.53
Sewage sludge	0.09	0.17	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
Grazing animal	1.00	1.00	0.64	0.68	0.67	0.66	0.67	0.67	0.67	0.67
Atmospheric deposition	1.47	1.13	0.93	0.89	0.85	0.81	0.82	0.83	0.84	0.92
N-leaching and run-off	7.91	5.66	4.57	4.64	4.47	4.35	4.33	4.31	4.30	4.68
Field burning	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Total N_2O, Gg	26.52	20.47	17.33	17.40	16.64	15.92	15.69	15.47	15.26	17.64

Apart from the biogas treatment of slurry, no other technical solutions aimed at limiting greenhouse gas emission, exist. Implementation of ammonia reducing technology has a slight indirect reduction effect on greenhouse gas emission. However, new research results indicate a reduction in methane emission in relation to acidification of slurry, which is not taken into account in this projection.

At present the historical emission inventory do not include ammonia reducing technology, which mean that the reduction effect is not reflected in the annual emission inventory. To include the reduction effect, documentation from farmers in form of an official statistic or registry is strongly needed.

The development towards larger farm units with a higher productivity level compared with today’s average, is expected to continue. This lead to production efficiency, improvements of feed utilisation and better utilisation of nitrogen in animal manure – all measures which reduce the greenhouse gas emission. It has to be pointed out, that another important driving force to further reduce of emissions is the increase in the environmental requirements.

There is no doubt that the emission of both ammonia and greenhouse gases from the agricultural sector will be reduced over time. However, it is more difficult to predict the rate at which this will occur and the limit for how much the emission can be reduced. This depends on general structural developments and developments within the decisive environmental regulation, especially for larger farm units. EU agricultural policy also plays a role and, of course, the conditions for export and import of agricultural products.

8.7 Green growth further objectives

Some of the objectives from the Agreement of Green Growth are not taken into account in this projection. The projection includes expansion of biogas production and establishment of 50 000 ha non-cultivated area along water streams and lakes because these objectives have already been implemented in the regulation in form of legislation and subsidy scheme. The remaining objectives are not yet implemented in the regulation. However, in this chapter is given an estimate of how much they could de- or increase the emission.

8.7.1 Establishment of 30 000 ha non-cultivated area along water streams instead of 50 000 ha

In the Agreement of Green Growth is one of the objectives to establish a 10 m non-cultivated area along water streams and lakes. In the projection is implemented a total non-cultivated area of 50 000 ha, but some of this area have already been established due to legislation on rivers which dictate an area of 2 m non-cultivated area along water streams and lakes. It is also possible to seek dispensation from the law, therefore the area of 50 000 ha non-cultivated area could be considered as an overestimation. If a reduction of the area to 30 000 ha is assumed will the projected emission increase with 23 Gg CO_2 eqv. per year.

8.7.2 Establishment of 10 000 ha wetlands

Establishment of wetlands will retain the nitrogen and then reduce the nitrogen loss to the water streams. Based on Miljøministeriet (2010) it is assumed that wetlands will reduce the N loss by 113 kg N per ha. Establishment of 10 000 ha of wetlands will decrease the emission with 11 Gg CO_2 eqv. per year.

8.7.3 Implementation of 140 000 ha fields with catch crop

In principle the cultivation of a catch crop will decrease the emission as a consequence of reduced N-loss. However, it seems that the emission is actually increased due to higher nitrogen input to the soil in form of more organic matter. Olesen et al. (2012) has estimated the effect of catch crops and it shows an increase in the emission of N_2O by 19 kg CO_2 eqv. per ha per year. An implementation of 140 000 ha fields with catch crop will therefore increase the emission with 2.7 Gg CO_2 eqv. per year.

8.7.4 Further objectives – total emission

In Table 8.13 is given an estimate of the projected total emission of GHG from agriculture in CO_2 eqv. with the above mentioned changes and further measures implemented. It is expected that the measures, which is not implemented in the projection will increase the GHG emission by 16 Gg CO_2 eqv. per year compared with the present projection.

Table 8.13 Projection without and with further measures from Green Growth

CO_2 eqv., Gg	Projection	Projection with further measures
2015	9 156	9 172
2020	8 903	8 919
2035	8 859	8 875

8.8 References

Aaes, 2012: Ole Aaes pers. comm., the Knowledge Centre for Agriculture, division of cattle.

Agreement of Green Growth, 2009: Aftale om Grøn Vækst indgået af Regeringen og Dansk Folkeparti 16. juni 2009. Available at (in Danish):

http://www.mim.dk/NR/rdonlyres/D5E4FC9A-B3AC-4C9A-B819-C42300F23CCA/0/GROENVAEKST_2904rapporten.pdf (11-09-2012).

Agreement of Green Growth 2.0, 2010: Aftale om Grøn Vækst 2.0 er indgået mellem Regeringen og Dansk Folkeparti den 9. april 2010. Available at (in Danish): http://www.mim.dk/NR/rdonlyres/89DD7552-E925-4CA0-8E5B-C5072D40D18D/0/GroenVaekst2_0.pdf (11-09-2012).

DEPA, 2006. Ammoniakudredningsrapport, Danish Ministry of the Environment. Available at (in Danish): http://www.mst.dk/NR/rdonlyres/B046E41F-73E1-4CA1-898B-EFBF1E225CAA/21076/Ammoniakudredningrapport.pdf (11-09-2012).

BAT 1: Sulphuric acid treatment of slurry in housings for fattening pigs. Available at (in Danish): http://www.mst.dk/NR/rdonlyres/87FD1443-C032-47BB-93AC-C6C38D1C2828/0/SlSt01forsuringslagtesvinBATbladendelig.pdf (11-09-2012).

BAT 2: Sulphuric acid treatment of cattle slurry. Available at (in Danish): http://www.mst.dk/NR/rdonlyres/53A4E928-3D24-407F-B8D6-E1C8EF4F4CEF/83990/MaSt01forsuringkvgBATbladudenkorr.pdf (11-09-2012).

BAT 3: Air cleaning with acid. Available at (in Danish): http://www.mst.dk/NR/rdonlyres/53A4E928-3D24-407F-B8D6-E1C8EF4F4CEF/83989/SlSt02luftrensBATbladudenkorr.pdf (11-09-2012).

BEK No 294 of 31/03/2009: Bekendtgørelse om tilladelse og godkendelse m.v. af husdyrbrug. Available at (in Danish): https://www.retsinformation.dk/Forms/R0710.aspx?id=124123 (11-09-2012).

DEA, 2012. The Danish Energy Agency, Søren Tafdrup. Pers. Comm.

EU Decision No 406/2009/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 23 April 2009 on the effort of Member States to reduce their greenhouse gas emissions to meet the Community's greenhouse gas emission reduction commitments up to 2020. Available at: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2009:140:0136:0148:EN:PDF (11-09-2012).

Kyoto Protocol. Kyoto Protokol to the United Nations Framework – Convention on Climate Change. Available at: http://unfccc.int/resource/docs/convkp/kpeng.pdf (11-09-2012).

LBK No. 1486 of 04/12/2009. Bekendtgørelse af lov om miljøgodkendelse m.v. af husdyrbrug. Available at (in Danish): https://www.retsinformation.dk/forms/r0710.aspx?id=128754 (11-09-2012).

Miljøministeriet, 2010: Virkemiddelkatalog. Available at (In Danish): http://www.naturstyrelsen.dk/NR/rdonlyres/C88AD233-0775-45B5-8C50-0A93B11F133D/116445/Virkemiddelkatalog_vers_offhoering_3_Samlet.pdf

NEC Directive. Directive 2001/81/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 23 October 2001- on national emission ceilings for certain atmospheric pollutants, Available at:
http://eurlex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2001:309:0022:0030:EN:PDF (11-09-2012).

Nielsen, O-K., Winther, M., Nielsen, M., Mikkelsen, M.H., Albrektsen, R., Gyldenkærne, S., Plejdrup, M., Hoffmann, L., Thomsen, M., Hjelgaard, K. & Fauser, P., 2011: Projection of Greenhouse Gas Emissions 2010 to 2030. National Environmental Research Institute, Aarhus University, Denmark. 178 pp. – NERI Technical Report no. 841. Available at:
http://www.dmu.dk/Pub/FR841 (11-09-2012).

Olesen, J.E., Jørgensen, U., Hermansen, J.E., Petersen, S.O., Eriksen, J., Søgaard, K., Vinther, F.P., Elsgaard, L., Lund, P. and Nørgaard, J.V., 2012: Effekter af tiltag til reduktion af landbrugets udledning af drivhusgasser. Aarhus Universitet (In press).

Poulsen, H.D. (ed.), 2012: Normtal. Available at (in Danish):
http://anis.au.dk/forskning/sektioner/husdyrernaering-og-miljoe/normtal/ (11-09-2012).

Sommer, S.G., Møller, H.B. & Petersen, S.O., 2001: Reduktion af drivhusgasemission fra gylle og organisk affald ved Biogasbehandling. DJF rapport - Husdyrbrug, 31, 53 pp. (In Danish).

Statistics Denmark: Available at: www.dst.dk (11-09-2012).

Tybirk, 2011: Per Tybirk, Pers. comm. The Knowledge Centre for Agriculture, The Pig Research Centre.

9 Solid waste disposal on land

The CRF source category *6.A Solid waste disposal sites,* gives rise to CH_4 emissions.

CH_4 emissions are calculated by means of a first order decay (FOD) emissions model, where activity data is annual data for the amount of waste deposited and where emissions factors, which are the amounts of CH_4 emitted per amount of waste deposited, result from model assumptions about the decay of waste and release of CH_4 as described in Nielsen et al., 2012.

9.1 Activity data

Waste quantities are collected by the Danish Environmental Protection Agency (DEPA) under the 'Information System for Waste and Recycling' ('Informations System for Affald og Genanvendelse', ISAG). The annual waste statistics include the amount of waste sent to landfill, whereas projected waste data (Andersen, 2010) have been used for the years 2010-2035, as presented in Table 9.1.

Table 9.1 Historical and projected amounts of deposited waste at Danish landfill sites [Gg].

1990	1995	2000	2005	2010'	2015	2020	2025	2030	2035
3174	1978	1469	948	910	1034	1043	1080	1110	1160

The FRIDA model do not present information about the waste categories deposited at landfills as presented in the national waste statistics. Therefore, the projected total amounts of deposited waste, presented above, were distributed into fractions normalised according to the fractional distribution in the last historical year 2010 (Nielsen et al., 2012). The emission projection from 2010-2035 presented in Chapter 9.3 are based on the assumption of a constant fractional distribution of the individual waste types deposited waste. The distribution of the projected total amounts of waste into waste types were normalised according to the year 2010.

Table 9.2 Projected waste amounts according to nine ISAG waste types grouped according to the eight ISAG waste categories [Gg].

Year	Other combustible, domestic waste	Other combustible, bulky waste	Other Combustible, garden waste	Other Combustible, commercial & office waste	Other Combustible, building & constr. waste	Other Combustible, sludge waste	Other Combustible, ash & slag	Metal	Other not combustible	Total waste
2010	1,55	2,77	0,15	11,58	3,94	10,70	1,55	7,96	915,40	955,60
Norm 2010	0,0016	0,0029	0,0002	0,0121	0,0041	0,0112	0,0016	0,0083	0,9579	
2011	1,55	2,77	0,15	11,58	3,94	10,70	1,55	7,96	915,40	956
2012	1,69	3,01	0,17	12,62	4,29	11,66	1,69	8,67	997,55	1041
2013	1,69	3,01	0,17	12,59	4,28	11,63	1,69	8,65	995,12	1039
2014	1,68	3,00	0,17	12,56	4,27	11,60	1,68	8,63	992,70	1036
2015	1,68	2,99	0,17	12,53	4,26	11,57	1,68	8,61	990,27	1034
2016	1,68	2,98	0,17	12,50	4,25	11,54	1,68	8,59	987,85	1031
2017	1,68	2,99	0,17	12,53	4,26	11,58	1,68	8,61	990,62	1034
2018	1,69	3,00	0,17	12,57	4,28	11,61	1,69	8,64	993,38	1037
2019	1,69	3,01	0,17	12,60	4,29	11,64	1,69	8,66	996,15	1040
2020	1,70	3,02	0,17	12,64	4,30	11,67	1,70	8,69	998,92	1043
2021	1,71	3,04	0,17	12,73	4,33	11,76	1,71	8,75	1006,07	1050
2022	1,72	3,06	0,17	12,82	4,36	11,84	1,72	8,81	1013,23	1058
2023	1,73	3,08	0,17	12,91	4,39	11,92	1,73	8,87	1020,38	1065
2024	1,74	3,10	0,17	13,00	4,42	12,01	1,74	8,93	1027,53	1073
2025	1,76	3,13	0,17	13,09	4,45	12,09	1,76	9,00	1034,68	1080
2026	1,77	3,14	0,17	13,16	4,48	12,16	1,77	9,05	1040,39	1086
2027	1,78	3,16	0,17	13,23	4,50	12,23	1,78	9,10	1046,10	1092
2028	1,78	3,18	0,18	13,30	4,53	12,29	1,78	9,15	1051,81	1098
2029	1,79	3,20	0,18	13,38	4,55	12,36	1,79	9,19	1057,52	1104
2030	1,80	3,21	0,18	13,45	4,58	12,43	1,80	9,24	1063,23	1110
2031	1,82	3,24	0,18	13,57	4,62	12,54	1,82	9,33	1072,89	1120
2032	1,84	3,27	0,18	13,69	4,66	12,65	1,84	9,41	1082,54	1130
2033	1,85	3,30	0,18	13,81	4,70	12,76	1,85	9,50	1092,19	1140
2034	1,87	3,33	0,18	13,94	4,74	12,88	1,87	9,58	1101,85	1150
2035	1,89	3,36	0,19	14,06	4,78	12,99	1,89	9,66	1111,50	1160

9.2 Emissions model

The model has been developed and used in connection with the historic emissions inventories prepared for the United Nation Climate Convention. As a result, the model has been developed in accordance with the guidelines found in the IPCC Guidelines (1996) and IPCC Good Practice Guidance (2001). Based on the recommendation in these reports, a so-termed Tier 2 method, a decay model, has been selected for the model. The model is described in the National Inventory Report which is prepared for the Climate Convention, the latest being the 2012 NIR report (Nielsen et al., 2012). In short, the model assumes that the carbon in the deposited waste types decays and is converted to CH_4 according to first order degradation (FOD) kinetics and waste type specific half-life times. For a detailed description of the model and input parameters the reader is referred to Nielsen et al., 2012.

9.3 Historical emission data and Projections

Projections of quantities of waste produced, in connection with ISAG reporting, are carried out using the model FRIDA (FRemskrivning af Isag DAta – Projection of ISAG Data) (Andersen & Larsen, 2006). The model is a further development of the model described in the report from DEPA (Andersen et al., 1998) and is based on data from the information system for waste, ISAG, and the macroeconomic model, ADAM, assuming proportionality between the amounts of waste generated and the waste generating economic activity. Projection of the development in the amount of waste produced is based on the Ministry of Finance's projection of the economic development December 2008 (Danish Government, 2008).

The represented projection of emissions from solid waste disposal sites are based on total deposited amounts estimated based on the economic projection from 2008 (Andersen, 2010) even though a more updated economic survey (Danish Government, 2010) is available and accordingly an updated primary waste projection report published by the Danish EPA in august 2010 (DEPA, 2010). The estimated total amounts of generated waste do not differ significantly in the period 2010-2030 when comparing the projected amounts of primary waste production estimated from the economic projection models based on 2008 and 2009 data, respectively (Andersen, 2010; DEPA, 2010). Furthermore, the FRIDA 2009 report (Andersen, 2010) include, for the first time, projection estimates of the total amounts of deposited waste taking into account the Danish waste strategy plans (Andersen, 2010), these were used as input data for the landfill emission model.

The amount of recovered methane was estimated based on information from the Danish Energy statistics and a correlation analysis between historical data on the annual generated and collected amounts of methane. The amount of recovered methane is estimated to be stabilised around 7 % of the yearly generated methane since.

The content of degradable organic matter within each fraction and degradation rate and oxidation in top layers was set equal to the model input parameter values of the FOD model as described in Nielsen et al., 2012.

The emission projection uses the same CH_4 emission model used for calculation of the historic emissions. The resulting projections of the generated, recovered and net CH_4 emissions can be seen in Table 9.3 and Figure 9.1.

Table 9.3 Amount of waste deposited at landfill and CH_4 emissions. Historic data: 1993-2009. Projections: 2010-2030.

Year	Waste	Generated 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 eqv.
1990	3174	98,5	0,5	7,8	70,3	1477
1995	1978	53,1	8,0	6,7	60,1	1261
2000	1469	3,6	11,9	3,7	50,0	1050
2005	948	5,0	10,5	2,8	40,3	846
2010'	910	5,9	5,6	4,0	33,0	693
2015	1034	5,0	4,6	2,8	25,5	536
2020	1043	5,0	3,2	2,2	19,7	415
2025	1080	5,1	2,2	1,7	15,3	321
2030	1110	5,3	1,6	1,3	11,8	248
2035	1160	5,5	1,1	1,0	9,1	192

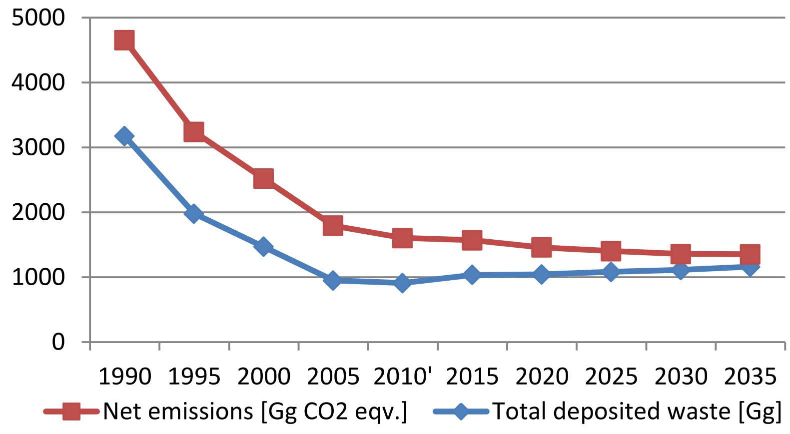


Figure 9.1 Historical and projected amounts of waste deposited at landfill and net CH_4 emissions. Historic data: 1993-2009. Projections: 2010-2035.

Due to a combination of the Danish waste strategies and goals of minimising the amount of deposited waste in replace of an increased reuse and combustion for energy production, the sharp decrease in historical data on the deposited amounts of waste is observed. The total amount of deposited waste has decreased by 70 % from 1990 to 2010 accompanied by a decrease in the methane emission of only 53 %. For projection period 2011-2035, an overall increase in the deposited amounts of waste is 21 % not taking into account, e.g., an increase in the fraction of WEEE being reused and i.e. not deposited; still the fractional distribution of the waste has moved towards a low carbon content, and a decrease a the methane emission of 71 % is estimated.

9.4 References

Andersen, F.M., Risø DTU, prepared for the .Danish Environmental Protection Agency, 2010. FRIDA – 2009. A model for projection of ISAG data. (In Danish: FRIDA – 2009. En model til fremskrivning af ISAG data.). Available at:
http://www.mst.dk/NR/rdonlyres/2803FDB0-89E8-4096-B4F9-E99868907EF1/0/Affaldsprognose2009.pdf

Andersen, F.M., Larsen, H.V., Forskningscenter Risø, prepared for the Danish Environmental Protection Agency, 2006. A model for projection of Danish waste amount data (ISAG) (In Danish: "En Model til Fremskrivning af Isag Data FRIDA". Summary and conclusions in English). Arbejdsrapport 35. Available at:
http://www2.mst.dk/udgiv/publikationer/2006/87-7052-239-1/pdf/87-7052-240-5.pdf

Andersen, F. M., Fenhann, J., Larsen, H., Schleisner, L., prepared for the Danish Environmental Protection Agency, 1998. A Scenario Model for the Generation of Waste. Environmental Project no. 434. Available at:
http://www.statensnet.dk/pligtarkiv/fremvis.pl?vaerkid=1950&reprid=0&iarkiv=1

Danish Government, 2008. Danmarks Konvergensprogram 2008. Available at:
http://ec.europa.eu/economy_finance/sgp/pdf/20_scps/2008-09/01_programme/dk_2008-12-04_cp_da.pdf

Danish Government, 2010. Danmarks Konvergensprogram 2009. Available at:
http://ec.europa.eu/economy_finance/sgp/pdf/20_scps/2009-10/01_programme/dk_2010-02-24_cp_da.pdf

Danish Environmental Projection Agency, 2010. Fremskrivning af affaldsmængder 2010-2050 (In English: Projection of waste amounts 2010-2050). Available at:
http://www.mst.dk/NR/rdonlyres/4EAE5003-89D5-4253-9BF5-BC50C5029FF7/0/fremskrivning_af_affaldsmaengder_2010.pdf

Nielsen, O.-K., Mikkelsen, M.H., Hoffmann, L., Gyldenkærne, S., Winther, M., Nielsen, M.,Fauser, P., Thomsen, M., Plejdrup, M.S., Albrektsen, R., Hjelgaard, K., Bruun, H.G.,Johannsen, V.K., Nord-Larsen, T., Bastrup-Birk, A., Vesterdal, L., Møller, I.S., Rasmussen,E., Arfaoui, K., Baunbæk, L. & Hansen, M.G. 2012. Denmark's National Inventory Report 2012. Emission Inventories 1990-2010 - Submitted under the United Nations Framework Convention on Climate Change and the Kyoto Protocol. Aarhus University, DCE – Danish Centre for Environment and Energy, 1168 pp. Scientific Report from DCE – Danish Centre for Environment and Energy No. 19. Available at: http://www2.dmu.dk/pub/sr19.pdf

10 Wastewater handling

The CRF source category *6.B Waste water handling,* constitutes emission of CH_4 and N_2O from wastewater collection and treatment.

10.1 Emission models and Activity Data

10.1.1 Methane emission

Methane emissions from the municipal and private wastewater treatment plants (WWTP) are 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. For a detailed description of the model equations and input parameters (process-specific emissions factors and activity data) the reader is referred to Nielsen et al., 2012. Below, a short overview of historical and projected key activity data is provided.

A key parameter is the influent degradable organic matter at the wastewater treatment plants, measured in units of biological oxygen demand (BOD), as presented in Table 10.1.

Table 10.1 Total degradable organic waste (TOW) and the contribution from industry to the influent TOW [tonnes BOD per year].

1990	1995	2000	2005	2010'	2015	2020	2025	2030	2035
97	117	141	150	146	148	150	153	155	157

Historical data: 1999-2010, Projected data: 2011-2030.

Projection from 2010 and forward is based on the assumption of the industrial contribution to the influent BOD having reached a constant level of 40.3 % since 2004 (Nielsen et al., 2012). From 2010 and forward, TOW increases according to population statistics (Table 10.2) assuming that only households contribute to the increase in the influent TOW.

Emission 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 are derived from the projected TOW data and population statistics. The projection of methane emissions from septic tanks are estimated from the population statistics and the assumption of ten per cent of the population not being connected to the sewerage system (Nielsen et al., 2012).

The fraction of wet weight sewage sludge treated anaerobic is set constant to the 2009 level of 34 %. From the influent TOW data and the amount of sludge treated anaerobic, the gross emission is derived. The fugitive emission from anaerobic process, all with energy production, equals 1 % of the gross methane emissions (Nielsen et al., 2012). Methane emission projections are provided in Chapter 10.2, Table 10.5.

10.1.2 Nitrous oxide

Both the direct and indirect N_2O emission from wastewater treatment processes is calculated based on country-specific and process specific emission factors (Nielsen et al., 2012) and the amount of nitrogen in the influent and effluent wastewater, respectively. The influent total N was verified to correlate and therefore projected according to population statistics. Population statistics are provided in Table 10.2.

Table 10.2 Population statistics (Statistics Denmark).

Year	1990	1995	2000	2005	2010'	2015	2020	2025	2030	2035
Population-Estimates (1000s)	5140	5228	5322	5411	5497	5633	5723	5821	5911	5984

Historical data: 1999-2010, Projected data: 2011-2030.

Table 10.3 Total N in the influent waste water [Mg].

Year	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035
Total N, influent	17614	26808	32342	38746	38247	38926	39551	40223	40850	41350

Historical data: 1999-2010, Projected data: 2011-2030.

For the total N in the effluents, the contribution from separate industries, rainwater conditioned effluents, scattered settlements and mariculture and fish farming, a decreasing trend followed by a close to constant level are observed and the 2010 emission data was kept constant throughout the projection period. The total N content in the effluent from WWTPs is increasing according to population statistics as shown in Table 10.4.

Table 10.4 Total N in the effluent waste water [Mg].

Years	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035
Total effluent N	16884	15152	10005	7038	7019	7090	7154	7223	7288	7340

Historical data: 1999-2010, Projected data: 2010-2030.

Implied emission factors, calculated as average emissions for the period 2005-2010 assuming constant industrial influent N load, and the population statistics have been used for projecting emissions from WWTPs. The emission projection for the total N_2O emission is provided in Table 10.6.

10.2 Historical emission data and projections

Historical and projected methane emissions are shown in Table 10.5.

Table 10.5 Gross, recovered, emissions for sewer system, anaerobic treatment, septic tanks and total net CH_4 emission [Gg].

Year	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035
CH_4, produced	16,64	20,08	34,58	30,50	29,83	25,52	25,92	25,27	25,66	26,09
CH_4, recovered	16,48	19,88	34,24	30,19	29,54	25,27	25,66	26,09	26,48	26,80
CH_4, emitted from sewer system	0,17	0,21	0,25	0,27	0,26	0,27	0,27	0,28	0,28	0,28
CH_4, septic tanks	2,81	2,86	2,91	2,96	3,01	3,08	3,13	3,19	3,24	3,28
CH_4, emission from anaerobic treatment	0,17	0,20	0,35	0,30	0,30	0,26	0,26	0,26	0,27	0,27
CH_4, net emission	3,15	3,27	3,51	3,54	3,57	3,61	3,66	3,73	3,78	3,83

Historical data: 1999-2010, Projected data: 2011-2030. Emissions for 2010 provided as an average of 2008-2010.

The total N_2O and net CH_4 emission figures converted to CO_2 equivalents and the sum up result for emissions from wastewater in total is given in Table 10.6.

Table 10.6 Net CH4, Indirect and direct N_2O emission and the sectoral total emission [CO_2 eqv.].

Year	1990	1995	2000	2005	'2010'	2015	2020	2025	2030	2035
Indirect N_2O	82,2	73,8	48,7	34,3	33,3	33,3	33,3	33,3	33,3	33,3
Direkte N_2O	27,2	41,5	50,0	59,9	57,2	58,2	59,2	60,2	61,1	61,9
Net CH_4	66,2	68,7	73,8	74,3	74,7	75,7	76,9	78,2	79,5	80,4
Total Emission	175,7	184,0	172,6	168,5	165,2	167,2	169,4	171,7	173,8	175,6

Emissions for 2010 provided as an average of 2008-2010.

10.3 Agreement of Green Growth, further measures

10.3.1 Scattered houses

Further upgrading of treatment technologies for decentralised WWTPs will result in a further reduction in the indirect emission of N to Danish freshwater systems. These will be included in the emission projections if national goals are defined for such development of the Danish wastewater management system. Likewise, reduced emissions from scattered settlements may be included as knowledge of 1)a reduction in the fraction of the population not connected to the municipal sewer system and 2) alternative solutions to the treatment of wastewater from scattered houses.

10.3.2 Indirect emissions from mariculture and fishfarming

The Agreement of Green Growth is a plan to improve conditions in aquaculture and marine fish farms. The allocated fund for aquaculture is not included in the calculations. The deduced N amount to streams from aquaculture is approx. 800-1000 tonnes N/year. However, it is unknown how big an impact the Agreement of Green Growth will have on the indirect emission from mariculture and fish farming and therefore the expected increased N effluent from these activities has not been included this in the projection.

10.3.3 References

Nielsen, O.-K., Mikkelsen, M.H., Hoffmann, L., Gyldenkærne, S., Winther, M., Nielsen, M.,Fauser, P., Thomsen, M., Plejdrup, M.S., Albrektsen, R., Hjelgaard, K., Bruun, H.G.,Johannsen, V.K., Nord-Larsen, T., Bastrup-Birk, A., Vesterdal, L., Møller, I.S., Rasmussen,E., Arfaoui, K., Baunbæk, L. & Hansen, M.G. 2012. Denmark's National Inventory Report 2012. Emission Inventories 1990-2010 - Submitted under the United Nations Framework Convention on Climate Change and the Kyoto Protocol. Aarhus University, DCE – Danish Centre for Environment and Energy, 1168 pp. Scientific Report from DCE – Danish Centre for Environment and Energy No. 19. Available at: http://www2.dmu.dk/pub/sr19.pdf

11 Waste Incineration

The CRF source category *6.C Waste Incineration,* includes cremation of human bodies and cremation of animal carcasses.

Incineration of municipal, industrial, clinical and hazardous waste takes place with energy recovery, therefore the emissions are included in the relevant subsectors under CRF sector 1A. For documentation please refer to Chapter 2. Flaring off-shore and in refineries are included under CRF sector 1B2c, for documentation please refer to Chapter 3. No flaring in chemical industry occurs in Denmark.

Table 11.1 gives an overview of the projections of the Danish greenhouse gas emissions from the CRF source category 6.C waste incineration.

CO_2 emissions from cremations of human bodies and animal carcasses are biogenic and therefore not included in the CO_2 equivalents.

Table 11.1 Projection of greenhouse gas emissions from the incineration of human bodies and animal carcasses.

	Unit	1990	2000	2005	2010	'2010'*	2015	2020	2025	2030	2035
CO_2 emission from											
Human cremation	Gg	2.05	2.08	2.04	2.10	2.13	2.24	2.34	2.45	2.56	2.66
Animal cremation	Gg	0.12	0.34	0.59	1.12	1.05	1.04	1.04	1.04	1.04	1.04
Total biogenic	Gg	2.17	2.43	2.63	3.22	3.18	3.28	3.38	3.49	3.60	3.70
CH_4 emission from											
Human cremation	Mg	0.48	0.49	0.48	0.49	0.50	0.53	0.55	0.58	0.60	0.62
Animal cremation	Mg	0.03	0.08	0.14	0.26	0.25	0.24	0.24	0.24	0.24	0.24
Total	Mg	0.51	0.57	0.62	0.76	0.75	0.77	0.79	0.82	0.85	0.87
N_2O emission from											
Human cremation	Mg	0.60	0.61	0.60	0.62	0.63	0.66	0.69	0.72	0.75	0.78
Animal cremation	Mg	0.03	0.10	0.17	0.33	0.31	0.31	0.31	0.31	0.31	0.31
Total	Mg	0.64	0.71	0.77	0.95	0.93	0.96	0.99	1.03	1.06	1.09
6C. Waste incineration											
Non-biogenic											
CO_2 equivalents	Gg	0.21	0.23	0.25	0.31	0.31	0.31	0.32	0.34	0.35	0.36

*Average of historical years 2008-2010 and projection for 2011-2012.

11.1 Human cremation

It is assumed that no drastic changes are made in the subject of human cremation that will influence greenhouse gas emissions.

The projection of greenhouse gas emissions from human cremation is performed based on a projection of population done by Statistics Denmark and on known developments from the last two decades. The development in the total number of cremations and the cremation fraction in relation to the total number of deceased are shown in Figure 11.1 for 1990-2010.

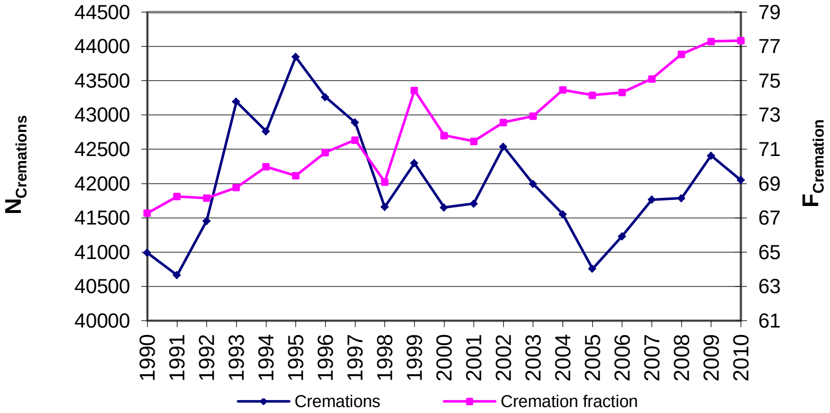


Figure 11.1 The development in the number of yearly cremations.

Based on this historical development, it is assumed that the increase of the cremation fraction will continue, and that the increase can be described by the linear regression based on 1990-2010 data. By comparing data for population with the yearly number of deceased for the years 1901-2010, the fraction of deaths is found to be 1 %.

Table 11.2 Projection of the population. number of deaths. cremation fraction and number of cremations.

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Population	5560628	5579374	5597569	5615414	5633081	5650726	5668496	5686490	5704827	5723492
Deaths	55606	55794	55976	56154	56331	56507	56685	56865	57048	57235
Cremation fraction	77.4 %	77.9 %	78.4 %	78.8 %	79.3 %	79.8 %	80.3 %	80.7 %	81.2 %	81.7 %
Cremations	43043	43453	43861	44267	44674	45083	45494	45908	46327	46750
Continued										
	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Population	5742554	5761948	5781575	5801256	5820779	5840049	5858832	5877052	5894632	5911483
Deaths	57426	57619	57816	58013	58208	58400	58588	58771	58946	59115
Cremation fraction	82.2 %	82.6 %	83.1 %	83.6 %	84.1 %	84.5 %	85.0 %	85.5 %	86.0 %	86.4 %
Cremations	47179	47612	48048	48488	48927	49366	49804	50238	50668	51093
Continued										
	2031	2032	2033	2034	2035					
Population	5927529	5942754	5957206	5970834	5983797					
Deaths	59275	59428	59572	59708	59838					
Cremation fraction	86.9 %	87.4 %	87.9 %	88.3 %	88.8 %					
Cremations	51513	51928	52337	52741	53139					

The projection of greenhouse gas emissions from human cremation shown in Table 11.1 is calculated by multiplying the estimated activity data from Table 11.2 with the emission factors known from Nielsen et al. (2012).

11.2 Animal cremation

Historically, the development in the amount of cremated animal carcasses is difficult to explain. It is therefore also difficult to predict the future development. Figure 11.2 shows historical data from 1998-2010.

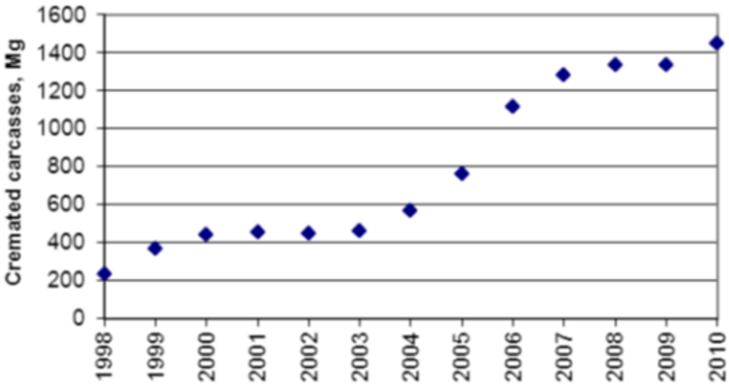


Figure 11.2 Cremated amount of carcasses, 1998-2010.

It is assumed that the 2011-2035 projection of activity data for animal cremation can be described by the constant average of the years 2007-2010.

Table 11.3 Amount of incinerated carcasses.

	2007	2008	2009	2010	Average
Cremated carcasses, Mg	1284.2	1338.3	1338.9	1448.7	1352.5

The projection of greenhouse gas emissions from animal cremation shown in Table 11.1 are calculated by multiplying the estimated activity data from Table 11.3 with the emission factors known from Nielsen et al. (2012).

11.3 Source specific recalculations

Changes were made in the activity data for this year's submission. Activity data for human cremation is based on a projection of population made by Statistics Denmark, this projection is updated each year.

Activity data for animal cremation was also updated. In last year's submission animal cremation was estimated as the average of 2007-2009 data, this year's submission uses the average of 2007-2010.

No changes were made to emission factors or methodology in the waste incineration category.

Table 11.4 Recalculations in CO_2 equivalents.

	2011	2012	2013	2014	2015	2020	2025	2030
Human cremation, Mg	0.5	0.6	0.7	0.9	1.0	1.7	2.3	2.8
Animal cremation, Mg	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4
Total 6C, Mg	2.8	3.0	3.1	3.2	3.4	4.0	4.6	5.2
Fraction, %	0.9	1.0	1.0	1.0	1.1	1.3	1.4	1.5

11.4 References

Nielsen, O.-K., Mikkelsen, M.H., Hoffmann, L., Gyldenkærne, S., Winther, M., Nielsen, M., Fauser, P., Thomsen, M., Plejdrup, M.S., Albrekt-sen, R., Hjelgaard, K., Bruun, H.G., Johannsen, V.K., Nord-Larsen, T., Bastrup-Birk, A., Vesterdal, L., Møller, I.S., Rasmussen, E., Arfaoui, K., Baunbæk, L. & Hansen, M.G. 2012: Denmark's National Inventory Report 2012 – Emission Inventories 1990-2010 - Submitted under the United Nations Framework Convention on Climate Change and the Kyoto Protocol. Aarhus University, DCE – Danish Centre for Environment and Energy, 1168 pp. Scientific Report from DCE – Danish Centre for Environment and Energy No. 19. Available at: http://www2.dmu.dk/Pub/FR827.pdf

Statistics Denmark, StatBank Denmark 2011. Available at: http://www.statistikbanken.dk/statbank5a/default.asp?w=1024 (Danish/English) (1/8-2012).

12 Waste Other

This category is a catch all for the waste sector. Emissions in this category could stem from accidental fires, sludge spreading, compost production, biogas production and other combustion. Currently, the projections in this section cover accidental fires and compost production.

Table 12.1 gives an overview of the Danish non-biogenic greenhouse gas emission from the CRF source category *6.D waste other*.

CO_2 emissions from compost production are considered to be biogenic. Buildings have a high content of wood both in the structure and in the interior; this leads to 82 % of the CO_2 emission from accidental building fires to be biogenic.

Table 12.1 Projection of overall emission of greenhouse gases from accidental fires and compost production.

	Unit	1990	2000	2005	2010	'2010'*	2015	2020	2025	2030	2035
CO_2 emission from											
Building fires	Gg	11.46	11.58	11.34	11.14	12.55	12.78	12.78	12.78	12.78	12.78
Vehicle fires	Gg	6.88	7.24	6.92	7.11	7.45	6.64	6.80	7.05	7.32	7.33
Total non-biogenic	Gg	18.34	18.82	18.26	18.24	20.00	19.42	19.58	19.83	20.10	20.11
CH_4 emission from											
Building fires	Mg	64.16	64.88	63.78	64.62	70.88	71.88	71.88	71.88	71.88	71.88
Vehicle fires	Mg	14.34	15.08	14.42	14.80	15.53	13.83	14.17	14.68	15.26	15.28
Compost production	Mg	1268.82	2882.60	3086.68	3829.54	3622.18	3991.21	4393.91	4796.60	5199.30	5602.00
Total	Mg	1347.32	2962.56	3164.88	3908.96	3708.58	4076.92	4479.96	4883.17	5286.44	5689.15
N_2O emission from											
Compost production	Mg	36.17	130.90	100.56	137.57	130.42	147.01	163.84	180.66	197.49	214.32
Total	Mg	36.17	130.90	100.56	137.57	130.42	147.01	163.84	180.66	197.49	214.32
6C. Waste incineration											
Non-biogenic CO_2 equivalents	Gg	57.85	121.61	115.89	142.98	138.31	150.61	164.45	178.38	192.34	206.02

*Average of historical years 2008-2010 and projection for 2011-2012.

12.1 Sludge spreading

Sludge from waste water treatment plants is only spread out in the open with the purpose of fertilising crop fields. Any greenhouse emissions that might derive from this activity are estimated in Chapter 8 (CRF Sector 4).

12.2 Biogas production

Emissions from biogas production are divided and reported in different sections according to use.

For the biogas production from organic waste with the purpose of energy production, see Chapter 2, Stationary Combustion.

Biogas production from manure is included in Chapter 8, Agriculture.

Emissions from wastewater handling are described in Chapter 10, Wastewater Treatment.

12.3 Other combustion

Other waste types under the "Waste Other" category are the open burning of yard waste and bonfires.

Occurrence of wild fires and crop burnings are categorised under Chapter 13 LULUCF and 8 Agriculture respectfully.

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 banning (DEPA, 2011b). There is no registration of private waste burning and the activity data on this subject are very difficult to estimate. People are generally incited to compost their yard waste or to dispose of it through one of the many waste disposal/-recycling sites.

The occurrence of bonfires at midsummer night and in general are likewise not registered, therefore it has not been possible to obtain historical activity data or to predict the development of this activity.

12.4 Accidental building fires

Activity data for building fires are classified in four categories: full, large, medium and small. The emission factors comply for full scale building fires and the activity data is therefore recalculated as a full scale equivalent (FSE). Here it is assumed that a full, large, medium and a small scale fire makes up 100 %, 75 %, 30 % and 5 % of a FSE respectively.

Calculations of greenhouse gas emissions for 1990-2010 are based on surrogate data and on detailed information for 2007-2010 given by the Danish Emergency Management Agency (DEMA). Because of the very limited amount of detailed historical information available, it has been difficult to predict the future development of this activity. Activity data for accidental building fires are therefore chosen as the average of 2007-2010 data.

Table 12.2 Number of accidental building fires 2006-2009.

	2007	2008	2009	2010	Average
Container FSE fires	958	1004	841	623	856
Detached house FSE fires	757	886	876	833	838
Undetached house FSE fires	343	278	208	194	255
Apartment building FSE fires	405	433	413	348	400
Industrial building FSE fires	435	346	344	281	352
Additional building FSE fires	483	523	466	429	475
All building FSE fires	3380	3470	3148	2707	3176

By assuming that building compositions and sizes will not significantly change over the next 25 years, the emission factors known from Nielsen et al. (2012) are used for this projection.

Table 12.3 Emission factors for accidental building fires.

	Unit	Containers	Detached houses	Undetached houses	Apartment buildings	Industrial buildings	Additional buildings
CH_4	kg per fire	0.3	42.3	34.7	20.0	52.0	2.1
CO_2	Mg per fire	1.8	32.0	26.2	15.1	78.1	3.9
Where from:							
biogenic	Mg pr fire	0.2	26.1	21.4	12.3	67.6	3.2
non-biogenic	Mg pr fire	1.7	5.9	4.9	2.8	10.5	0.7
N_2O	-	NAV	NAV	NAV	NAV	NAV	NAV

Greenhouse gas emissions from accidental building fires in 2011-2035 are shown in Table 12.1.

12.5 Accidental vehicle fires

The Danish Emergency Management Agency (DEMA) provides data for the total number of accidental vehicle fires 2007-2010 divided into the categories; passenger cars, light duty vehicles, heavy duty vehicles, buses, motorcycles/mopeds, other transport, caravans, trains, ships, airplanes, bicycles, tractors, combined harvesters and machines.

DTU transport (Jensen & Kveiborg, 2011) provides the national population of vehicles in these same categories for historical years as well as a projection of the 2011-2030 vehicle population, 2031-2035 data are assumed constant on a 2030 level. These data are shown in Table 12.4.

Table 12.4 Population of vehicles.

	Passenger cars	Buses	Light duty vehicles	Heavy duty vehicles	Motorcycles /mopeds	Caravan	Train	Ship	Airplane	Tractor	Combined harvester
1990	1645587	8109	192321	45664	164111	86257	7156	2324	1055	135980	35118
2000	1916686	15051	272387	50227	233695	106935	4907	1759	1070	115692	24128
2005	2012399	15131	372674	49311	274264	121350	3195	1792	1073	107867	21436
2010	2247021	14577	362389	44812	301766	142354	2740	1773	1152	106025	19354
2015	2115246	14578	402306	48661	304533	151398	2609	1750	1110	87069	12555
2020	2178575	14582	425145	52773	313901	165216	2609	1750	1119	77755	12343
2025	2287251	14585	460352	57262	321811	179033	2609	1750	1129	78220	11154
2030	2396376	14587	493994	61748	332635	192851	2609	1750	1139	75710	11080

The data quality for vehicle fires for 2007-2010 is of a very high standard. These data are, like the data for building fires, divided into four damage rate categories; full, large, medium and small. A full, large, medium and small scale fire, leads to 100, 75, 30 and 5 % burnout, respectively. From these data, an average full scale equivalent (FSE) is calculated for each vehicle category.

Table 12.5 Average number of full scale vehicle fires relative to the total number of nationally registered vehicles, for 2007-2010.

Category	Fraction %
Passenger cars	0.03
Buses	0.14
Light duty vehicles	0.01
Heavy duty vehicles	0.13
Motorcycles/Mopeds	0.04
Caravan	0.03
Train	0.12
Ship	1.11
Airplane	0.07
Tractor	0.06
Combined Harvester	0.16

There is no data for the population of the categories; other transport, bicycles and machines. For these categories the average FSE fires for 2007-2010 is used in the projection 2011-2035.

By assuming that the average number of FSE fires from 2007-2010 (shown in Table 12.5), is applicable for describing the risk of accidental fires in the future vehicle population, activity data for the projection 2011-2035 can be calculated.

Table 12.6 Projection of number of full scale equivalent accidental vehicle fires.

	1990	2000	2005	2010	2015	2020	2025	2030	2035
Passenger cars	479	558	586	646	616	634	666	698	698
Buses	12	22	22	23	21	21	21	21	21
Light duty vehicles	19	26	36	38	39	41	45	48	48
Heavy duty vehicles	58	64	63	60	62	67	73	78	78
Motorcycles/mopeds	58	83	97	83	108	111	114	117	117
Other transport	-	-	-	58	83	83	83	83	83
Caravan	24	29	33	37	42	45	49	53	57
Train	9	6	4	2	3	3	3	3	3
Ship	26	19	20	16	19	19	19	19	19
Airplane	1	1	1	1	1	1	1	1	1
Bicycle	-	-	-	4	3	3	3	3	3
Tractor	82	70	65	77	52	47	47	46	46
Combined harvester	57	39	35	32	20	20	18	18	18
Machine	-	-	-	94	104	104	104	104	104

It is assumed that no significant changes in the average vehicle weight will occur during the next 25 years. The average weight of passenger cars, light duty vehicles, trucks, busses and motorcycles/mopeds are known for 2010 (Statistics Denmark, 2011). The average weight of the units from the remaining categories is estimated by an expert judgement.

Table 12.7 Average vehicle weight in 2010, kg.

Passenger cars	1144
Buses	11804
Light duty vehicles	4498
Heavy duty vehicles	11883
Motorcycles/Mopeds	104

It is assumed that the average weight of a bus equals that of a ship. That vans and tractors weigh the same and that trucks have the same average weight as trains, airplanes and combined harvesters.

Bicycles, machines and other transport can only be calculated for the years 2007-2010 due to the lack of surrogate data (number of nationally registered vehicles). The average weight of a bicycle, caravan, machine and other transport is set 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 results are shown in Table 12.8.

Table 12.8 Activity data for accidental vehicle fires.

	Burnt mass of vehicles, Mg
1990	2867
2000	3016
2005	2884
2010	2960
2015	2766
2020	2834
2025	2936
2030	3051
2035	3055

By assuming that vehicle compositions will not significantly change over the next 25 years, the emission factors known from Nielsen et al. (2012) are used for this projection.

Table 12.9 Emission factors for accidental vehicle fires.

	Unit	Vehicle
CH_4	kg per Mg	5
CO_2, fossil	Mg per Mg	2.4
N_2O	-	NAV

Calculated emissions are shown in Table 12.1.

12.6 Compost production

In Denmark, composting of solid biological waste includes composting of:

- garden and park waste (GPW),
- organic waste from households and other sources,
- sludge and,
- home composting of garden and vegetable food waste.

The future activity of each category has been projected individually.

Garden and park waste is for 1995-2009 determined based on the Danish waste statistics (DEPA, 2011a) and on the two statistical reports Petersen (2001) and Petersen & Hansen (2003). The projection of this waste category is made from the linear regression of the 1999-2009 activity data. The 1995-1998 data is not used for the projection because the strong increase for these years does not match the 1999-2009 trend.

Activity data for both waste-categories; organic waste from households and other sources and sludge, are for the historical years 1995-2009 based on data from the Danish waste statistics. The projection of organic waste is carried out as an average of the activity data from 1995-2009 and sludge as an expert judgement.

Home composting of garden and vegetable food waste is for 1990-2010 determined based on data from Statistics Denmark and on Petersen & Kielland (2003). The 1990-2010 data is used in a linear regression to project home composting for 2011-2035.

Table 12.10 Projected activity data for compost production.

Gg	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Garden and park waste	839	858	877	896	914	933	952	971	990	1009
Organic waste	50	50	50	50	50	50	50	50	50	50
Sludge	125	130	135	140	145	150	155	160	165	170
Home composting	23	23	23	23	23	23	24	24	24	24
Continued										
	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Garden and park waste	1028	1047	1066	1085	1104	1123	1142	1161	1180	1199
Organic waste	50	50	50	50	50	50	50	50	50	50
Sludge	175	180	185	190	195	200	205	210	215	220
Home composting	24	24	24	25	25	25	25	25	25	25
Continued										
	2031	2032	2033	2034	2035					
Garden and park waste	1218	1237	1256	1275	1293					
Organic waste	50	50	50	50	50					
Sludge	225	230	235	240	245					
Home composting	25	26	26	26	26					

By assuming that the process of compost production will not significantly change over the next 25 years, the emission factors known from Nielsen et al. (2012) are used for this projection.

Table 12.11 Emission factors for compost production.

		Garden and Park waste	Organic waste	Sludge	Home composting
CH_4	Mg per Gg	4.20	0.27	0.04	5.63
N_2O	Mg per Gg	0.12	0.07	0.22	0.11

Calculated emissions are shown in Table 12.1.

12.7 Source specific recalculations

12.7.1 Composting

The high amount of composted sludge in 2010 results in a projection that is higher than that of last year's submission. The increase is 20 Gg or 19 % in 2011 (20 Gg or 10 % in 2030). The increasing slope of the projection is unchanged.

12.7.2 Accidental building fires

Accidental fires in containers and additional buildings are both new categories in this year's submission. This improvement has led to both an increase in emissions from the 172 extra full scale equivalent fires that were not previously included, but also a decrease in emission because fires in additional buildings (sheds, greenhouses, garages, etc.) have previously been reported as detached buildings which have a much higher average floor space, content mass and hence emission factor.

Additionally there are now four damage categories; full, large, medium and small scale fires, corresponding to 100, 75, 30 and 5 % damage rate respectfully. In last year's submission there were only three.

The effect of these changes is a reduction of 46 % for CH_4 and 26 % for CO_2 for all years 2011-2030.

12.7.3 Accidental vehicle fires

For accidental vehicle fires, this year's submission introduces a differentiated damage rates similar to those used for building fires. Previously, an average burn out rate of 70 % was assumed overall for vehicle fires, but in this submission the damage rate is divided in four damage categories according to the measure of fire extinguishing; full, large, medium and small scale fires, corresponding to 100, 75, 30 and 5 % damage rate respectfully. This improvement leads to a decrease in emissions, as the new data that have been analysed show that the actual average burn out for 2007-2010 where data are available is 34 %.

Also the activity data now includes other transport, trains, ships, airplanes, bicycles, tractors, combined harvesters and machines.

The joint effect of these two improvements in methodology is a decrease in the projection of emissions.

The decrease caused by the two improvements is between 2.5 % (2011) and 3.5 % (2030) calculated for overall CO2 equivalent emissions for vehicle fires.

12.8 References

Danish Emergency Management Agency (DEMA), Beredskabsstyrrelsen, statistikbanken. Available at: https://statistikbank.brs.dk/sb/main/p/a0109 (in Danish) (01/8-2012)

Danish Environmental Protection Agency (DEPA), 2011a: Affaldsstatistik 2009 og fremskrivning af affaldsmængder 2011-2050. (Waste Statistics 2009). Available at: http://www2.mst.dk/udgiv/publikationer/2011/10/978-87-92779-44-1/978-87-92779-44-1.pdf (01/31/2012) (in Danish).

Danish Environmental Protection Agency (DEPA), 2011b: Legislation on waste (Affaldsbekendtgørelsen), BEK nr. 1415 af 12/12/2011 Gældende, Chapter 7, §46 and §47. Available at: https://www.retsinformation.dk/forms/r0710.aspx?id=139654#Kap7 (in Danish) (02/06/2012).

Jensen, T.C., Kveiborg, O. 2011: Dokumentation af konvertering af trafiktal til emissionsopgørelser, arbejdsnotat, 22 pp. DTU Transport, 2011.

Nielsen, O.-K., Mikkelsen, M.H., Hoffmann, L., Gyldenkærne, S., Winther, M., Nielsen, M., Fauser, P., Thomsen, M., Plejdrup, M.S., Albrekt-sen, R., Hjelgaard, K., Bruun, H.G., Johannsen, V.K., Nord-Larsen, T., Bastrup-Birk, A., Vesterdal, L., Møller, I.S., Rasmussen, E., Arfaoui, K., Baunbæk, L. & Hansen, M.G. 2012: Denmark's National Inventory Report 2012 – Emission Inventories 1990-2010 - Submitted under the United Nations Framework Convention on Climate Change and the Kyoto Protocol. Aarhus University, DCE – Danish Centre for Environment and Energy, 1168 pp. Scientific Report from DCE – Danish Centre for Environment and Energy No. 19. Available at: http://www2.dmu.dk/Pub/FR827.pdf (01/8-2012)

Petersen, C., 2011: Statistik for behandling af organisk affald fra husholdninger – Revideret udgave, 1999 (Statistics for treatment of organic waste from households – revised version), ECONET A/S, Miljøprojekt Nr. 654 2001, Miljøstyrelsen, Miljøministeriet. Available at: http://www2.mst.dk/Udgiv/publikationer/2001/87-7944-932-8/pdf/87-7944-933-6.pdf (in Danish) (01/8-2012).

Petersen, C.& Hansen, V. L., 2003: Statistik for behandling af organisk affald fra husholdninger 2001 (Statistics for treatment of organic waste from households), ECONET A/S. Miljøprojekt Nr. 856 2003, Miljøstyrelsen, Miljøministeriet. Available at: http://www2.mst.dk/Udgiv/publikationer/2003/87-7972-962-2/pdf/87-7972-963-0.pdf (in Danish) (01/8-2012).

Petersen, C. & Kielland, M., 2003: Statistik for hjemmekompostering 2001 (Statistics on home composting), Econet A/S. Miljøprojekt Nr. 855 2003, Miljøstyrelsen, Miljøministeriet. Available at: http://www2.mst.dk/udgiv/publikationer/2003/87-7972-960-6/pdf/87-7972-961-4.pdf (in Danish) (01/8-2012).

Statistics Denmark, StatBank Denmark 2011. Available at: http://www.statistikbanken.dk/statbank5a/default.asp?w=1024 (in Danish/English) (01/8-2012).

13 LULUCF

The emission of GHGs from the LULUCF sector (Land Use, Land Use Change and Forestry) includes primarily the emission of CO_2 from land use and small amounts of N_2O from disturbance of soils not included in the agricultural sector.

The LULUCF sector is subdivided into six major categories:

- Forest
- Cropland
- Grassland
- Wetlands
- Settlements
- Other Land

The projections are made on best available knowledge on the past development in the land use in Denmark and expectations for the future. Regarding the methodology for estimation of the sources/sinks from the different sectors, see Chapter 7 in Nielsen et al. (2012).

Approximately two thirds of the total Danish land area is cultivated and 13.4 per cent is forest, Figure 13.1. Intensive cultivation and large numbers of animals exerts a high pressure on the landscape, and regulations have been adopted to reduce this pressure. The adopted policy aims at doubling the forested area within the next 80-100 years, restoration of former wetlands and establishment of protected national parks. In Denmark almost all natural habitats and all forests are protected. Therefore only limited conversions from forest or wetlands into cropland or grassland has occurred and is expected to occur in the future.

Figure 13.1 shows the land use in 1990, 2010 and the expected land use in 2035. A decrease in cropland is expected. The conversion is mainly from Cropland to Forest, Grassland and Settlements. It should be noted that the definition of the LULUCF-sectors differs slightly from the normal Danish land use definitions and the shown distribution will therefore differ from other national statistics.

Land use conversions impacts whether a category is a sink or a source. In the following, emissions by sources are given as positive values (+) and removals by sinks are given as negative values (-).

Under the Kyoto protocol, Denmark has selected Forest Management, Cropland Management and Grazing Land Management under article 3.4 to meet its reduction commitments besides the obligatory Afforestation, Reforestation and Deforestation under article 3.3. Since land, which is converted from one category to another (e.g. from Cropland to Settlements), cannot be omitted from the reporting obligation under the Kyoto Protocol, the actual estimates in each category reported under the Convention, may not be the same as accounted for under the Kyoto Protocol, see Section 13.11.

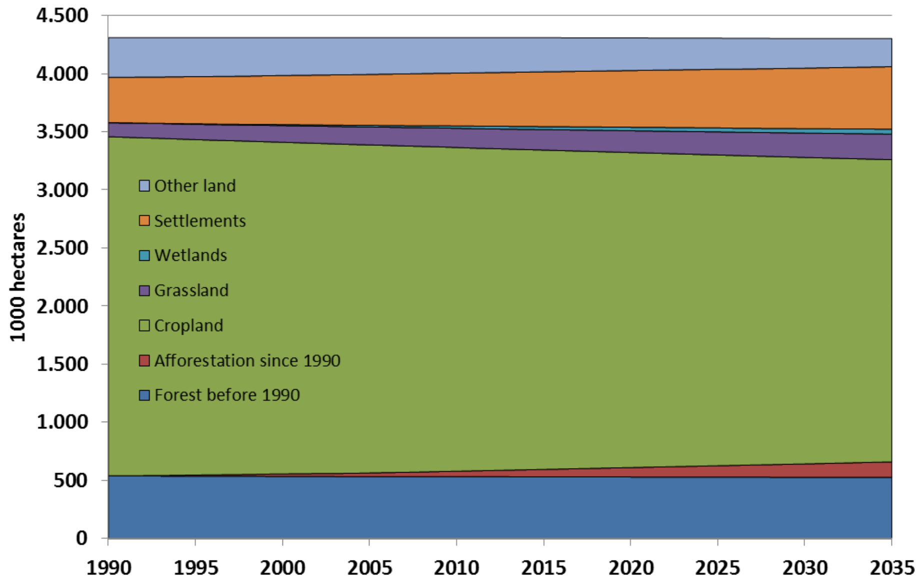


Figure 13.1 Land area use 1990-2035.

13.1 Forest

The emission/sink estimates from the Danish forest are based on the report "Submission of information on forest management reference levels" (Johannsen et al., 2011). This report includes these estimates. The same planting and harvesting rate is used in 2020 to 2035 as in 2019 as well as increase and decrease in carbon stocks. Further information on the forest projections in relation to Denmark's commitment under the Kyoto-protocol is given in Chapter 13.11.

Since 1990 the forested area has increased. This is expected to continue in the future as a Danish policy aim is to double the forest area from 1980 to 2080. Afforestation is expected to take place on 1 745 hectares per year in the future. The cumulative effect of the afforestation since 1990 combined with carbon stock changes in the existing forests indicate an annual increase in the total carbon stock in the Danish forests of approximately 400-500 Gg CO_2 per year in the period 2010 to 2035 (as further described in Chapter 13.11).

The Danish forests are well protected and only limited deforestation is expected to occur in connection with new settlements and building of new infrastructure. It is assumed that deforestation will take place on a limited area of 264 hectares per year until 2035. Deforestation is therefore estimated to be responsible for an emission of around 85-90 Gg CO_2 eqv. per year (as further described in Chapter 13.11).The old forest existing before 1990 is in the longer term assumed to be net source of approx. 40-50 Gg CO_2 eqv. per year after a reduction for deforestation.

In total, the amount of living and dead biomass in the Danish forests is expected to increase with around 110 Gg C per year in the future (Table 13.1). The mineral forest soils in afforestation are also expected to have total net build-up. The forested soils at equilibrium are expected to have a C content of 158 t per ha (0-100 cm) which is a higher carbon stock than the soils which is afforested (for cropland is an average of 151 tonnes used). No changes in the carbon stock are expected in mineral forest soils for forests existing before 1990. The organic forest soils are expected to have a continuous emission associated with drainage.

Table 13.1 Annual changes in area and carbon stock (inclusive N_2O emission from forest soils) until 2035.

	1990	2000	2008	2009	2010	2011	2012	2015	2020	2025	2030	2035
Area, 1000 ha	539.6	556.6	573.1	576.4	579.7	582.7	585.9	595.3	611.1	626.9	642.7	659.8
Living and dead biomass, Gg C	-241.7	513.7	-281.6	-985.9	-1554.5	-242.6	-124.4	-136.4	-112.4	-112.4	-112.4	-112.4
Mineral soils, Gg C	-0.1	-3.1	-5.7	-6.2	-6.7	-7.2	-7.7	-9.1	-11.6	-14.0	-16.5	-18.9
Organic soils, Gg C	13.8	11.6	9.8	9.6	9.7	9.7	9.8	9.9	10.1	10.3	10.5	10.7
Total, Gg C	-228.0	522.2	-277.5	-982.5	-1551.5	-240.0	-122.3	-135.7	-113.9	-116.2	-118.4	-120.7
Total, CO_2	-835.9	1914.8	-1017.4	-3602.5	-5688.9	-880.2	-448.5	-497.5	-417.7	-426.0	-434.2	-442.5
CH_4, Mg CH_4	26.07	0.00	0.00	0.00	0.00	0.00	0.00	0.35	0.35	0.35	0.35	0.35
N_2O, Mg N_2O	32.87	28.67	26.52	26.26	26.26	26.25	26.23	26.21	26.14	26.07	26.00	25.99
Total, Gg CO_2 eqv.	-825.7	1923.6	-1009.2	-3594.4	-5680.8	-872.0	-440.4	-489.4	-409.6	-417.9	-426.1	-434.4

Note: removals by sinks are given as negative values (-) and emission by sources are given as positive values (+).

The small CH_4 emission is due to wild fires in the forests.

A very high variability in the emission estimates for forests established before 1990 is noted for the year 2008 to 2012. The high variability is primarily due to the new National Forest Inventory, which was established in 2002 and introduced in the GHG inventory but still needs a couple of years of monitoring before a stabilisation in the C stock estimates can be expected.

13.2 Cropland

Agriculture occupies the major part of the Danish territory. In total approximately 2.7 million hectares are utilised for agricultural activities.

Cropland is subdivided into four types: Agricultural cropland which is the area defined by Statistics Denmark, Wooden agricultural crops which are fruit trees, willow etc., Hedgerows and small biotopes and “other agricultural land”. The latter is defined as the difference between the area in the national statistics and the Cropland area defined by satellite monitoring cadastral information. This area varies slightly between years due to annual differences in agricultural area reported by Statistics Denmark.

In Cropland five different carbon pools are accounted for: Above ground living biomass, below ground living biomass, dead wood, litter and soil organic carbon (SOC). The major part of the cropland area is covered with annual crops. Approximately 60.000 hectares are covered with hedgerows or small biotopes that do not meet the definition of forest.

13.2.1 Agricultural cropland

The area with Cropland has decreased over the last 20 years primarily due to urbanisation and afforestation. This is expected to continue in the future. The area with agricultural crops has declined with 141 000 hectares from 1990 to 2000 or 14 100 hectares per year. From 2000 to 2010 the reduction in the area with agricultural crops was only 23 000 hectares or 2 500 hectares per year. The reduced loss of agricultural land to other land uses can be attributed to less need of land for settlements and other infrastructure, but more importantly, the EU subsidiary system has changed and as a result more agricultural cropland is reported to Statistics Denmark than previously. Because of this irregularity it is assumed that the average loss is 6 500 hectares of agricultural cropland every year in the projection.

The Danish government has planned that 50 000 hectares along water courses shall be unmanaged grassland by the end of 2012 (Ministry of the Environment, 2009). This is implemented by September 1st 2012 as a 10 meter buffer zone along all water courses and ponds. Currently there is a 2 m buffer zone. The buffer zones will be grassland and must not be ploughed, fertilised or sprayed with pesticides. No changes in the drainage in the zones are expected. It is currently unknown on which soil types these zones will be established, but is must be assumed that many of these buffer zones are low laying areas, which are already cultivated with grass. It can therefore be assumed that the organic soils will continue to have high rates of organic matter decomposition and consequently high emissions and that the annual crops will be converted to low input perennial grass. The establishment of buffer zones is therefore expected to have a small influence on the overall emission.

13.2.2 Methodology

The amount/change of living biomass in Cropland is by default estimated as the amount of living biomass at its peak, e.g. just before harvest. This peak is estimated as the average barley yield for the 10 year period 1999 to 2008.

As a consequence of the loss of agricultural cropland the amount of living biomass will be reduced according to the conversion and thus reported as a loss. Due to the reduced area with agricultural cropland an average loss of biomass of approx. 35 Gg C per year is expected. This is partly counteracted by an increase in the amount of living biomass in the land class to which it is converted.

The change in Soil Organic Carbon (SOC) in mineral agricultural soils is estimated with C-TOOL version 2.0 (www.agrsci.dk/c-tool) in reporting to the UNFCCC. C-TOOL is a dynamic 3-pooled soil carbon model, which uses annual carbon input and carbon stock in soil as driving parameters. The input to C-TOOL is the amount of straw and roots returned to soil based on actual crop yield, areas with different crop types and applied animal manure divided in untreated and biogas treated manure. Based on this, C-TOOL estimates the degradation of Soil Organic Matter (SOM) and returns the net annual change in carbon. In the projection C-TOOL has not been used but instead the average change in the mineral soils for the last 5 years has been used as a proxy as no major changes in the future crop yields and changes the field management and removal of crop residues are foreseen.

Hence, an annual loss of approximately 367 Gg C (0.367 million tonne C) per year is included from the mineral soils for all years. This value is of course very dependent on the actual temperature, harvest yield and removal of animal manure and straw components for other purposes.

The area of organic soils with annual crops or grass in rotation is based on data from the EU subsidy register and a new soil map for organic soils. It is assumed to be very precise. The new soil map has shown a dramatic decrease in the area with organic soils in Denmark. Using the 2010 boundary of agricultural land on the soil map from 1975, an area of 70 107 hectares with >12 % organic carbon. In 2010 only 41 817 hectares with organic soils could be found within this area. The area of soils having 6-12 % organic C in 1975 were > 40 000 hectares, and in 2010 it has decreased to 30 174 hectares. The dramatic change is attributed to the fact that the Danish organic soils are very shallow, and due to the high losses of CO_2 caused by drainage and cultivation, they are rapidly depleted of organic matter. In the future, it is assumed that a further decrease in the area with organic soils will take place with the same rate as in the period since 1975. This amounts to 1362 hectares of organic soils per year (>6 % OC) - of these, 791 hectares have a C-content >12 % OC with an emission of 8.7 tonnes C per ha per year. It is assumed that the 791 hectares >12 % OC is converted to organic soils low in organic carbon (6-12 % OC) with an emission of half the high organic soils (4.4 tonnes C per ha per year). Because of the high uncertainty on the organic soils and their actual emission no area has been assumed to be converted to below 6 % OC. As a consequence the area with light organic soils is increasing from 2010 and onwards.

The plan for turning 50 000 hectares along rivers and water sheds into grassland is not operational yet. It is therefore not possible to estimate a precise area of organic soils that will be converted. If the area is on organic soil it will probably already be located along water courses and due to unsecure growing conditions be permanent grassland already. The overall effect of implementing the 50 000 hectare buffer zones on the emission estimate will therefore probably be low. Hence a simple assumption has been made that the decrease in the area with organic soils follows the decrease in Cropland. For organic soils converted to other land use classes the same rate is assumed as for the past years on around 370 hectares per year. The applied emission factor is 8 727 kg C per ha for annual crops and 5 182 kg C per year for grass in rotation. The overall result is a decrease in the annual emission from the organic soils reported in Cropland from 476 Gg C in 2010 to 393 Gg C in 2035 as shown in Table 13.2.

13.2.3 Perennial wooden crops

Perennial wooden crops in Cropland covers fruit trees, fruit plantations and energy crops. Christmas trees are reported under forest. Fruit trees are marginal in Denmark and covers only around 7 000 hectares. No changes in the area with fruit trees are expected. The area with willow as energy crop is expected to increase from 4 795 hectares in 2011 by 1 000 hectares per year until 2035. The increase in this area has only very marginal effect on the emission estimates as the area is harvested every 2-3 year and thus no larger amounts of C in living biomass is present in the willow plantations. Overall, an increase in living biomass of 8.7 Gg C per year until 2035 is estimated for Perennial wooden crops.

13.2.4 Hedgerows and small biotopes

The area with hedgerows and small biotopes not meeting the definition of forest is today around 60 000 hectares in the defined Cropland area. Analysis has shown (Fuglsang et al., 2011) that the area has not changed significantly over the last 20 years although there is very high dynamic in the landscape as old hedgerows are removed and replaced with new ones to facilitate new farming technologies. Establishing hedgerows and small biotopes are partly subsidised by the Danish government. It is assumed that the subsidy system combined with legal protection of the existing hedgerows will not change in the future. Therefore, the area is expected to be maintained at the same level, but due to changes in the composition of the hedgerows towards higher carbon densities, a small increase in the total carbon stock in hedgerows is estimated with an average annual increase of 15-25 Gg C per year.

The overall expected emission trend for Cropland is shown in Table 13.2. Generally, an increasing trend in the emission from Cropland is expected. The major factor in the decline in the emission in the final years is the expected depletion of the organic soils for organic matter.

Table 13.2 Overall emission trend for Cropland from 1990 to 2035.

	1990	2000	2008	2009	2010	2011	2012	2015	2020	2025	2030	2035
Area, 1000 ha	2917.9	2853.3	2801.0	2793.9	2785.3	2776.6	2769.2	2747.1	2710.3	2673.5	2636.7	2599.9
Living and dead biomass, Gg C	50.2	33.6	25.0	17.9	26.6	30.2	22.3	25.6	22.9	29.8	25.8	32.6
Mineral soils, Gg C	386.0	249.2	367.6	98.2	314.1	366.5	366.5	366.5	366.4	366.4	366.4	366.3
Organic soils, Gg C	659.9	567.9	494.3	485.1	476.0	472.7	469.4	459.5	443.0	426.5	410.0	393.6
Total, Gg C	1096.2	850.7	886.9	601.3	816.7	869.3	858.2	851.5	832.4	822.7	802.2	792.5
CH_4, Mg CH_4	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
N_2O, Mg N_2O	0.010	0.020	0.002	0.002	0.002	0.002	0.004	0.004	0.004	0.004	0.004	0.005
Total, Gg CO_2 eqv.	4019.2	3119.1	3252.1	2204.6	2994.4	3187.6	3146.6	3122.3	3052.0	3016.6	2941.3	2905.9

13.3 Grassland

Grassland is defined as permanent grassland and areas without perennial vegetation meeting the forest definition. Grass in rotation is reported under Cropland.

A total of 165 200 hectares has been reported in the Grassland sector in 2010. The area is expected to increase until 2035 primarily due to regulation for more environmental friendly farming. In total it is expected that the Grassland area will increase to 220 100 hectares in 2035. It should be mentioned here that the Grassland definition differs from the one used by Statistics Denmark for permanent Grassland.

The amount of living biomass in Grassland is limited and only minor changes are foreseen.

No changes in SOC in mineral soils are expected except for a small change in SOC in areas converted from other land use categories into Grassland. As the major change is from Cropland, which has a slightly higher SOC than Grassland, a small loss of carbon is estimated.

For drained organic soils in Grassland an average emission of 1 250 kg C per ha per year is assumed. The emission from Grassland will increase from 40 Gg C per year in 2010 to 44 Gg C per year in 2035 Due to the increased area. As the major change will increase conversion from Cropland with higher emission factor for the organic soils the overall emission from organic soils will decrease.

The overall expected emission trend is shown in Table 13.3. Generally an increasing trend in the emission from Grassland is expected. For living biomass the increasing trend is due to the amount of living biomass being lower in Grassland than in the area from which it was converted, e.g. cropland, which has a high amount of living biomass. Also the emission from soils is expected to increase, due to the increased area with organic soils classified in this category.

The small amount of CH_4 from grassland is caused by burning of heath land.

Table 13.3 Overall emission trend for Grassland from 1990 to 2035.

	1990	2000	2008	2009	2010	2011	2012	2015	2020	2025	2030	2035
Area, 1000 ha	119.9	143.1	160.9	163.0	165.2	167.4	169.6	176.2	187.1	198.1	209.1	220.1
Living and dead biomass, Gg C	60.7	55.8	10.8	10.8	10.7	10.9	16.9	17.0	17.2	17.4	17.6	17.8
Mineral soils, Gg C	0.1	0.8	1.3	1.3	1.4	1.4	1.5	1.6	1.9	2.1	2.4	2.7
Organic soils, Gg C	49.9	44.7	40.6	40.0	39.5	39.7	39.8	40.4	41.2	42.0	42.9	43.7
Total, Gg C	110.7	101.4	52.7	52.2	51.6	52.0	58.2	59.0	60.2	61.6	62.9	64.2
CH_4, Mg CH_4	0.08	0.20	0.47	0.49	0.60	0.63	0.67	0.67	0.67	0.67	0.67	0.67
N_2O, Mg N_2O	0.007	0.019	0.043	0.045	0.055	0.057	0.061	0.061	0.061	0.061	0.061	0.061
Total, Gg CO_2 eqv.	406.1	371.7	193.2	191.5	189.1	190.6	213.4	216.3	220.9	225.8	230.7	235.5

13.4 Wetlands

Wetlands are defined as peat land, where peat excavation takes place, and restored wetlands. Due to the intensive utilisation of the Danish area for farming purposes wetland restoration has taken place for many years.

13.4.1 Peat land

Peat excavation is taking place at three locations in Denmark. The sites are managed by Pindstrup Mosebrug A/S (www.pindstrup.dk). In total it is estimated that 1 596 hectares are under peat excavation. Pindstrup Mosebrug A/S is operating under a 10 year licence. Recently the license has been renewed (Pindstrup Mosebrug, pers. com). It is therefore not expected that any major changes will take place until the new licence expire in 2021. From then on no peat extraction is expected in Denmark.

The emission is estimated as a degradation of peat on the soil surface and an immediate oxidation of the excavated peat which is mainly used for horticultural purposes.

In 2011 200 000 m^3 of peat were excavated. The total emission from this is estimated at 12.2 Gg C and 0.000436 Gg N_2O per year.

13.4.2 Re-established wetlands

Only re-established wetlands are included in the Wetland category. Naturally occurring wetlands are included under Other Land where no emission estimates are made. Some larger wetland restoration projects were carried out in the 1990's. Lately, only smaller areas have been converted. Previous GIS analysis of restored wetlands has shown that only a part of the re-established wetland is located within Cropland and Grassland areas. Often a large part of the wetlands is located in Other Land.

There has been a large variation in the area converted to restored wetlands within the past years. The Danish Green Growth plan estimate a conversion of total 15 000 ha within the coming years. In the projection, it is assumed that 500 hectares of Cropland, 68 hectare of Grassland and 700 hectares of Other Land are converted to wetland per year or in total 1 268 ha per year. In the projection is this rate used for the whole period 2011-2035.

The wetlands are assumed to be a net sink because some of the area is only partially water covered. This leads to a net build-up of organic matter in these soils each year (like a new peat land). It is assumed that there is a net build-up of 500 kg C per hectare per year and that half the established wetlands are partly water covered and the remaining 50 % is fully water covered with no build-up of organic matter.

No CH_4 emission from the wetlands has been estimated as there is no methodological guidance from the IPCC on this issue. However, a new Wetlands Supplement 2013 is under development by the IPCC. From this it is foreseen that emissions of CH_4 is a source, which in the future shall be included in the estimates.

The overall expected emission trend for Wetlands is shown in Table 13.4. Generally an increasing sink is expected in wetlands, which is due an expected continuously build-up of organic matter in the restored wetlands. The large source in 1990 is caused by peat extraction being the only source in this category. The sum of emissions from human influenced/human made wetlands is almost zero in 2011 increasing to be a net sink of 17 Gg C per year in 2035 (Table 13.4).

When establishing wetlands on agricultural soils one of the important factors is halting the degradation on the agricultural land by re-wetting the soils, and not the build-up of organic matter.

Table 13.4 Overall emission trend for Wetlands from 1990 to 2035.

	1990	2000	2008	2009	2010	2011	2012	2015	2020	2025	2030	2035
Area, 1000 ha	1.6	8.8	17.1	18.3	20.1	22.2	23.1	25.9	30.5	35.1	38.1	42.7
Living and dead biomass, Gg C	0.2	-2.1	-3.1	-3.1	-1.4	-0.5	0.5	0.5	0.5	0.5	0.5	0.5
Peat extraction areas, Gg C	23.5	14.8	9.0	12.8	10.6	12.2	12.2	12.2	12.2	0.8	0.0	0.0
Soil, build-up of new organic matter	0.0	-3.6	-7.7	-8.4	-9.2	-10.2	-10.5	-11.4	-13.0	-14.6	-16.2	-17.8
Total, Gg C	23.6	9.2	-1.8	1.4	0.0	1.5	2.2	1.3	-0.3	-13.3	-15.7	-17.3
CH_4, Mg CH_4	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
N_2O, Mg N_2O	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total CO_2 eqv.	86.8	33.9	-6.3	5.1	0.0	5.8	8.3	4.8	-1.0	-48.5	-57.5	-63.3

13.5 Settlements

The need for areas for housing and other infrastructure has resulted in an increase in the Settlement area from 1990 to 2010 of 62 617 hectare or 3 300 hectare per year. In 2011 the Danish Nature Agency estimated the need for settlements areas in the vicinity of Copenhagen to 1 250 hectares per year for the period 2013 to 2025 (Danish Nature Agency, 2011). To this should be added the remaining part of Denmark as well as areas for roads and other purposes. It is assumed that the historic increase of 3 300 hectares per year will continue in the future and mainly result from conversion of Cropland.

The overall expected emission trend is shown in Table 13.5. A constant emission from Settlements from living biomass is expected. It is expected that land converted to settlement contained more living biomass before than after conversion. Furthermore an increasing emission from converted soils is expected. The soils, which are converted, contain more carbon than are found in the later settlements areas and a loss of 120 tonnes C per ha is therefore expected. It is assumed that it takes 100 years to reach this new equilibrium stage. As a consequence the emission from converted soils will continue to increase for the next many years.

Table 13.5 Overall emission trend for Settlements from 1990 to 2035.

	1990	2000	2008	2009	2010	2011	2012	2015	2020	2025	2030	2035
Area, Hectare	388.8	421.9	448.2	451.5	454.7	458.0	461.3	471.2	487.6	504.1	520.5	537.0
Living and dead biomass, Gg C	27.4	25.7	14.7	14.8	14.8	14.9	17.7	17.6	17.6	17.6	17.6	17.6
Soil, Gg C	1.1	11.5	19.8	20.8	21.8	22.8	23.9	27.0	32.2	37.4	42.5	47.7
Total, Gg C	28.5	37.2	34.5	35.6	36.6	37.8	41.5	44.6	49.8	55.0	60.2	65.4
CH_4, Mg CH_4	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
N_2O, Mg N_2O	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
Total, Gg CO_2 eqv.	104.4	136.4	126.5	130.4	134.4	138.6	152.3	163.7	182.5	201.6	220.7	239.7

13.6 Other Land

Other Land is defined as areas without or with only sparse vegetation and not meeting the definition of forest.

Other Land has very limited influence on the emission and no estimate has been made.

13.7 Liming and CAN

CO_2 emissions from liming of agricultural soils shall be reported in the LULUCF sector. The amount of lime used in agriculture has decreased from 1990 to 2003 and is now stabilised around 400 000 tonnes per year. The decrease is due to less atmospheric deposition of acidic compounds and a decreased application of reduced nitrogen to the fields. No further decreases in the deposition of acidic compounds and only small decreases in the amount of reduced nitrogen applied to soils are foreseen. Therefore, the need for fertilisation will remain at the same level in the future and hence an unaltered consumption of lime is assumed.

The use of Calcium Ammonium Nitrate (CAN) is very marginal in Denmark. No changes are foreseen in consumption of CAN.

In total the annual emission is projected to 186 Gg CO_2 per year until 2035 from liming.

Table 13.6 Emission from liming of agricultural soils.

Liming	1990	2000	2008	2009	2010	2011	2012	2015	2020	2025	2030	2035
$CaCO_3$, Tonne per year	1417	682	523	421	421	421	421	421	421	421	421	421
Emission, Gg CO_2	622.9	300.0	230.1	184.9	185.3	185.3	185.3	185.3	185.3	185.3	185.3	185.3

13.8 Fires

Forest fires are very seldom in Denmark and only as wild fires. In general this is between 0 and 2 hectares burned per year. Controlled burning of heathland to maintain the heath is made by the Danish Nature Agency of around 400 hectares per year. These very small areas are not assumed to have any influence on the carbon stock as regeneration is very quickly taking place. The emissions from these fires are for clarification also included in table 13.1 (Forest) and 13.3 (Grassland).

Table 13.7 Emission from forest fires and burning of heath land.

	1990	2000	2008	2009	2010	2011	2012	2015	2020	2025	2030	2035
Forest area burned, ha	150.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	2.0	2.0	2.0	2.0
Heathland area burned, ha	47.0	121.6	282.2	296.0	359.0	377.0	400.0	400.0	400.0	400.0	400.0	400.0
Total burned area	197.0	121.6	282.2	296.0	359.0	377.0	400.0	402.0	402.0	402.0	402.0	402.0
Emission, CH_4, Gg	0.026	0.000	0.000	0.000	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Emission, N_2O, Gg	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total, Gg CO_2 eqv.	0.998	0.010	0.023	0.024	0.030	0.031	0.033	0.046	0.046	0.046	0.046	0.046

13.9 Total emission

The total emission from the LULUCF is shown in Table 13.8. For these categories an overall emission of around 3 300 Gg CO_2 eqv. per year in 2012 is assumed, decreasing to 3 100 Gg CO_2 eqv. per year in 2035.

The Danish forests are expected to be an overall sink of around 400 Gg CO_2 eqv. per year in the future. Utilisation of the organic soils for agricultural purposes is responsible for an emission of approximately 3 million tonnes CO_2 emission per year (3 000 Gg). 55 % of this derives from utilisation of organic soils, 43 % from mineral soils and 10 % from liming of the agricultural soils. Conversion of organic soils from annual crops into permanent grassland will reduce this emission substantially but not remove the emission totally unless the conversion includes a raised water table to prevent a degradation of the organic matter in the dry grasslands.

Another important loss factor is the conversion of cropland to other land use except forestry. The reason for this is that the current carbon stock for annual crops is defined as when the maximum carbon stock is in the field. Conversion of Cropland having a high amount of carbon in living biomass into other categories with a lower amount of living biomass like urban areas will therefore cause an overall loss of carbon.

The main driver for the increase in the emission is primarily an expected increase in the loss of carbon from agricultural soils. Increasing the input of organic matter into the agricultural soils to compensate for this loss seems very difficult as only 10-15 % of the annual input of organic matter will add to the soil Organic Carbon and the remaining will very rapidly be degraded and return to the air as CO_2.

Growing of energy crops will only have marginal effect on the emissions in the LULCUF-sector as only small amounts of carbon will be stored temporarily in the energy crops before it is harvested. The major effect of growing energy crops is the substitution in the energy sector.

Table 13.8 Emission from the LULUCF sector, Gg CO_2 eqv. per year.

	1990	2000	2008	2009	2010	2011	2012	2015	2020	2025	2030	2035
5. Land Use, Land-Use Change and Forestry, Total	4422.6	5893.6	2788.1	-876.4	-2176.4	2836.8	3267.0	3203.9	3230.2	3162.3	3093.2	3066.9
A. Forest Land	-819.8	1928.5	-1005.2	-3590.5	-5676.9	-868.1	-436.5	-485.5	-405.7	-414.0	-422.3	-430.5
1. Forest Land remaining Forest Land	-828.2	2245.0	-691.6	-3048.4	-5677.3	-124.6	199.2	166.2	415.4	415.3	415.2	415.2
2. Land converted to Forest Land	8.4	-316.5	-313.6	-542.1	0.4	-743.6	-635.7	-651.6	-821.2	-829.3	-837.5	-845.7
B. Cropland	4645.2	3424.9	3482.8	2390.2	3180.3	3373.4	3333.0	3308.7	3238.4	3203.1	3127.9	3092.6
1. Cropland remaining Cropland	4607.0	3380.1	3463.9	2370.5	3159.6	3351.8	3299.7	3273.0	3198.7	3159.2	3079.8	3040.4
2. Land converted to Cropland	38.2	44.7	18.9	19.7	20.6	21.6	33.3	35.7	39.7	43.9	48.1	52.2
C. Grassland	405.9	370.0	190.3	188.4	185.9	187.2	209.9	212.3	216.1	220.2	224.4	228.4
1. Grassland remaining Grassland	188.7	165.5	144.6	141.9	138.3	138.3	139.3	139.3	139.3	139.3	139.3	139.3
2. Land converted to Grassland	217.2	204.5	45.7	46.5	47.6	48.9	70.6	73.0	76.8	80.9	85.0	89.1
D. Wetlands	86.8	33.9	-6.3	5.1	0.0	5.8	8.3	4.7	-1.2	-48.7	-57.5	-63.3
1. Wetlands remaining Wetlands	86.2	54.5	33.3	47.0	39.1	44.7	44.7	44.6	44.6	3.0	0.0	0.0
2. Land converted to Wetlands	0.6	-20.6	-39.6	-42.0	-39.1	-39.0	-36.4	-39.9	-45.8	-51.6	-57.5	-63.3
E. Settlements	104.4	136.4	126.5	130.4	134.4	138.6	152.3	163.7	182.5	201.6	220.7	239.7
1. Settlements remaining Settlements	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2. Land converted to Settlements	104.4	136.4	126.5	130.4	134.4	138.6	152.3	163.7	182.5	201.6	220.7	239.7
F. Other Land	0	0	0	0	0	0	0	0	0	0	0	0
1. Other Land remaining Other Land	0	0	0	0	0	0	0	0	0	0	0	0
2. Land converted to Other Land	0	0	0	0	0	0	0	0	0	0	0	0

The increased area with afforestation will also in the future increase the carbon stock in these areas. Forest & Landscape, Copenhagen University has in their projection until 2019 assumed a carbon sequestration in afforested areas of approx. 600 Gg CO_2 per year increasing to approx. 800 Gg CO_2 per year in 2035. Including the expected sink in the afforested areas will reduce the overall loss by approx. 2 000 Gg CO_2 eqv. from now on and to 2035 (Table 13.8).

13.10 Uncertainty

The uncertainties are low in some of the estimates whereas in others very high. Generally, the conversion of one land use category to another (except for Forestry) has a low effect on the emission estimates.

The highest uncertainty relates to the use of the dynamic model for estimating the degradation of SOM, C-TOOL, where the input data depends on actual harvest yields and the degradation on future temperature regimes in combination with a low annual change compared with a very large carbon stock in the soil. The total carbon stock in the agricultural mineral soils has been estimated to approximately 420 Tg C, which is equivalent to 1540 million tonnes of CO_2. Even small changes in the parameters may change the emission prediction substantially. The average temperature in Denmark was very high in 2006-2008 whereas in 2009 and 2010 the average temperature decreased, Figure 13.2. This difference in temperature has an impact on the modelled outcome from C-TOOL. The effect of the cold winter in 2009 could be seen directly in the reported inventory on the emission from agricultural soils. The difference between the reported emission from the agricultural soils from 2008 to 2009 is 1 089 Gg CO_2. A high uncertainty should therefore be expected for the emission estimate from especially mineral agricultural soils. The uncertainty for the organic soils mainly relate to the uncertainty on the estimate of the absolute emission factor used for these soils.

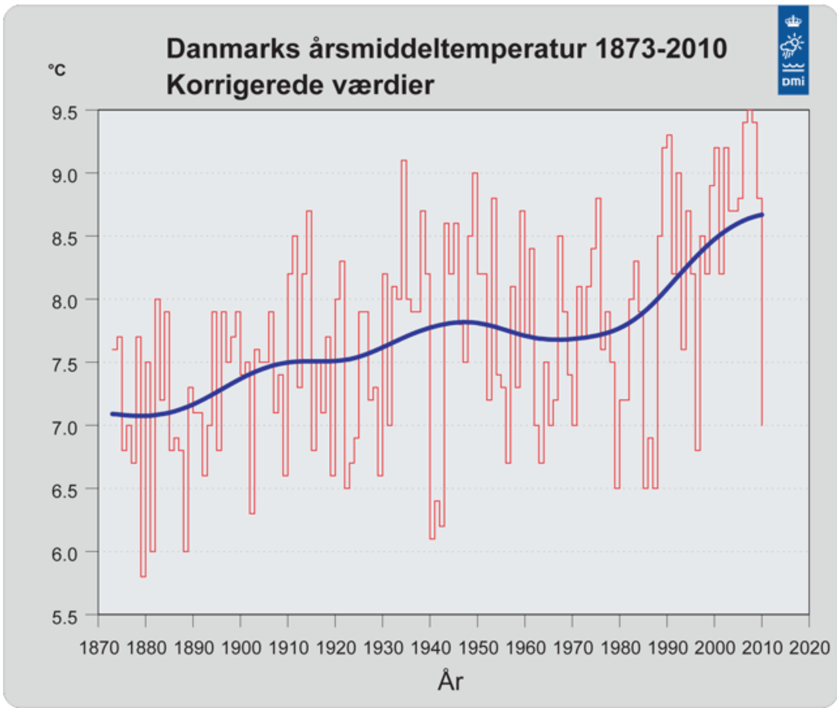


Figure 13.2 Average temperature in Denmark 1873 to 2010. Source: www.dmi.dk.

For Forestry there is a high variability in the projected carbon stock change in 2008 to 2012. This is due to the incorporation of the National Forest Inventory (NFI) in 2002 into the Danish GHG inventory. In the first year of the NFI a large variability in the collected data was found. It is expected that the variability will decrease so that the data after 2012 will be much more stable.

A conservative uncertainty estimate for the overall LULUCF estimate will be in the range of ± 500 Gg CO_2 eqv. or ±0.5 million tonnes CO_2 eqv.

13.11 The Danish Kyoto commitment

Denmark has besides the obligatory inclusion of Afforestation/Reforestation and Deforestation (article 3.3) elected Forest Management, Cropland Management and Grazing Land Management under article 3.4 to meet its reduction commitment. Although, the reduction commitment is based on the national inventory to UNFCCC there are several differences. The major differences are that for Cropland and Grazing Land Management the reduction is estimated based on the net-net principle. Furthermore, a land elected for any activity in 1990 cannot leave the commitment and shall therefore be accounted for in the future. It means that land converted from Cropland to e.g. Settlements shall still be accounted for in the reduction commitment in the first and all subsequent commitment periods.

For Forest Management there is a maximum amount of 183 Gg CO_2 per year in the first commitment period 2008-2010 (the cap), in total 916.67 Gg CO_2 for the whole period, which can be included in the Danish reduction commitment. Any exceeds of this amount will not add to the Danish reduction commitment. There is no cap on Afforestation/Reforestation, Cropland and Grazing Land Management.

The first commitment period is from 2008 to 2012. Table 13.9 shows the projected estimates for the different categories as conservative estimates.

For the first commitment period (2008-2012) a total sink is projected from Afforestation/Reforestation under article 3.3 of 2421.3 Gg CO_2 equivalent to 484.3 Gg CO_2 per year. In the period 2013-2020 a total sink of 5881.8 Gg CO_2 equivalent to an average of 735.2 Gg CO_2 is projected per year. In 2035 an annual sink of 845.7 Gg CO_2 is estimated (Table 13.9).

Deforestation due to conversion to settlements and infrastructure is estimated to be around 85 Gg CO_2 per year in the future.

Forest Management shows a very high variability, which will be reduced when further measurements in the National Forest Inventory has been made in the coming years. The current data shows that there will be a carbon sequestration in Forest Management of 9347.0 Gg CO_2 eqv. in the first commitment period. As mentioned is there a cap of 916.67 Gg CO_2 eqv. or approximately 10 per cent of the current sink estimate.

For the second commitment period, 2013-2020, a Forest Management Reference Level (FMRL) has been estimated for the period 2013-2020 (http://unfccc.int/resource/docs/2011/tar/dnk01.pdf). The Danish FMRL has been settled to be a net average source of 409 Gg CO_2 eqv. per year assuming a first order decay of Harvested Wood Product (HWP) or 333.7 assuming an instantaneous oxidation of HWP. As the FMRL is based on a projection on the development of the Danish forest until 2020 the forest will not add further accounting quantities to the Danish reduction commitments unless further initiatives are made in the Danish forests existing before 1990. Currently there is no knowledge on new initiatives.

Cropland Management and Grazing Land Management is projected to contribute to the Danish reduction commitment by 1 400 Gg CO_2 eqv. per year or 7 000 Gg CO_2 eqv. in total for the first commitment period. Cropland and Grassland will still be net sources of CO_2 but due to an increased incorporation of plant debris, animal manure, a reduced area with organic soil under cultivation and establishment of wetlands, the change in the agricultural activities will contribute positively to further Danish reduction commitments.

Table 13.9 Projected emission estimates for article 3.3 and 3.4 activities 1990 to 2035.

	1990	2000	2008	2009	2010	2011	2012	2015	2020	2025	2030	2035
Afforestation/Reforestation	8.4	-316.5	-313.6	-542.1	-22.6	-907.4	-635.7	-651.6	-821.2	-829.3	-837.5	-845.7
Deforestation a)	300.4	263.0	38.2	38.6	39.4	40.9	82.2	83.0	84.1	85.8	87.5	89.1
Forest Management b)	-832.1	2245.0	-691.6	-3048.4	-5677.3	-125.3	195.6	162.5	378.8	378.7	378.6	378.5
Cropland Management	4650.4	3461.5	3577.8	2488.5	3278.9	3472.7	3424.4	3409.7	3355.5	3336.1	3276.7	3257.3
Grassland Management	205.1	189.5	175.3	173.4	171.3	172.4	173.7	176.2	180.3	184.5	188.6	192.8

a) N_2O emission associated with deforestation is reported under Cropland in the convention reporting but for clarification in the accounting under KP given here under Deforestation

b) In the first commitment period (2008-2012) there is a cap (a maximum) on the amount stored in forest remaining forest, which can be included in the Danish reduction commitment. The Danish cap for 2008-2012 is 916.7 Gg CO_2. For the second commitment period (2013-2020) a Forest Management Reference Level (FMRL) has been made of 282-573 Gg CO_2 per year in the period 2013-2020. See text for further explanation.

Table 13.10 Accounting estimates for 2008 to 2020 for Afforestation, Reforestation, Deforestation under Art. 3.3. and Forest Management (FM), Cropland Management (CM) and Grassland Management (GM) under Art. 3.4 of the Kyoto-protocol and Harvested Wood Product (HWP).

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
3.3													
AR	-313.6	-542.1	-22.6	-907.4	-635.7	-633.7	-635.3	-651.6	-645.9	-838.2	-836.2	-819.5	-821.2
D[a]	38.2	38.6	39.4	40.9	82.2	82.4	82.7	83.0	83.3	83.6	83.7	83.9	84.1
3.3 total	-275.3	-503.5	16.9	-866.5	-553.6	-551.3	-552.6	-568.7	-562.7	-754.7	-752.5	-735.6	-737.1
3.4													
FM	-691.6	-3048.4	-5677.3	-125.3	195.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HWP	NO	NO	NO	NO	NO	102.0	108.0	119.0	118.0	120.0	125.0	119.0	121.0
CM	-1072.6	-2161.9	-1365.9	-1178.6	-1226.1	-1214.3	-1228.2	-1240.7	-1272.4	-1228.4	-1278.8	-1285.4	-1295.0
GM	-29.8	-31.7	-33.8	-32.6	-31.4	-30.6	-29.8	-28.9	-28.1	-27.3	-26.4	-25.6	-24.8
CM+GM	-1102.4	-2193.7	-1399.7	-1211.2	-1257.5	-1244.8	-1257.9	-1269.7	-1300.5	-1255.6	-1305.2	-1311.0	-1319.7
3.4 total incl. HWP	-1794.0	-5242.1	-7077.0	-1336.5	-1061.9	-1244.8	-1257.9	-1269.7	-1300.5	-1255.6	-1305.2	-1311.0	-1319.7
3.3 and 3.4 incl. HWP	-2069.3	-5745.5	-7060.1	-2203.0	-1615.5	-1796.1	-1810.5	-1838.3	-1863.2	-2010.3	-2057.7	-2046.7	-2056.8

Note: N_2O emission associated with deforestation is reported under Cropland in the convention reporting but for clarification in the accounting under KP stated here under Deforestation.

13.12 References

Danish Nature Agency, 2011, Forslag til Fingerplan 2012. Available at: www.naturstyrelsen.dk/NR/rdonlyres/FCF0784F-0A7B.../NetPDFny.pdf

Fuglsang, M., Münier, B & Levin, G., 2011: Hedgerows in Denmark (In preparation).

Johannsen, V. K., T. Nord-Larsen and K. Suadicani, 2011, Submission of information on forest management reference levels by Denmark, Forest & Landscape, University of Copenhagen, Denmark, Forest & Landscape Working Papers, No. 58, pp 34. Available at: www.sl.life.ku.dk

Ministry of the Environment 2009,: Grøn Vækst. Available at: http://www.mim.dk/Nyheder/Temaer/Groen_vaekst/

Nielsen, O.-K., Mikkelsen, M.H., Hoffmann, L., Gyldenkærne, S., Winther, M., Nielsen, M., Fauser, P., Thomsen, M., Plejdrup, M.S., Albrektsen, R.,

Hjelgaard, K., Bruun, H.G., Johannsen, V.K., Nord-Larsen, T., Bastrup-Birk, A., Vesterdal, L., Møller, I.S., Rasmussen, E., Arfaoui, K., Baunbæk, L. & Hansen, M.G. 2011: Denmark's National Inventory Report 2011 – Emission Inventories 1990-2009 - Submitted under the United Nations Framework Convention on Climate Change. National Environmental Research Institute, Aarhus University. 1199 pp. Available at:
http://www2.dmu.dk/Pub/FR827.pdf

14 Conclusions

In assessing the projection it is valuable to separate the emissions included in the EU ETS. The current projection provides a projection of the CO_2 emissions covered by the EU ETS. The CO_2 emissions covered by EU ETS are shown for selected years in Table 14.1.

The historic and projected greenhouse gas (GHG) emissions are shown in Tables 14.8 – 14.15 and illustrated in Figure 14.1. Projected GHG emissions include the estimated effects of policies and measures implemented until September 2012 and the projection of total GHG emissions is therefore a so-called 'with existing measures' projection. The emission/removals by LULUCF is included in Table 14.16.

The main sectors for GHG emission in the years 2008-2012 ('2010') are expected to be Energy Industries (38 %), Transport (23 %), Agriculture (16 %) and Other Sectors (10 %). For the latter sector the most important sources are fuel combustion in the residential sector. GHG emissions show a decreasing trend in the projection period from 2010 to 2035, with decreasing emissions from 2010 to 2025 and slightly increasing emissions from 2025 to 2035. In general, the emission share for the energy industries sector is decreasing while the emission share for the transport sector is increasing. The total emissions in '2010' are estimated to be 59 255 ktonnes CO_2 equivalents and 45 731 ktonnes in 2035, corresponding to a decrease of 23 %. From 1990 to '2010' the emissions are estimated to have decreased 14 %.

The commitment to a reduction of 21 % or a maximum emission of about 55 million tonnes in '2010' under the Kyoto Protocol can be obtained by national reductions, use of the flexible mechanisms under the Kyoto Protocol or by including CO_2 uptake in forestry and soil.

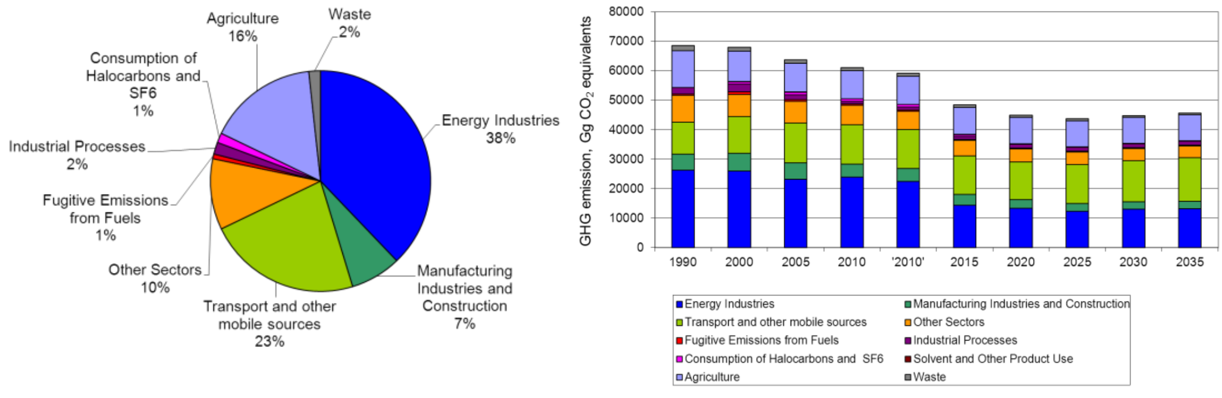


Figure 14.1 Total GHG emissions in CO_2 equivalents. Distribution according to main sectors ('2010') and time series for 1990 to 2035.

14.1 Stationary combustion

Stationary combustion includes Energy industries, Manufacturing industries and construction and Other sectors. Other sectors include combustion in commercial/institutional, residential and agricultural plants. The GHG emissions in '2010' from the main source, which is public power (64 %), are estimated to decrease significantly in the period from 2011 to 2024 due to a partial shift in fuel type from coal to wood and municipal waste. From 2025 to 2035 the emission is projected to be almost constant. Also, for residential combustion plants and combustion in manufacturing plants a significant decrease in emissions is projected; the emissions decrease by 46 % and 48 % from 2011 to 2035 respectively. The emissions from the other sectors remain almost constant over the period except for energy use in the offshore industry (oil and gas extraction), where the emissions are projected to increase by 274 % from 1990 to '2010' and by 145 % from '2010' to 2035.

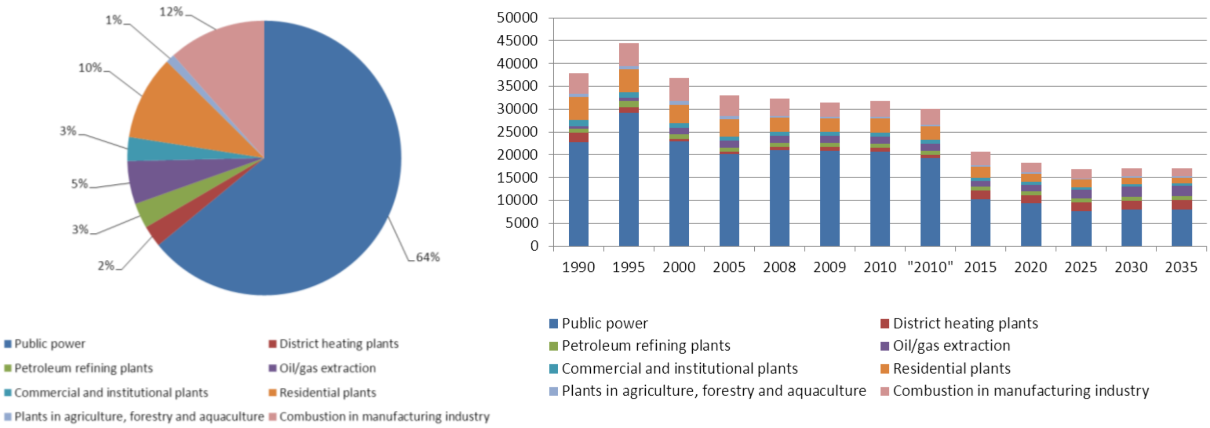


Figure 14.2 GHG emissions in CO_2 equivalents for stationary combustion. Distribution according to sources ('2010') and time series for 1990 to 2035 for main sources.

14.2 Fugitive emission

The GHG emissions from the sector Fugitive emissions from fuels increased in the years 1990-2000 when a maximum was reached. The emissions are estimated to decrease in the projection years 2011-2035, mainly from 2011-2015. The decreasing trend mainly owes to decreasing amounts of gas being flared at offshore installations. Further, the decrease owes to technical improvements at the raw oil terminal and thereby a large decrease in the emissions from storage of oil in tanks at the terminal and to a lesser degree from onshore loading of ships. Emissions from extraction of oil and gas are estimated to decrease in the period 2011-2035 due to a decreasing oil and natural gas production. The GHG emissions from the remaining sources show no or only minor changes in the projection period.

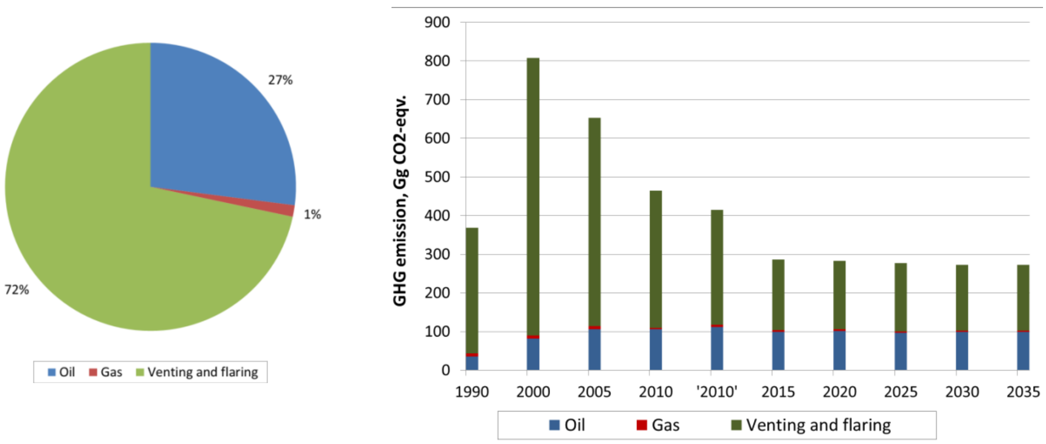


Figure 14.3 GHG emissions in CO_2 equivalents for fugitive emissions. Distribution according to sources for '2010' (average for the years 2008-2012) and time series for 1990 to 2035 for main sources.

14.3 Industrial processes

The GHG emission from industrial processes increased during the nineties, reaching a maximum in 2000. Closure of the nitric acid/fertiliser plant in 2004 has resulted in a considerable decrease in the GHG emission. The most significant source is cement production, which contributes with more than 83 % of the process-related GHG emission in '2010'. Consumption of limestone and the emission of CO_2 from flue gas cleaning are assumed to follow the consumption of coal and waste for generation of heat and power. The GHG emission from this sector will continue to be strongly dependent on the cement production at Denmark's only cement plant.

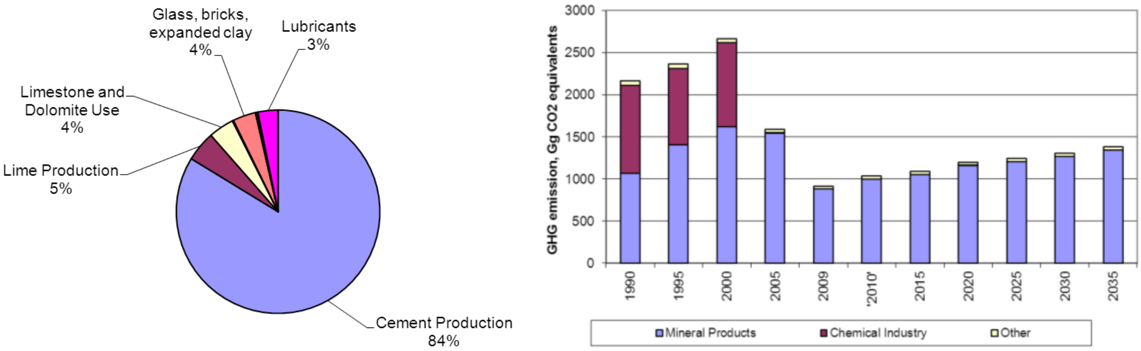


Figure 14.4 Total GHG emissions in CO_2 equivalents for industrial processes. Distribution according to main sectors ('2010') and time series for 1990 to 2035.

14.4 Solvents

In 2010 solvent and other product use account for 0.2 % of the total GHG emissions. The major sources of GHG emissions are N_2O from the use of anaesthesia and indirect CO_2 emissions from other use of solvents, which covers e.g. use of solvents in households. The CO_2 emission from use of solvents is expected to decrease in the projection timeframe, due to a decrease in the solvent use.

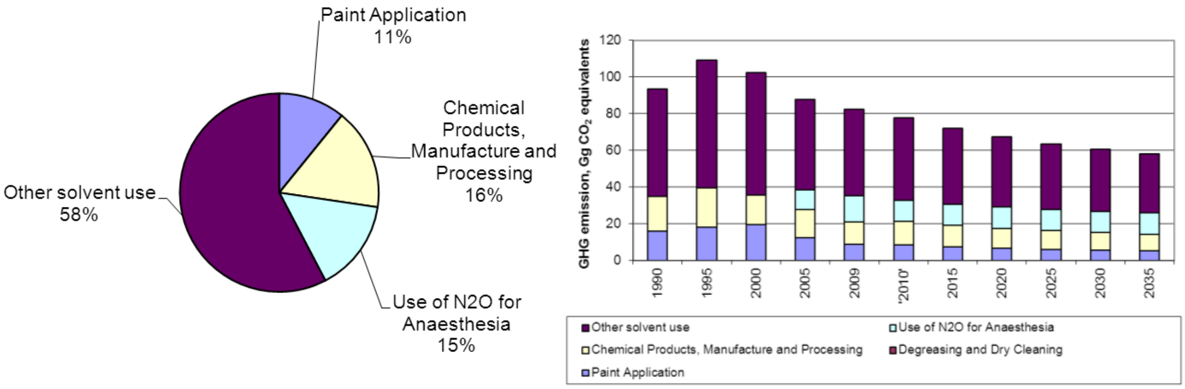


Figure 14.5 Total GHG emissions in CO_2 equivalents for solvent use. Distribution according to main sectors ('2010') and time series for 1990 to 2035.

14.5 Transport

Road transport is the main source of GHG emissions in '2010' and emissions from this sector are expected to increase by 47 % from 1990 to 2035 due to growth in traffic. The emission shares for the remaining mobile sources are small compared with road transport, and from 1990 to 2035 the total share for these categories reduces from 31 % to 20 %. For non-road machinery in industry, the emissions increase by 4 % from 1990-2035. For this sector there is a significant emission growth from 1990-2009 (due to increased activity), followed by a decline in the level of GHG emissions from 2010 onwards, due to gradually more fuel efficient machinery. However, in the later years of the time series an increase in emissions is projected. For agriculture/fishing and navigation the projected emission in 2030 is almost the same as the 1990 emission.

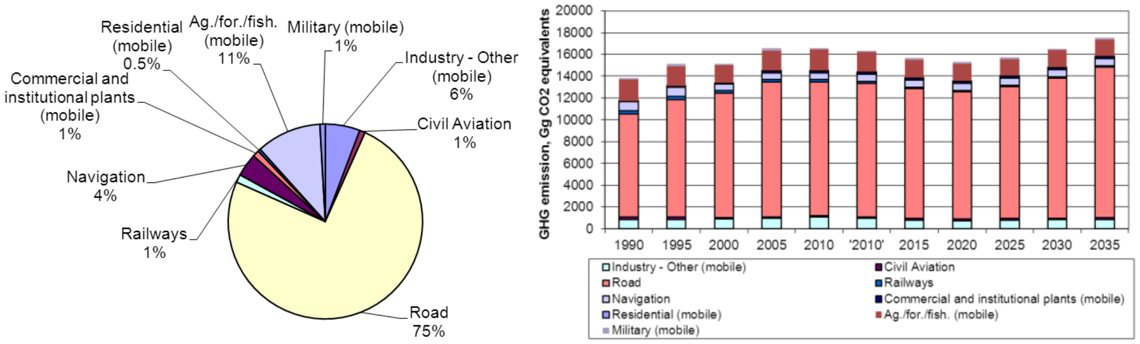


Figure 14.6 GHG emissions in CO_2 equivalents for mobile sources. Distribution according to sources ('2010') and time series for 1990 to 2035 for main sources.

14.6 Fluorinated gases

Danish regulation concerning the powerful F-gas GHGs includes phasing out of some F-gases and taxation on others. Although the use of SF_6 in double-glazing window panes was in banned in 2002, throughout the period there will still be emission of SF_6 in connection with the disposal of the panes. HFCs are dominant F-gases, which in '2010' are expected to contribute with 91 % of the F-gas emission, Figure 14.7.

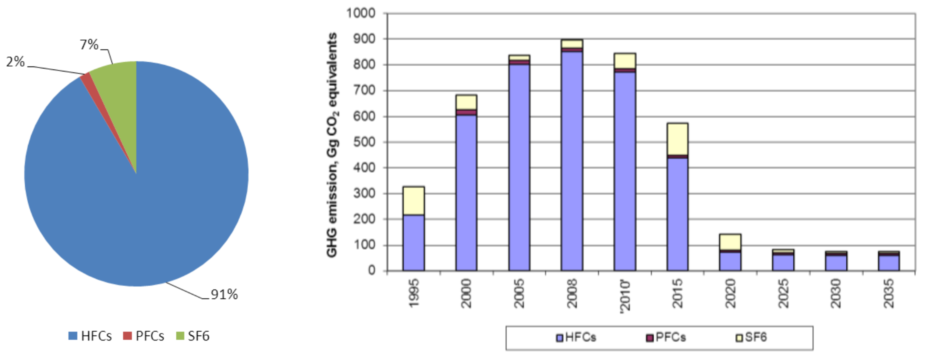


Figure 14.7 GHG emissions in CO_2 equivalents for F-gases. Distribution according to F-gas type ('2010') and time series for 1990 to 2035 for F-gas type.

14.7 Agriculture

From 1990 to 2010, the emission of GHGs in the agricultural sector has decreased from 12 462 ktonnes CO_2 equivalents to 9 520 ktonnes CO_2 equivalents, which corresponds to a 24 % reduction. This development continues and the emission to 2035 is expected to decrease further to 8 859 ktonnes CO_2 equivalents. The reduction both in the historical data and the projection can mainly be explained by improved utilisation of nitrogen in manure and a significant reduction in the use of fertiliser and a lower emission from N-leaching. These are consequences of an active environmental policy in this area. Measures in the form of technologies to reduce ammonia emissions in stables and expansion of biogas production are taken into account in the projections.

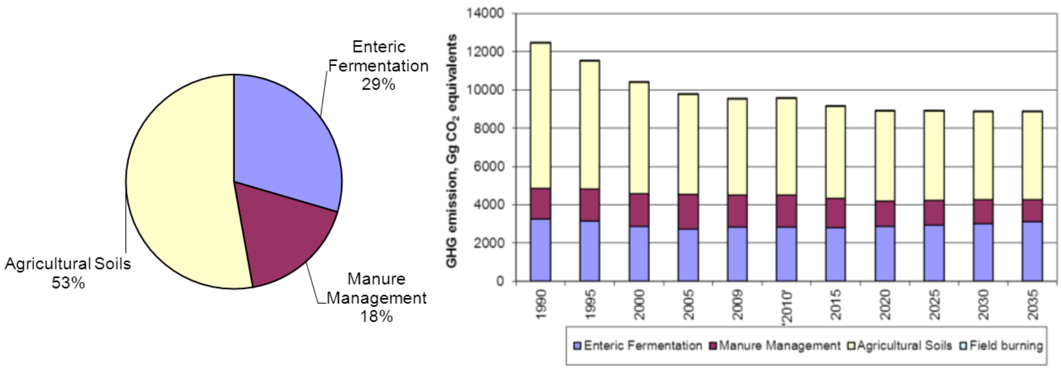


Figure 14.8 GHG emissions in CO_2 equivalents for agriculture sources. Distribution according to sources ('2010') and time series for 1990 to 2035 of main sources.

14.8 Waste

Solid waste disposal on land (SWDS) is by far the largest source of GHG emissions from the waste sector. The projection of the contribution of CH_4 from landfill to the sector total in '2010' is 70 %, Figure 14.9. Due to the decrease in waste deposited to landfills the emission has been decreasing during the later historical years and this trend is expected to continue in the projection timeframe.

The predicted GHG emission from wastewater is 16 %. The estimated increase in the total amount of organic material in the influent wastewater is assumed to be a function of an increase in the population size alone, while the contribution from industry is assumed to stay at a constant level.

The category waste incineration and other waste cover cremations of corpses and carcasses, accidental fires and composting. The category contributes with 14 % of the total GHG emission from the waste sector. The emission is expected to increase due to increasing use of composting as waste disposal.

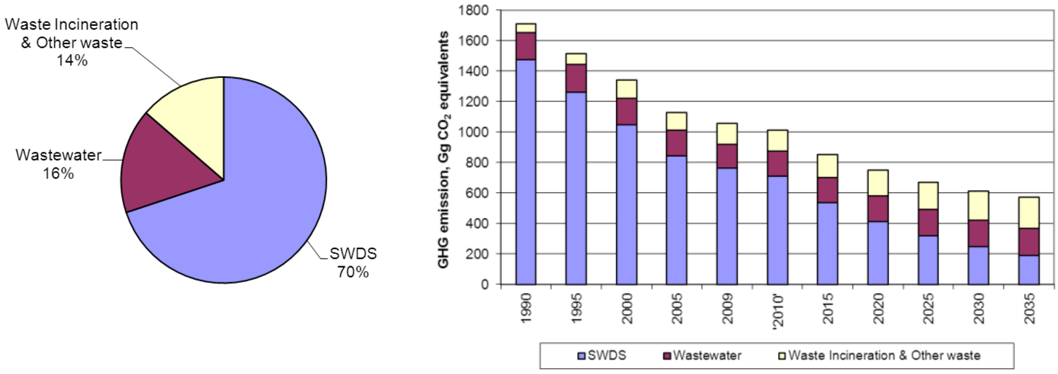


Figure 14.9 GHG emissions in CO_2 equivalents for Waste. Distribution according to main sources ('2010') and the time series for 1990 to 2035.

14.9 LULUCF

The overall picture of the LULUCF sector is a net source of 4 423 Gg CO_2 eqv. in 1990. In the future it is expected that the whole LULUCF sector will be a net source of 3 000 Gg CO_2 eqv. in 2035. Until 2035 the emission trend is expected to be relatively stable. The major reason for this decrease is that agricultural organic soils have been depleted for degradable organic matter and that the agricultural mineral soils are in an equilibrium state. Afforestation is expected to continue to take place in Denmark with an estimated rate of 1 745 hectare per year. Together with a very small deforestation rate, the C-stock in the Danish forest is expected to increase in the future. Cultivation of organic soils is a major steady source. Agricultural regulations will reduce the area with cultivated agricultural organic soils further in the future, but there will still be a large net emission from these soils.

The result of the projection is shown in Table 14.16.

14.10 EU ETS

CO_2 emissions covered by EU ETS are from the energy sector and from industrial processes. From 2012 aviation will be included in EU ETS, but otherwise only CO_2 emissions from stationary combustion plants are included under fuel combustion. The major part of industrial process CO_2 emissions are covered by EU ETS. It is dominated by cement production and other mineral products. The result of the projection for EU ETS covered emissions are shown in Table 14.1.

Table 14.1 CO_2 emissions covered by EU ETS.

			2015	2020	2025	2030	2035
1A1a	0101	Public power	9959	9076	7279	7741	7642
1A1a	0102	District heating plants	1320	1251	1593	1479	1792
1A1b	0103	Petroleum refining plants	900	900	900	900	900
1A1c	0105	Coal mining, oil / gas extraction, pipeline c	1253	1380	1847	2195	2172
1A2	03	Combustion in manufacturing industry	2297	1603	1463	1331	1229
1A2f		Industry - Other (mobile)					
1A3a		Civil Aviation	148	153	155	152	152
1A3b		Road					
1A3c		Railways					
1A3d		Navigation					
1A4a	0201	Commercial and institutional plants (t)	9	8	8	8	7
1A4b	0202	Residential plants					
1A4b		Residential (mobile)					
1A4c	0203	Plants in agriculture, forestry and aquaculture	140	134	134	134	135
1A4c		Ag./for./fish. (mobile)					
1A5		Military (mobile)					
1B2a	05	Fugitive emissions from oil					
1B2b	05	Fugitive emissions from gas					
1B2c	090206	Fugitive emissions from flaring	180	174	174	168	168
2A		Mineral Products	1034	1145	1186	1248	1321
2B		Chemical Industry					
2C		Metal Production					
2D		Food and drink	2	2	2	3	3
2F		Consumption of Halocarbons and SF_6					
2G		Consumption of lubricants					
		Total	17242	15828	14741	15358	15519
1A3a		Civil Aviation, international	2746	3137	3248	3042	3042
1A3d		Navigation, international					

14.11 Impact of 2006 IPCC Guidelines and new GWPs

Previously DCE has prepared a memorandum on the implications of the 2006 IPCC Guidelines (GL) on the emission inventory. The analysis identified that the major changes were found in the agricultural sector but that there were potentially large changes regarding fugitive emissions from fuels. In connection with the projection carried out in September 2012, DEA requested an update regarding these two sectors. In the following the changes in these two sectors are further described. For fugitive emissions the data provided by the DEA has made it possible to assess the emissions based on country-specific emission factors. Therefore it is not judged that Denmark will have to use the high default EFs in the 2006 GL. The implication for the projection is difficult to assess since the activity level varies considerably. In the discussion below the average value for 2000-2009 is provided to display the possible impact.

For agriculture the expected impact of the change will be a reduction of 5-6 % through the time series.

One further issue that was not covered by the previous memorandum is the CH_4 emission from anaerobic digestion at biogas facilities. The 2006 IPCC GL includes a default emission factor of 1 g CH_4 per kg waste treated. It has not been possible to acquire sufficient activity at the moment on the amount of organic waste being biogas treated. However, this source is likely to increase significantly in the future, but the level has not been assessed.

The new GWPs are a result of switching from the Second IPCC Assessment Report to the Fourth IPCC Assessment Report. For CH_4 and N_2O the switch means that the GWPs will change from 21 to 25 and 310 to 296, respectively. Additionally, the GWPs of many of the F-gases have been changed.

14.11.1 Fugitive emissions from fuels

The Danish emission inventory of fugitive emissions from fuels follows the 1996 IPCC Guidelines, but it does not make use of default emission factors given in the Guidelines. Therefore, a shift from the 1996 IPCC Guidelines to the 2006 IPCC Guidelines will not cause changes of the emission calculation. Yet, the 2006 IPCC Guideline has been updated according to more subjects with importance to the inventory of fugitive emissions. New, the 2006 IPCC Guidelines holds a more detailed description of the sources in the sector, of which some are not included in the Danish inventory. In some instances the sources are already noted as future improvements, and the work on collecting activity data has started. Other sources must be investigated further and implemented if the necessary data is available. The parts of the 2006 IPCC Guidelines that could cause changes in the inventories by adding emissions from new sources are listed and commented in the following.

More sources have got a Tier 1 CO_2 emission factor as a new initiative in the IPCC 2006. Today only fugitive CO_2 emissions from flaring offshore and onshore are included in the Danish emission inventory but if a shift to IPCC 2006 is carried out this will lead to an increase in the estimated fugitive CO_2 emission.

An indication of the proportion of the emissions will be given where possible. As the data collection is still limited, the given proportions should be seen as a rough indication.

14.11.2 Fugitive emissions from well testing

Fugitive emissions from oil and gas in Denmark are mainly due to the activities in the North Sea. Oil and natural gas consists mostly of carbon hydrides and the inventory estimates emissions of CH_4 and NMVOC in case of evaporation. For flaring, emissions of CH_4, NMVOC, SO_2, CO_2, NO_x, CO and N_2O

are estimated. A description of the new sources and plans on future improvements for fugitive emissions from oil and gas is given here, as is the influence of the new Tier 1 CO_2 emission factors.

In the 2006 IPCC GL (Table 4.2.1, 1 B 2 a iii 1 and 1 B 2 b iii 1) emissions from oil and gas exploration is mentioned as a source, which was not the case in the 1996 GL. Exploration is not included in the Danish emission inventory as an isolated source.

When new wells are drilled a test production is carried out to test the production capacity. The test production is either vented or flared leading to emissions of CH_4, CO_2, NMVOC and N_2O. Emissions from well drilling and well service are assumed to be very limited, while emissions from well testing might be a considerable source, depending on the number of well testings, the amount extracted and the ratio of venting and flaring of the extracted amounts of oil and gas.

Tier 1 emission factors for well drilling, testing and service are included in the IPCC 2006 GL and emission estimates are given below based on the Tier 1 methodology and emission factors. These estimations will have to be added to the Danish emission inventory for fugitive emissions from fuels if Tier 2 or Tier 3 methodology cannot be applied.

Table 14.2 Emissions from exploration based on to Tier 1 emission factors in IPCC 2006 and activity data for 2011.

	CH_4	CO_2	NMVOC	N_2O	Unit
Well drilling	0.42	1.3	0.011	ND	Gg
Well testing	0.65	116	0.15	0.001	Gg
Well service	1.4	0.024	0.22	ND	Gg
Sum	2.5	117	0.4	0.001	Gg

The Danish Energy Agency, DEA, has provided data on well testing including extracted amounts of oil and gas for the single test productions. Further molar composition has been provided for most test productions. Data are provided for the years 1990 (base year) and 2000-2011. CO_2 emission estimates based on data provided by DEA is presented in table 2. CH_4 and N_2O emissions are included based on the ratio CH_4/CO_2 and N_2O/CO_2, respectively, for the Tier 1 emission factors.

A ten-year average for the years 2000-2009 are included in the table. As test productions are not carried out every year, this average could be applied for projection years in order to include the source well testing with an average activity. Even though the number of exploration/evaluation drillings might be known for the first years of the projection period, it remains unknown how many of these lead to test productions. Further, the amounts of oil and gas from the test productions is not predictable.

Table 14.3 Amounts and emissions from test productions based on country specific data. Note that emissions of CO_2 are given in Gg and emissions of CH_4 and N_2O are given in Mg.

	Test production, Sm^3	CO_2 emission, Gg	CH_4 emission, Mg	N_2O emission, Mg
1990	4823	6.58	37	0.06
2000	1123	0.183	1	0.002
2002	8996	18.3	103	0.16
2003	0	0	0	0
2005	2591	1.69	9	0.02
2009	357	0.034	0.2	0.0003
Average 2000-2009[1]	1307	2.02	11	0.02

[1] Estimate for the projection years 2011-2035.

Compared to the emission estimates based on IPCC 2006 Tier 1 methodology, the CO_2 emissions based on country specific data are significantly lower (~ 2 % of the Tier 1 estimate). It is assumed that the Tier 1 emission factors for drilling and well service are too high for Danish conditions, leading to very limited emissions from these sources. Therefore emissions from well drilling and well service have not been estimated.

Including country specific data lead to a significantly less impact of emissions from well testing to the national emissions of greenhouse gases. The country specific methodology based on the data provided by DEA is found to fulfil the requirements in the IPCC 2006 Guidebook. It will be considered if further information could improve the emission estimates, but this is not expected to change the emission estimates notable.

14.11.3 Agriculture

With the introduction of the IPCC 2006 guidelines (GL) several changes take place in the GHG emission estimates compared to the Revised 1996 IPCC GL. The 1996 GL were based on a limited number of observations and thus the used emission factors (EF) were based on a conservative assessment. The conservativeness caused many of the used EF to be high compared to average figures.

In the 1996 GL agricultural emissions solely include methane (CH_4) and nitrous oxide (N_2O) emissions, whereas carbon dioxide (CO_2) was estimated in the Land Use section (LULUCF). The 2006 GL have merged these two chapters into one section called AFOLU (Agriculture, Forestry and Other Land Use).

CH_4 and N_2O emissions in the agricultural sector are based on biological processes and hence very variable. Especially for N_2O the variability in the observations is up to 100 %. This gives a high uncertainty in the emission estimates as well as a high degree of flexibility to adapt local conditions into the national inventories.

Due to environmental constraints Denmark has collected agricultural activity data such as feed consumption and nitrogen excretion data on a high scientific level since the late 1980s. As a result Denmark has activity data with a low uncertainty and in many cases using higher Tiers methodology. Because of a limited amount of EF in the literature most countries are using default EF data for both CH_4 and N_2O. This is also the case for Denmark except for

CH_4 emission from enteric fermentation from dairy cattle and heifers and for nitrogen leaching rates.

The effect of the 2006 GL is thus primarily allocated to a shift in the used EF.

The major changes in the EF are given in Table 14.4.

Table 14.4 Major changes from Danish 2010 inventory and the 1996 GL to 2006 GL.

	Gas	DK 2010	1996 GL	2006 GL	Effect in Denmark
Enteric fermentation, cattle, Y_m	CH_4	5.95[a]	6.0	6.5	Denmark is currently working on an update of the CS[b] Y_m.
Manure management, MCF, solid	CH_4	1 %	1 %	2 %	Limited effect since most animals are in liquid based manure systems
Manure management, MCF, deep litter bedding > 1 month	CH_4	10 %	10 %	17 %	Some effect since most animals are in liquid based manure systems
Manure management, MCF, deep litter bedding < 1 month	CH_4	0 %	0 %	3 %	Limited effect since most animals are in liquid based manure systems
Manure management, MCF, liquid	CH_4	10 %	39 %	10 %	No effect since Denmark previous has used a MCF of 10 % as a national value
Manure management, liquid	N_2O	0.1 %	0.1 %	0.5 %	Relatively large since most animals are in liquid based manure systems
Manure management, solid	N_2O	2.0 %	2.0 %	0.5 %	Relatively small since most animals are in liquid based manure systems
Animal manure applied to soil	N_2O	1.25 %	1.25 %	1.0 %	A 20% reduction in the emission
Mineral fertiliser	N_2O	1.25 %	1.25 %	1.0 %	A 20% reduction in the emission
N in crop residues and sewage sludge	N_2O	1.25 %	1.25 %	1.0 %	A 20% reduction in the emission
N-fixing by plants	N_2O	1.25 %	1.25 %	0.0 %	This source has been removed in the guidelines since it cannot be verified scientifically that the N-fixing process produce N_2O
Leached nitrogen	N_2O	1.94 %[c]	2.5 %	0.75 %	The major part of the emission from nitrogen leaving the root zone cannot be found. This significantly reduces the emission since Denmark has a high N-leaching.
Global Warming Potential (GWP)	N_2O	310	310	298[e]	Limited effect. Reduces 2010 emission by 4 %
	CH_4	21	21	25[e]	Some effect. Increases 2010 emission by 19 %

[a] Used for dairy cattle and heifers. Y_m from1996 GL are used for additional categories

[b] Country specific

[c] Based on measured amounts of N in groundwater, rivers and estuaries. Vary from year to year.

[d] Not Included

[e] The 2006 IPCC Guidelines uses the GWPs from the 3rd Assessment Report, which uses 23 for CH_4 and 296 for N_2O. However, in the reporting from 2015 the GWPs from the 4th Assessment report will be used, which is the values provided in the table.

14.11.4 Results

Table 14.5 shows the CH_4 and N_2O emission estimates for the agricultural sector in 2010. The emission from enteric fermentation will increase 7 % due to rise of Ym for dairy cattle and heifers. Denmark is currently in a working process with an update of the country specific (CS) Ym. The temporary results indicate a rise of CS Ym and thus are the new estimate made with Ym from 2006 GL. CH_4 from manure management will increase with 15 % due to increase of MCF for all solid and deep litter manure housing systems.

The N_2O emission from manure management will increase with 0.44 Gg N_2O due to the increased EF for liquid manure. This is, however, also counteracted by the reduction in the EF for solid manure.

The general decrease in the EF for nitrogen from 1.25 % to 1.0 % will decrease the emission from the N_2O sources. The largest decrease is however from leached N where the EF has been reduced from 1.94 % (CS) to 0.75 %.

The overall effect of the change from 1996 GL to 2006 GL is an increase of 1.24 M tonnes CO_2 eqv. for CH_4 and a decrease of 1.84 M tonnes CO_2 eqv. for N_2O. In total the agricultural emission are estimated to decrease 0.60 M tonnes CO_2 eqv. (rounded figures) in 2010, corresponding to 6 % reduction.

In order to reduce the overall GHG emission from the agricultural sector the changed EF will change the priority of which areas should be focused on. The lower EF for leached N will probably lead to a lower priority than before. In consequence of this, focus on reduction possibilities could be turned towards the direct emissions from livestock, enteric fermentation and manure management.

Table 14.5 Estimated emission in 2010 with the CS/1996 and the 2006 guidelines combined with the new GWP figures.

		2010 emission		
		CS/1996 GL	2006 GL	Difference
CH_4, Gg	Enteric fermentation	136.02	145.11	9.10
	Manure Management (incl. reduction from biogas)	61.33	70.43	9.10
	Manure Management	62.44	71.54	9.10
	Red. from biogas production	-1.11	-1.11	0.00
	- part from Dairy Cattle	-0.33	-0.33	0.00
	- part from Swine	-0.78	-0.78	0.00
	Field burning of crop residue	0.10	0.10	0.00
	Total	197.44	215.64	18.20
CO_2 eqv. M tonnes		4.15	5.39	1.24
N_2O, Gg	Manure Management (incl. reduction from biogas)	1.36	1.80	0.44
	Manure Management	1.42	1.86	0.44
	Red. from biogas production	-0.06	-0.06	0.00
	Pasture	0.64	0.68	0.05
	Mineral fertiliser	3.68	2.94	-0.74
	Animal manure applied to soils	3.72	2.98	-0.74
	Sewage sludge/industrial waste	0.13	0.11	-0.03
	Atmospheric deposition	0.93	0.93	0.00
	N-leaching and run-off	4.57	1.08	-3.49
	N-fixing crops	0.77	0.00	-0.77
	Crop residue	1.02	0.81	-0.20
	Histosols	0.53	0.53	0.00
	Field burning of crop residue	0.003	0.003	0.00
	Total	17.33	11.85	-5.48
CO_2 eqv. M tonnes		5.37	3.53	-1.84
CH_4, CO_2 eqv., M tonnes		4.15	5.39	1.24
N_2O, CO_2 eqv., M tonnes		5,37	3.53	-1.84
CO_2 eqv., M tonnes		9.52	8.92	-0.60

The currently used Global Warming Potential (GWP) for CH_4 and N_2O is 21 and 310 respectively. These values are used in the calculation with 1996 GL.

In the future reporting GWPs will be revised to 25 and 298, respectively and these values are used in estimate for the 2010 emission with the 2006 GL. For CH_4 the change of GWP increases CH_4 emission with 19 %, while change of GWP decreases the emission of N_2O with 4 %.

The effect of the above mentioned differences on the projection is generally a 5-6 % lower emission. The table below shows the difference for 2015, 2020, 2035, 2030 and 2035.

Table 14.6 Projected emission, comparison between use of CS/1996 GL and 2006 GL..

		2015	2020	2025	2030	2035
CS/1996 GL	CO_2 eqv. M tonnes	9.16	8.90	8.89	8.88	8.86
2006 GL	CO_2 eqv. M tonnes	8.57	8.36	8.39	8.42	8.44
Difference	CO_2 eqv. M tonnes	-0.59	-0.54	-0.50	-0.46	-0.42
Difference	Pct.	-6	-6	-6	-5	-5

14.11.5 Agricultural land use

The 2006 GL have no effect on the CO_2 emission estimates from agricultural soils because Denmark is using a Tier 3 modelling approach for mineral soils and standard CO_2-emission figures per ha for organic soils. In general is it assumed that the mineral soils are in balance and the net emission is 1.0 M tonnes CO_2 from the cultivated organic soils. The monitoring programme under the Danish election of article 3.4 for cropland and grassland will gain new knowledge on the CO_2 emission from these soils as well as the area. Changes in the CO_2 emission from these soils will affect the overall emission but not change the Danish reduction commitments in the first commitment period as changes in these emissions shall be accounted for with the net-net principle.

The emission of N_2O from the organic soils of 0.16 M tonnes CO_2 eqv. in 2010 is accounted for in the agricultural sector and is therefore included in the reduction commitments. The emission measured in CO_2 eqv. from this source will decrease due to the lower GWP for N_2O.

14.11.6 Future improvements in the Danish inventory

The introduction of the EF's from 2006 GL and new GWPs hardly change the overall emission in CO_2 eqv. in 2010. It must be assumed that the change from use of the 1996 GL to the 2006 GL will decrease the uncertainty in the inventory. However, below is given emission sources where it could be valuable to improve the inventory with Danish EF, because the IPCC default values is assumed not to be applicable for Danish conditions.

- CH_4 emission from enteric fermentation. Today is used a simple modelled output from a cattle model (Karoline). For dairy cattle is an Y_m of 5.95 estimated. The IPCC default Y_m-value is 6.5. The future increase in milk production per dairy cow gives a higher need for high quality feed. Actual feeding plans are collected and analysed every year to estimate normative data (Normtal) for feed consumption and nitrogen excretion values. To improve the inventory it could be an advantage to make annual estimations of Y_m based on the actual feeding plans.

- The default Methane Conversion Factor (MCF) for liquid manure is 10 %. Due to a long storage period in Denmark (up to 10 months) this value is very uncertain. Updated EF is highly needed.
- The new default MCF for deep litter bedding of 17 % is a very high value and should be investigated further.
- The increased use of manure in biogas plants reduce the above mentioned storage time and lower the CH_4 and N_2O emission from manure management. There is a need for an updated model to estimate CH_4 and N_2O emission from biogas treated manure.
- B_0 values for pig manure of 0.45 is probably too high according to preliminary results from DCA - Danish Centre for Food and Agriculture, Aarhus University. B_0 values for pig, cattle and fur animals should be verified.
- The EF for mineral fertiliser and animal manure applied to the field is 1 % in the 2006 GL. In general it is assumed that the EF for mineral fertiliser is overestimated in Denmark and is more likely 0.6-0.7 on soils with high content of sand and organic matter. The EF for manure management is probably higher than 1 %, more close to 1.25 to 2.0 %. This should be investigated further.
- Emission from lime application is included in the LULUCF sector. The currently used model for CO_2 emission from lime application assumes that all $CaCO_3$ is converted to CO_2. Under the wet Danish conditions this is not valid as leached HCO_3^- can be found in streams and lakes. An American investigation showed that 50 % of the CO_3^- was leached. Applying this result to Danish conditions will lower the Danish emission of CO_2 with 0.06 M tonnes CO_2 per year.

14.11.7 F-gases

The new reporting guideline (UNFCCC, 2012) introduces revised GWP for F-gases. Table 14.7 presents old and new GWP and the consequence of applying the new GWP on the 2010 emission of F-gases. For a few F-gases the GWP have decreased by 4.6-72.9 % but for most of the F-gases the GWP have increased by 3.8-55.7 %. The consequence for the 2010 F-gas emission is an increase of 15 % that can be explained by the increased GWP for the three most common F-gases. The GWP for HFC-125 has increased 25 %, the GWP for HFC-134a has increased 10 %, and the GWP for HFC-143a has increased 18 %.

Table 14.7 Old and new GWP (UNFCCC, 2012) and consequences of application of the new GWP on the Danish F-gas emission in 2010.

Substance	Chemical formula	GWP	GWP new	Difference %	2010 emission Mg	Gg CO_2 eqv.	New Gg CO_2 eqv.	Difference %
HFC-23	CHF_3	11 700	14 800	26.5	0.36	4.21	5.33	
HFC-32	CH_2F_2	650	675	3.8	17.52	11.39	11.83	
HFC-41	CH_3F	150	92	-38.7	NO			
HFC-43-10mee	$CF_3CHFCHFCF_2CF_3$	1 300	1 640	26.2	NO			
HFC-125	C_2HF_5	2 800	3 500	25.0	72.76	203.72	254.65	
HFC-134	$C_2H_2F_4$ (CHF_2CHF_2)	1 000	1 100	10.0	NO			
HFC-134a	$C_2H_2F_4$ (CH_2FCF_3)	1 300	1 430	10.0	263.69	342.80	377.08	
HFC-152a	CH_2FCH_2F	140	38	-72.9	4.38	0.61	0.17	
HFC-143	$C_2H_3F_3$ (CHF_2CH_2F)	300	353	17.7	NO			
HFC-143a	$C_2H_3F_3$ (CF_3CH_3)	3 800	4 470	17.6	62.50	237.51	279.39	
HFC-227ea	C_3HF_7	2 900	3 220	11.0	NO			
HFC-236fa	$C_3H_2F_6$	6 300	9 810	55.7	NO			
HFC-245ca	$C_3H_3F_5$	560	693	23.8	NO			
Unspecified mix of listed HFCs (1)					NO			
PFC-14	CF_4	6 500	7 390	13.7	0.36	2.34	2.66	
PFC-116	C_2F_6	9 200	12 200	32.6	NO			
PFC-218	C_3F_8	7 000	8 830	26.1	1.00	7.01	8.85	
PFC-3-1-10	C_4F_{10}	7 000	8 860	26.6	NO			
PFC-318	c-C_4F_8	8 700	10 300	18.4	0.45	3.92	4.64	
PFC-4-1-12	C_5F_{12}	7 500	9 160	22.1	NO			
PFC-5-1-14	C_6F_{14}	7 400	9 300	25.7	NO			
Unspecified mix of listed PFCs (1)					NO			
	SF_6	23 900	22 800	-4.6	1.58	37.88	36.14	
						851.39	980.72	15.19

A potential change in the ratio between the three most relevant F-gases has not been included in the present evaluation of the new GWP.

14.12 References

UNFCCC, 2012. Report of the Conference of the Parties on its seventeenth session, held in Durban from 28 November to 11 December 2011. Addendum: Part Two: Action taken by the Conference of the Parties at its seventeenth session. FCCC/CP/2011/9/Add.2. 15 March 2012.

Table 14.8 Historic and projected greenhouse gas (GHG) emissions in ktonnes CO_2 equivalents.

GHG emissions and projections (Gg)		KP Base year	1990	1995	2000	2005	2008	2009	2010	2011	2012	2008-12	2015	2020	2025	2030	2035
Denmark's total emissions excluding net emissions/removals from LULUCF		69323.336	68560	76050	68090	63740	63554	60683	61065	55874	55137	59255	48463	44898	43733	44822	45731
1. Energy		52121	52098	60182	52862	50298	50215	48238	48789	43497	42898	46726	36721	33836	32784	33891	34787
A. Fuel Combustion (Sectoral Approach)		51817	51729	59660	52054	49644	49695	47853	48325	43127	42579	46316	36434	33554	32507	33618	34514
1. Energy Industries		26315	26246	32515	25962	23204	24203	24123	23915	20031	19701	22395	14333	13383	12318	12994	13186
a Public Electricity and Heat Production		24861	24787	30376	23485	20636	21664	21658	21559	17675	17337	19978	12171	11093	9559	9884	10100
b Petroleum Refining		908	908	1388	1001	939	928	934	855	837	901	891	901	901	901	901	901
c Manufacture of Solid Fuels and Other Energy Industries		546	552	751	1475	1629	1612	1531	1501	1519	1463	1525	1261	1389	1858	2209	2185
2. Manufacturing Industries and Construction		5493	5446	5909	6033	5519	4966	4028	4453	4265	4318	4406	3776	2841	2703	2576	2493
3. Transport		10529	10784	12137	12365	13341	14025	13292	13248	12928	12590	13217	12850	12641	13042	13802	14746
a Civil Aviation		246	246	202	157	138	165	156	158	143	147	154	149	155	156	153	153
b Road Transport		9418	9427	10763	11379	12372	13017	12295	12241	11894	11664	12222	11922	11707	12107	12869	13813
c Railways		300	300	306	230	234	239	232	244	252	107	215	107	107	107	107	107
d Navigation		566	811	867	600	597	604	609	605	639	672	626	672	672	672	672	672
4. Other Sectors		9359	9132	8844	7582	7306	6392	6249	6600	5707	5815	6153	5320	4534	4288	4091	3934
a Commercial and Institutional		1419	1499	1248	1016	1027	1066	1028	1135	921	944	1019	880	799	766	730	698
b Residential		5208	5089	5110	4133	3822	3045	3116	3237	2912	2969	3056	2507	1891	1684	1522	1389
c Agriculture/Forestry/Fisheries		2732	2545	2486	2433	2457	2281	2105	2228	1875	1902	2078	1933	1844	1838	1839	1847
5. Other	(1)	120	120	254	112	274	109	162	108	195	155	146	155	155	155	155	155
B. Fugitive Emissions from Fuels		304	369	522	808	653	521	384	465	370	319	410	286	283	277	273	273
1. Solid Fuels		NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
2. Oil and Natural Gas		304	369	522	808	653	521	384	465	370	319	410	286	283	277	273	273
a Oil		32	35	54	82	106	125	118	106	106	105	112	99	102	97	99	99
b Natural Gas		6	9	18	8	8	4	3	4	12	5	4	5	4	4	4	4
c Flaring		267	325	451	718	539	392	263	355	252	209	294	183	177	177	170	170
2. Industrial Processes		2470	2195	2727	3388	2442	2256	1765	1685	1850	1831	1877	1660	1342	1325	1380	1454
A. Mineral Products		1072	1069	1405	1616	1544	1320	881	796	988	998	997	1049	1162	1203	1266	1340
1 Cement Production		882	882	1204	1385	1363	1155	764	672	862	874	865	933	1036	1076	1131	1198
2 Lime Production		152	116	88	77	63	66	43	46	47	47	50	50	54	56	59	62
3 Limestone and Dolomite Use		18	14	54	90	56	39	38	46	46	42	42	30	30	27	28	28
4 Soda Ash Production and Use	NO																
5 Asphalt Roofing	(<0,5)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 14.8 Historic and projected greenhouse gas (GHG) emissions in ktonnes CO_2 equivalents.

GHG emissions and projections (Gg)		KP Base year	1990	1995	2000	2005	2008	2009	2010	2011	2012	2008-12	2015	2020	2025	2030	2035
6 Road Paving with Asphalt		2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
7 Other	(2)	17	55	58	63	59	60	34	31	32	33	38	35	40	43	46	49
B. Chemical Industry		1044	1044	905	1004	3	2	2	2	2	2	2	2	3	3	3	3
2 Nitric Acid Production		1043	1043	904	1004	0	0	0	0	0	0	0	0	0	0	0	0
5 Other	(3)	1	1	1	1	3	2	2	2	2	2	2	2	3	3	3	3
C. Metal Production		64	28	74	62	16	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
1 Iron and Steel Production		28	28	39	41	16	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
4 SF_6 Used in Aluminium and Magnesium Foundries		36	0	36	21	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
D. Other Production		NE, NA	4	4	4	4	3	2	2	2	2	2	2	2	2	3	3
E. Production of Halocarbons and SF_6	NO																
F. Consumption of Halocarbons and SF_6		290		290	662	838	897	849	851	825	796	844	573	142	83	75	76
1. Refrigeration and Air Conditioning Equipment		36		36	436	676	739	691	699								
2 Foam Blowing		183		183	168	119	103	96	87								
3 Fire Extinguishers		0		0	0	0	0	0	0								
4 Aerosol/Metered Dose Inhalers		0		0	19	21	19	18	17								
8 Electrical Equipment		4		4	11	13	16	15	14								
9 Other		68		68	28	9	20	31	34								
C_3F_8	(4)	0		0	2	0	4	6	6								
SF_6	(5)	68		68	26	9	15	22	24								
G. Other		NO	50	49	40	38	34	31	33	33	33	33	33	33	33	33	33
3. Solvent and Other Product Use		137	93	109	102	88	78	82	76	76	75	74	72	67	64	61	58
A Paint Application		24	16	18	19	12	9	9	8	8	8	8	7	6	6	5	5
B Degreasing and Dry Cleaning		46	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C Chemical Products, Manufacture and Processing		3	19	21	16	15	15	12	12	13	12	13	12	11	10	10	9
D Other		64	59	70	67	60	54	62	56	55	55	56	53	50	47	46	44
1 Use of N_2O for Anaesthesia		0	0	0	0	11	10	14	11	12	12	12	12	12	12	12	12
5 Other	(6)	64	59	70	67	49	44	47	45	44	43	45	41	38	36	34	32
4. Agriculture		13048	12462	11515	10394	9783	9884	9540	9520	9487	9399	9563	9156	8903	8889	8876	8859
A Enteric Fermentation		3259	3247	3134	2861	2737	2830	2823	2856	2826	2798	2827	2795	2853	2935	3017	3098
1 Cattle		2950	2929	2781	2470	2299	2394	2405	2442								
Dairy Cattle		1844	1844	1762	1564	1518	1531	1582	1603								

Table 14.8 Historic and projected greenhouse gas (GHG) emissions in ktonnes CO_2 equivalents.

GHG emissions and projections (Gg)		KP Base year	1990	1995	2000	2005	2008	2009	2010	2011	2012	2008-12	2015	2020	2025	2030	2035
Non-Dairy Cattle		1106	1085	1019	906	781	863	823	839								
2 Buffalo	NO																
3 Sheep		33	33	29	40	46	42	42	40								
4 Goats		2	2	2	2	3	4	4	4								
5 Camels and Llamas	NO																
6 Horses		60	62	65	69	80	87	81	76								
7 Mules and Asses	NO																
8 Swine		213	217	252	277	305	300	287	291								
9 Poultry	NE	0	1	1	1	1	1	1	1								
10 Other			2	2	2	2	2	2	2								
Fur farming & Deer	NE		2	2	2	2	2	2	2								
B. Manure Management		1437	1593	1669	1722	1816	1730	1693	1709	1665	1635	1686	1536	1354	1293	1232	1161
1 Cattle		282	519	545	572	601	582	589	596								
Dairy Cattle		213	333	337	368	406	377	391	396								
Non-Dairy Cattle		69	186	208	204	195	205	198	200								
2 Buffalo	NO																
3 Sheep		1	5	5	7	7	7	7	7								
4 Goats		0	0	0	0	1	1	1	1								
5 Camels and Llamas	NO																
6 Horses		4	8	9	9	11	12	11	10								
7 Mules and Asses	NO																
8 Swine		448	423	509	555	630	607	595	607								
9 Poultry		6	10	11	11	11	10	11	11								
10 Other livestock		9	27	23	31	42	54	56	56								
Fur farming		9	27	23	31	42	54	56	56								
11 Anaerobic Lagoons	NO																
12 Liquid Systems		96	94	82	79	82	80	76	75								
13 Solid Storage and Dry Lot		589	314	250	199	155	111	93	88								
14 Other AWMS		0	192	234	260	275	266	255	258								
C. Rice Cultivation	NO																
D. Agricultural Soils		8352	7620	6709	5807	5226	5320	5020	4951	4992	4962	5049	4822	4692	4657	4624	4597
1 Direct Soil Emissions		4225	4401	3781	3391	3193	3242	3125	3051								

Table 14.8 Historic and projected greenhouse gas (GHG) emissions in ktonnes CO_2 equivalents.

GHG emissions and projections (Gg)		KP Base year	1990	1995	2000	2005	2008	2009	2010	2011	2012	2008-12	2015	2020	2025	2030	2035
2 Pasture, Range and Paddock Manure		312	311	323	312	236	213	203	197								
3 Indirect Emissions		3787	2907	2606	2105	1797	1866	1693	1703								
4 Other		28	0	0	0	0	0	0									
Industrial waste used as fertilizer		9	0	0	0	0	0	0									
Use of sewage sludge as fertilizers		19	0	0	0	0	0	0									
E. Prescribed Burning of Savannas	NO																
F. Field Burning of Agricultural Residues		NO	3	3	4	4	3	4	3	4	4	3	4	4	4	4	4
G. Other	NO																
6. Waste		1547	1711	1517	1344	1130	1121	1058	995	964	934	1014	854	749	671	615	574
A. Solid Waste Disposal on Land		1334	1477	1261	1050	846	805	765	693	658	625	709	536	415	321	248	192
B. Waste-water Handling		213	176	184	173	168	186	156	159	166	166	167	167	169	172	174	176
C. Waste Incineration		IE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D. Other		NO	58	72	122	116	129	137	143	140	143	138	151	164	178	192	206
7. Other	NO																
Memo Items (not included above):																	
International Bunkers		4904	4820	6963	6627	5002	5542	3858	4562	4829	4945	4747	5083	5479	5592	5383	5381
Aviation		1755	1755	1888	2376	2602	2677	2342	2448	2530	2645	2528	2783	3179	3292	3083	3083
Marine		3149	3065	5076	4251	2400	2866	1516	2115	2300	2300	2219	2300	2300	2300	2300	2299
Multilateral Operations	NE																
CO_2 Emissions from Biomass		4641	4662	5725	6899	10728	12328	12628	14864	NE	NE	NE	NE	NE	NE	NE	NE

Notes:

(1): Military mobile combustion of fuels

(2): Glass production, production of bricks and clay products

(3): Catalysts/Fertilizers, Pesticides and Sulphuric acid

(4): PFC used as detergent

(5): Window plate production, research laboratories and running shoes

(6): Other products, manufacture and processing such as vessels, vehicles, wood, food and graphic

NO: Not occurring

NE: Not estimated

NA: Not Applicable

IE: Included elsewhere

Table 14.9 Historic and projected CO_2 emissions in ktonnes CO_2.

CO_2 emissions and projections (Gg)		KP Base year	1990	1995	2000	2005	2008	2009	2010	2011	2012	2008-12	2015	2020	2025	2030	2035
Denmark's total emissions excluding net emissions/removals from LULUCF		52712	52808	60906	53666	51008	50724	48368	48786	43729	43139	46943	37154	34409	33359	34447	35370
1. Energy		51474	51545	59282	51847	49311	49278	47366	47872	42623	42025	45826	35992	33137	32049	33077	33928
A. Fuel Combustion (Sectoral Approach)		51211	51221	58832	51127	48768	48885	47101	47515	42364	41812	45535	35807	32958	31870	32905	33756
1. Energy Industries		26173	26146	32163	25544	22838	23887	23832	23577	19669	19343	22061	14100	13183	12090	12705	12869
a Public Electricity and Heat Production		24736	24695	30037	23088	20285	21359	21378	21231	17323	16989	19656	11947	10903	9343	9610	9798
b Petroleum Refining		897	906	1384	998	938	926	933	854	836	900	890	900	900	900	900	900
c Manufacture of Solid Fuels and Other Energy Industries		540	545	741	1457	1615	1602	1522	1492	1510	1454	1516	1253	1380	1847	2195	2172
2. Manufacturing Industries and Construction		5423	5385	5852	5961	5459	4910	3981	4402	4224	4271	4358	3725	2771	2632	2503	2417
3. Transport		10336	10617	11939	12173	13166	13862	13141	13099	12779	12444	13065	12707	12494	12885	13633	14566
a Civil Aviation		243	243	199	154	135	162	153	156	142	146	152	148	153	155	152	152
b Road Transport		9241	9282	10588	11203	12214	12871	12160	12108	11761	11532	12086	11793	11575	11964	12715	13648
c Railways		297	297	303	228	232	237	230	242	249	106	213	106	106	106	106	106
d Navigation		555	796	850	588	585	593	598	593	627	660	614	660	660	660	660	660
4. Other Sectors		9159	8954	8626	7339	7034	6119	5987	6331	5499	5600	5907	5122	4356	4110	3911	3750
a Commercial and Institutional		1403	1486	1222	987	997	1037	999	1106	905	928	995	864	783	749	714	682
b Residential		5084	4983	4985	4003	3660	2864	2944	3060	2766	2818	2890	2377	1786	1585	1427	1293
c Agriculture/Forestry/Fisheries		2673	2485	2419	2349	2377	2217	2044	2165	1828	1854	2022	1881	1787	1776	1770	1775
5. Other	(1)	119	119	252	111	271	108	160	107	193	153	144	153	153	153	153	153
B. Fugitive Emissions from Fuels		263	325	449	720	543	392	265	357	260	213	291	185	179	179	172	172
1. Solid Fuels		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2. Oil and Natural Gas		263	325	449	720	543	392	265	357	260	213	291	185	179	179	172	172
a Oil		NA	2	4	7	7	5	5	5	4	4	NA	3	3	3	3	3
b Natural Gas		NA	0	0	0	0	0	0	0	6	3	NA	2	2	2	2	2
c Flaring		263	322	446	713	536	387	260	352	249	206	291	180	174	174	168	168
2. Industrial Processes		1101	1152	1497	1701	1604	1360	916	833	1025	1035	1034	1086	1200	1242	1305	1379
A. Mineral Products		1072	1069	1405	1616	1544	1320	881	796	988	998	997	1049	1162	1203	1266	1340
1 Cement Production		882	882	1204	1385	1363	1155	764	672	862	874	865	933	1036	1076	1131	1198
2 Lime Production		152	116	88	77	63	66	43	46	47	47	50	50	54	56	59	62
3 Limestone and Dolomite Use		18	14	54	90	56	39	38	46	46	42	42	30	30	27	28	28
4 Soda Ash Production and Use	NO																
5 Asphalt Roofing	(<0,5)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 14.9 Historic and projected CO_2 emissions in ktonnes CO_2.

CO_2 emissions and projections (Gg)		KP Base year	1990	1995	2000	2005	2008	2009	2010	2011	2012	2008-12	2015	2020	2025	2030	2035
6 Road Paving with Asphalt		2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
7 Other	(2)	17	55	58	63	59	60	34	31	32	33	38	35	40	43	46	49
B. Chemical Industry		1	1	1	1	3	2	2	2	2	2	2	2	3	3	3	3
2 Nitric Acid Production																	
5 Other	(3)	1	1	1	1	3	2	2	2	2	2	2	2	3	3	3	3
C. Metal Production		28	28	39	41	16	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
1 Iron and Steel Production		28	28	39	41	16	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
4 SF_6 Used in Aluminium and Magnesium Foundries																	
D. Other Production		NE	4	4	4	4	3	2	2	2	2	2	2	2	2	3	3
E. Production of Halocarbons and SF_6																	
F. Consumption of Halocarbons and SF_6																	
1. Refrigeration and Air Conditioning Equipment																	
2 Foam Blowing																	
3 Fire Extinguishers																	
4 Aerosol/Metered Dose Inhalers																	
8 Electrical Equipment																	
9 Other																	
C_3F_8	(4)																
SF_6	(5)																
G. Other		NO	50	49	40	38	34	31	33	33	33	33	33	33	33	33	33
3. Solvent and Other Product Use		137	92	107	99	75	65	65	62	61	60	63	57	52	49	46	43
A Paint Application		24	16	18	19	12	9	9	8	8	8	8	7	6	6	5	5
B Degreasing and Dry Cleaning		46	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C Chemical Products, Manufacture and Processing		3	19	21	16	15	15	12	12	13	12	13	12	11	10	10	9
D Other		64	58	68	63	47	41	44	42	40	40	41	38	35	32	30	29
1 Use of N_2O for Anaesthesia																	
5 Other	(6)	64	58	68	63	47	41	44	42	40	40	41	38	35	32	30	29
4. Agriculture																	
A Enteric Fermentation																	
1 Cattle																	
Dairy Cattle																	

Table 14.9 Historic and projected CO_2 emissions in ktonnes CO_2.

CO_2 emissions and projections (Gg)		KP Base year	1990	1995	2000	2005	2008	2009	2010	2011	2012	2008-12	2015	2020	2025	2030	2035
Non-Dairy Cattle																	
2 Buffalo																	
3 Sheep																	
4 Goats																	
5 Camels and Llamas																	
6 Horses																	
7 Mules and Asses																	
8 Swine																	
9 Poultry	NE																
10 Other																	
Fur farming & Deer	NE																
B. Manure Management																	
1 Cattle																	
Dairy Cattle																	
Non-Dairy Cattle																	
2 Buffalo	NO																
3 Sheep																	
4 Goats																	
5 Camels and Llamas	NO																
6 Horses																	
7 Mules and Asses	NO																
8 Swine																	
9 Poultry																	
10 Other livestock																	
Fur farming																	
11 Anaerobic Lagoons																	
12 Liquid Systems																	
13 Solid Storage and Dry Lot																	
14 Other AWMS																	
C. Rice Cultivation	NO																
D. Agricultural Soils																	
1 Direct Soil Emissions																	

Table 14.9 Historic and projected CO_2 emissions in ktonnes CO_2.

CO_2 emissions and projections (Gg)		KP Base year	1990	1995	2000	2005	2008	2009	2010	2011	2012	2008-12	2015	2020	2025	2030	2035
2 Pasture, Range and Paddock Manure																	
3 Indirect Emissions																	
4 Other																	
Industrial waste used as fertilizer																	
Use of sewage sludge as fertilizers																	
E. Prescribed Burning of Savannas	NO																
F. Field Burning of Agricultural Residues	NO																
G. Other	NO																
6. Waste		NO	18	20	19	18	22	21	18	20	20	20	19	20	20	20	20
A. Solid Waste Disposal on Land	NE																
B. Waste-water Handling																	
C. Waste Incineration	IE																
D. Other		NO	18	20	19	18	22	21	18	20	20	20	19	20	20	20	20
7. Other	NO																
Memo Items (not included above):																	
International Bunkers		4823	4741	6843	6517	4926	5457	3803	4494	4751	4864	4674	5001	5392	5503	5297	5297
Aviation		1736	1736	1867	2350	2574	2647	2316	2421	2496	2610	2498	2746	3137	3248	3042	3042
Marine		3087	3005	4976	4168	2352	2809	1487	2073	2255	2255	2176	2255	2255	2255	2255	2255
Multilateral Operations																	
CO_2 Emissions from Biomass		4641	4662	5725	6899	10728	12328	12628	14864	NE	NE	NE	NE	NE	NE	NE	NE

Notes:

(1): Military mobile combustion of fuels

(2): Glass production, production of bricks and clay products

(3): Catalysts/Fertilizers, Pesticides and Sulphuric acid

(4): PFC used as detergent

(5): Window plate production, research laboratories and running shoes

(6): Other products, manufacture and processing such as vessels, vehicles, wood, food and graphic

NO: Not occurring

NE: Not estimated

NA: Not Applicable

IE: Included elsewhere

Table 14.10 Historic and projected methane (CH_4) emissions in ktonnes CO_2 equivalents.

CH_4 emissions and projections (Gg CO_2 equivalents)		KP Base year	1990	1995	2000	2005	2008	2009	2010	2011	2012	2008-12	2015	2020	2025	2030	2035
Denmark's total emissions excluding net emissions from LULUCF		5692	6041	6124	5867	5637	5611	5516	5534	5442	5355	5489	5091	4920	4916	4969	5001
1. Energy		222	228	519	633	607	554	505	538	535	524	531	396	367	390	448	481
A. Fuel Combustion (Sectoral Approach)		182	184	448	547	497	427	386	431	426	418	417	295	264	292	348	381
1. Energy Industries		23	14	239	308	262	215	188	231	283	270	237	159	127	153	207	234
a Public Electricity and Heat Production		22	14	238	307	260	213	186	230	282	269	236	158	126	152	206	232
b Petroleum Refining		1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
c Manufacture of Solid Fuels and Other Energy Industries		0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1
2. Manufacturing Industries and Construction		15	8	10	25	20	14	13	14	7	11	12	18	35	37	39	42
3. Transport		53	54	51	38	27	19	16	15	13	12	15	10	8	7	7	8
a Civil Aviation	(<0,5)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
b Road Transport		52	53	50	37	26	18	15	14	13	12	14	9	7	7	7	7
c Railways	(<0,5)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
d Navigation		1	1	1	1	1	1	1	1	0	0	1	0	0	0	0	0
4. Other Sectors		91	108	148	176	188	179	169	171	122	124	153	109	94	94	95	97
a Commercial and Institutional		4	4	16	21	21	18	18	17	6	6	13	7	8	8	8	8
b Residential		68	78	96	101	120	130	121	123	98	98	114	80	59	54	48	49
c Agriculture/Forestry/Fisheries		20	26	35	54	48	31	30	31	18	19	26	22	27	32	38	40
5. Other	(<0,5)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B. Fugitive Emissions from Fuels		40	44	71	86	109	127	118	107	109	106	114	101	103	98	100	100
1. Solid Fuels	NA																
2. Oil and Natural Gas		40	44	71	86	109	127	118	107	109	106	114	101	103	98	100	100
a Oil		32	33	50	75	99	120	113	102	102	102	108	96	98	94	96	96
b Natural Gas		6	9	18	8	8	4	3	4	5	2	4	2	2	2	2	2
c Flaring		2	2	4	3	2	4	2	2	2	2	3	2	2	2	2	2
2. Industrial Processes																	
A. Mineral Products																	
1 Cement Production																	
2 Lime Production																	
3 Limestone and Dolomite Use																	
4 Soda Ash Production and Use																	
5 Asphalt Roofing																	
6 Road Paving with Asphalt																	

Table 14.10 Historic and projected methane (CH_4) emissions in ktonnes CO_2 equivalents.

CH_4 emissions and projections (Gg CO_2 equivalents)		KP Base year	1990	1995	2000	2005	2008	2009	2010	2011	2012	2008-12	2015	2020	2025	2030	2035
7 Other																	
B. Chemical Industry																	
2 Nitric Acid Production																	
5 Other	NA																
C. Metal Production																	
1 Iron and Steel Production	NA																
4 SF_6 Used in Aluminium and Magnesium Foundries																	
D. Other Production	NE																
E. Production of Halocarbons and SF_6																	
F. Consumption of Halocarbons and SF_6																	
1. Refrigeration and Air Conditioning Equipment																	
2 Foam Blowing																	
3 Fire Extinguishers																	
4 Aerosol/Metered Dose Inhalers																	
8 Electrical Equipment																	
9 Other																	
C_3F_8																	
SF_6																	
G. Other	NO																
3. Solvent and Other Product Use																	
A Paint Application																	
B Degreasing and Dry Cleaning																	
C Chemical Products, Manufacture and Processing																	
D Other																	
1 Use of N_2O for Anaesthesia																	
5 Other																	
4. Agriculture		4011	4242	4239	4048	4043	4106	4095	4146	4095	4050	4096	3997	3967	4024	4082	4128
A Enteric Fermentation		3259	3247	3134	2861	2737	2830	2823	2856	2826	2798	2827	2795	2853	2935	3017	3098
1 Cattle		2950	2929	2781	2470	2299	2394	2405	2442								
Dairy Cattle		1844	1844	1762	1564	1518	1531	1582	1603								
Non-Dairy Cattle																	

Table 14.10 Historic and projected methane (CH_4) emissions in ktonnes CO_2 equivalents.

CH_4 emissions and projections (Gg CO_2 equivalents)		KP Base year	1990	1995	2000	2005	2008	2009	2010	2011	2012	2008-12	2015	2020	2025	2030	2035
2 Buffalo	NO																
3 Sheep		33	33	29	40	46	42	42	40								
4 Goats		2	2	2	2	3	4	4	4								
5 Camels and Llamas	NO																
6 Horses		60	62	65	69	80	87	81	76								
7 Mules and Asses	NO																
8 Swine		213	217	252	277	305	300	287	291								
9 Poultry		NE	1	1	1	1	1	1	1								
10 Other		NE	2	2	2	2	2	2	2								
Fur farming & Deer		NE	2	2	2	2	2	2	2								
B. Manure Management		752	993	1103	1184	1303	1273	1270	1288	1266	1250	1269	1199	1111	1087	1062	1028
1 Cattle		282	519	545	572	601	582	589	596								
Dairy Cattle		213	333	337	368	406	377	391	396								
Non-Dairy Cattle		69	186	208	204	195	205	198	200								
2 Buffalo	NO																
3 Sheep		1	5	5	7	7	7	7	7								
4 Goats		0	0	0	0	1	1	1	1								
5 Camels and Llamas	NO																
6 Horses		4	8	9	9	11	12	11	10								
7 Mules and Asses	NO																
8 Swine		448	423	509	555	630	607	595	607								
9 Poultry		6	10	11	11	11	10	11	11								
10 Other livestock		9	27	23	31	42	54	56	56								
Fur farming		9	27	23	31	42	54	56	56								
11 Anaerobic Lagoons																	
12 Liquid Systems																	
13 Solid Storage and Dry Lot																	
14 Other AWMS																	
C. Rice Cultivation	NO																
D. Agricultural Soils	NE																
1 Direct Soil Emissions	NE																
2 Pasture, Range and Paddock Manure																	

Table 14.10 Historic and projected methane (CH_4) emissions in ktonnes CO_2 equivalents.

CH_4 emissions and projections (Gg CO_2 equivalents)		KP Base year	1990	1995	2000	2005	2008	2009	2010	2011	2012	2008-12	2015	2020	2025	2030	2035
3 Indirect Emissions	NE																
4 Other	NA																
Industrial waste used as fertilizer	NA																
Use of sewage sludge as fertilizers	NA																
E. Prescribed Burning of Savannas	NO																
F. Field Burning of Agricultural Residues		NO	2	2	3	3	2	3	2	3	3	3	3	3	3	3	3
G. Other	NO																
6. Waste		1460	1572	1366	1186	986	951	916	850	812	781	862	697	586	502	439	392
A. Solid Waste Disposal on Land		1334	1477	1261	1050	846	805	765	693	658	625	709	536	415	321	248	192
B. Waste-water Handling		126	66	69	74	74	75	75	75	75	75	75	76	77	78	79	80
C. Waste Incineration	(<0,5)	IE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D. Other		NO	28	36	62	66	72	76	82	79	81	78	86	94	103	111	119
7. Other	NA																
Memo Items (not included above):																	
International Bunkers		2	2	3	3	2	2	2	2	1	1	2	1	1	1	1	1
Aviation		1	1	1	1	1	1	1	1	0	0	1	0	0	0	0	0
Marine		1	1	2	2	1	1	1	1	1	1	1	1	1	1	1	1
Multilateral Operations	NE																
CO_2 Emissions from Biomass																	

Notes:

(1): Military mobile combustion of fuels

(2): Glass production, production of bricks and clay products

(3): Catalysts/Fertilizers, Pesticides and Sulphuric acid

(4): PFC used as detergent

(5): Window plate production, research laboratories and running shoes

(6): Other products, manufacture and processing such as vessels, vehicles, wood, food and graphic

NO: Not occurring

NE: Not estimated

NA: Not Applicable

IE: Included elsewhere

Table 14.11 Historic and projected nitrous oxide (N_2O) emissions in ktonnes CO_2 equivalents.

N_2O emissions and projections (Gg CO_2 equivalents)		KP Base year	1990	1995	2000	2005	2008	2009	2010	2011	2012	2008-12	2015	2020	2025	2030	2035
Denmark's total emissions excluding net emissions from LULUCF		10593	9710	8693	7874	6258	6323	5950	5894	5878	5847	5980	5644	5427	5375	5331	5285
1. Energy		425	325	381	382	380	383	367	380	338	350	368	333	333	346	365	378
A. Fuel Combustion (Sectoral Approach)		424	325	380	380	379	382	367	379	337	349	363	332	332	345	365	378
1. Energy Industries		119	86	113	110	104	102	103	107	80	88	96	74	73	75	82	83
a Public Electricity and Heat Production		103	79	101	91	90	92	94	98	71	79	87	66	65	64	69	70
b Petroleum Refining		9	1	3	2	1	1	1	1	1	1	1	1	1	1	1	1
c Manufacture of Solid Fuels and Other Energy Industries		6	6	9	17	12	9	8	8	8	8	8	7	7	10	12	12
2. Manufacturing Industries and Construction		54	54	47	47	40	41	34	38	34	35	36	34	34	34	34	34
3. Transport		141	113	147	154	148	144	135	135	135	134	137	134	139	150	162	172
a Civil Aviation		3	3	3	2	3	3	2	3	2	2	2	2	2	2	2	2
b Road Transport		125	93	125	139	133	129	120	119	120	119	121	119	124	135	147	157
c Railways		3	3	3	2	2	2	2	2	2	1	2	1	1	1	1	1
d Navigation		10	15	16	11	10	11	11	11	12	12	11	12	12	12	12	12
4. Other Sectors		109	71	71	67	84	94	93	98	87	91	93	89	84	84	85	87
a Commercial and Institutional		12	8	10	8	9	10	10	11	10	10	10	10	9	8	8	8
b Residential		57	28	29	29	42	51	51	54	49	52	51	50	46	46	47	47
c Agriculture/Forestry/Fisheries		40	34	32	30	33	33	32	33	28	29	31	30	29	30	31	32
5. Other	(1)	1	1	2	1	3	1	2	1	2	2	2	2	2	2	2	2
B. Fugitive Emissions from Fuels		1	1	1	2	1	1	1	1	1	0	6	0	0	0	0	0
1. Solid Fuels	NA																
2. Oil and Natural Gas		1	1	1	2	1	1	1	1	1	0	6	0	0	0	0	0
a Oil	NA									0	0	5	0	0	0	0	0
b Natural Gas		NA,NO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
c Flaring		1	1	1	2	1	1	1	1	1	0	1	0	0	0	0	0
2. Industrial Processes	NO,NA	1043	1043	904	1004												
A. Mineral Products																	
1 Cement Production																	
2 Lime Production																	
3 Limestone and Dolomite Use																	
4 Soda Ash Production and Use	NO																
5 Asphalt Roofing																	
6 Road Paving with Asphalt																	

Table 14.11 Historic and projected nitrous oxide (N_2O) emissions in ktonnes CO_2 equivalents.

N_2O emissions and projections (Gg CO_2 equivalents)		KP Base year	1990	1995	2000	2005	2008	2009	2010	2011	2012	2008-12	2015	2020	2025	2030	2035
7 Other																	
B. Chemical Industry	NO,NA	1043	1043	904	1004												
2 Nitric Acid Production	NO	1043	1043	904	1004												
5 Other	NA																
C. Metal Production	NA																
1 Iron and Steel Production	NA																
4 SF_6 Used in Aluminium and Magnesium Foundries																	
D. Other Production	NA																
E. Production of Halocarbons and SF_6																	
F. Consumption of Halocarbons and SF_6																	
1. Refrigeration and Air Conditioning Equipment																	
2 Foam Blowing																	
3 Fire Extinguishers																	
4 Aerosol/Metered Dose Inhalers																	
8 Electrical Equipment																	
9 Other																	
C_3F_8																	
SF_6																	
G. Other	NO																
3. Solvent and Other Product Use		NA	1	2	3	13	13	18	14	15	15	12	15	15	15	15	15
A Paint Application	NA																
B Degreasing and Dry Cleaning	NA																
C Chemical Products, Manufacture and Processing	NA																
D Other		NA	1	2	3	13	13	18	14	15	15	15	15	15	15	15	15
1 Use of N_2O for Anaesthesia	(6)	NA	NE	NE	NE	11	10	14	11	12	12	12	12	12	12	12	12
5 Other		NA	1	2	3	3	3	4	4	4	4	3	4	4	4	3	3
4. Agriculture		9037	8220	7276	6346	5740	5778	5445	5373	5393	5348	5467	5159	4936	4864	4794	4730
A Enteric Fermentation																	
1 Cattle																	
Dairy Cattle																	
Non-Dairy Cattle																	

Table 14.11 Historic and projected nitrous oxide (N_2O) emissions in ktonnes CO_2 equivalents.

N_2O emissions and projections (Gg CO_2 equivalents)		KP Base year	1990	1995	2000	2005	2008	2009	2010	2011	2012	2008-12	2015	2020	2025	2030	2035
2 Buffalo	NO																
3 Sheep																	
4 Goats																	
5 Camels and Llamas	NO																
6 Horses																	
7 Mules and Asses	NO																
8 Swine																	
9 Poultry																	
10 Other																	
Fur farming & Deer																	
B. Manure Management		685	600	566	537	512	457	423	421	400	385	417	336	243	206	170	133
1 Cattle																	
Dairy Cattle																	
Non-Dairy Cattle																	
2 Buffalo	NO																
3 Sheep																	
4 Goats																	
5 Camels and Llamas	NO																
6 Horses																	
7 Mules and Asses	NO																
8 Swine																	
9 Poultry																	
10 Other livestock																	
Fur farming																	
11 Anaerobic Lagoons	NO																
12 Liquid Systems		96	94	82	79	82	80	76	75								
13 Solid Storage and Dry Lot		589	314	250	199	155	111	93	88								
14 Other AWMS		NO	192	234	260	275	266	255	258								
C. Rice Cultivation	NO																
D. Agricultural Soils		8352	7620	6709	5807	5226	5320	5020	4951	4992	4962	5049	4822	4692	4657	4624	4597
1 Direct Soil Emissions		4225	4401	3781	3391	3193	3242	3125	3051								
2 Pasture, Range and Paddock Manure		312	311	323	312	236	213	203	197								

Table 14.11 Historic and projected nitrous oxide (N_2O) emissions in ktonnes CO_2 equivalents.

N_2O emissions and projections (Gg CO_2 equivalents)		KP Base year	1990	1995	2000	2005	2008	2009	2010	2011	2012	2008-12	2015	2020	2025	2030	2035
3 Indirect Emissions		3787	2907	2606	2105	1797	1866	1693	1703								
4 Other	IE	28															
Industrial waste used as fertilizer	IE	9															
Use of sewage sludge as fertilizers	IE	19															
E. Prescribed Burning of Savannas	NO																
F. Field Burning of Agricultural Residues		NO	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
G. Other	NO																
6. Waste		88	121	131	140	126	148	121	127	132	134	132	137	144	150	156	162
A. Solid Waste Disposal on Land																	
B. Waste-water Handling		88	109	115	99	94	111	81	84	91	91	92	92	92	93	94	95
C. Waste Incineration	(<0,5)	IE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D. Other		NO	11	15	41	31	36	39	43	41	42	40	46	51	56	61	66
7. Other	NO																
Memo Items (not included above):																	
International Bunkers		78	77	117	107	73	83	54	66	77	79	72	81	86	87	85	85
Aviation		18	18	20	25	28	28	25	26	33	35	29	37	42	44	41	41
Marine		60	59	97	81	46	55	29	40	44	44	42	44	44	44	44	44
Multilateral Operations	NE																
CO_2 Emissions from Biomass																	

Notes:

(1): Military mobile combustion of fuels

(2): Glass production, production of bricks and clay products

(3): Catalysts/Fertilizers, Pesticides and Sulphuric acid

(4): PFC used as detergent

(5): Window plate production, research laboratories and running shoes

(6): Other products, manufacture and processing such as vessels, vehicles, wood, food and graphic

NO: Not occurring

NE: Not estimated

NA: Not Applicable

IE: Included elsewhere

Table 14.12 Historic and projected hydrofluorocarbons (HFCs) emissions in ktonnes CO_2 equivalents.

HFCs emissions and projections (Gg CO_2 equivalents)	KP Base year	1990	1995	2000	2005	2008	2009	2010	2011	2012	2008-12	2015	2020	2025	2030	2035
Denmark's total emissions excluding net emissions/removals from LULUCF	218		218	607	802	853	799	800	741	667	772	438	73	62	61	61
1. Energy																
A. Fuel Combustion (Sectoral Approach)																
1. Energy Industries																
a Public Electricity and Heat Production																
b Petroleum Refining																
c Manufacture of Solid Fuels and Other Energy Industries																
2. Manufacturing Industries and Construction																
3. Transport																
a Civil Aviation																
b Road Transport																
c Railways																
d Navigation																
4. Other Sectors																
a Commercial and Institutional																
b Residential																
c Agriculture/Forestry/Fisheries																
5. Other																
B. Fugitive Emissions from Fuels																
1. Solid Fuels																
2. Oil and Natural Gas																
a Oil																
b Natural Gas																
c Flaring																
2. Industrial Processes	218		218	607	802	853	799	800	741	667	772	438	73	62	61	61
A. Mineral Products																
1 Cement Production																
2 Lime Production																
3 Limestone and Dolomite Use																
4 Soda Ash Production and Use																
5 Asphalt Roofing																

Table 14.12 Historic and projected hydrofluorocarbons (HFCs) emissions in ktonnes CO_2 equivalents.

HFCs emissions and projections (Gg CO_2 equivalents)		KP Base year	1990	1995	2000	2005	2008	2009	2010	2011	2012	2008-12	2015	2020	2025	2030	2035
6 Road Paving with Asphalt																	
7 Other																	
B. Chemical Industry																	
2 Nitric Acid Production																	
5 Other																	
C. Metal Production																	
1 Iron and Steel Production																	
4 SF_6 Used in Aluminium and Magnesium Foundries																	
D. Other Production																	
E. Production of Halocarbons and SF_6		NO		NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
F. Consumption of Halocarbons and SF_6		218		218	607	802	853	799	800	741	667	772	438	73	62	61	61
1. Refrigeration and Air Conditioning Equipment		35		35	420	663	730	683	692								
2 Foam Blowing		183		183	168	119	103	96	87								
3 Fire Extinguishers		NO		NO	NO	NO	NO	NO	NO								
4 Aerosol/Metered Dose Inhalers		NA		NO	19	21	19	18	17								
8 Electrical Equipment		NA		NA	NA	NO	NO	NO	NO								
9 Other		NO		NO	NO	NO	1	3	4								
C_3F_8																	
SF_6																	
G. Other	NO																
3. Solvent and Other Product Use																	
A Paint Application																	
B Degreasing and Dry Cleaning																	
C Chemical Products, Manufacture and Processing																	
D Other																	
1 Use of N_2O for Anaesthesia																	
5 Other																	
4. Agriculture																	
A Enteric Fermentation																	
1 Cattle																	
Dairy Cattle																	

Table 14.12 Historic and projected hydrofluorocarbons (HFCs) emissions in ktonnes CO_2 equivalents.

HFCs emissions and projections (Gg CO_2 equivalents)		KP Base year	1990	1995	2000	2005	2008	2009	2010	2011	2012	2008-12	2015	2020	2025	2030	2035
Non-Dairy Cattle																	
2 Buffalo	NO																
3 Sheep																	
4 Goats																	
5 Camels and Llamas	NO																
6 Horses																	
7 Mules and Asses	NO																
8 Swine																	
9 Poultry																	
10 Other																	
Fur farming & Deer																	
B. Manure Management																	
1 Cattle																	
Dairy Cattle																	
Non-Dairy Cattle																	
2 Buffalo	NO																
3 Sheep																	
4 Goats																	
5 Camels and Llamas	NO																
6 Horses																	
7 Mules and Asses	NO																
8 Swine																	
9 Poultry																	
10 Other livestock																	
Fur farming																	
11 Anaerobic Lagoons	NO																
12 Liquid Systems																	
13 Solid Storage and Dry Lot																	
14 Other AWMS																	
C. Rice Cultivation	NO																
D. Agricultural Soils																	
1 Direct Soil Emissions																	

Table 14.12 Historic and projected hydrofluorocarbons (HFCs) emissions in ktonnes CO_2 equivalents.

HFCs emissions and projections (Gg CO_2 equivalents)		KP Base year	1990	1995	2000	2005	2008	2009	2010	2011	2012	2008-12	2015	2020	2025	2030	2035
2 Pasture, Range and Paddock Manure																	
3 Indirect Emissions																	
4 Other																	
Industrial waste used as fertilizer																	
Use of sewage sludge as fertilizers																	
E. Prescribed Burning of Savannas	NO																
F. Field Burning of Agricultural Residues																	
G. Other	NO																
6. Waste																	
A. Solid Waste Disposal on Land																	
B. Waste-water Handling																	
C. Waste Incineration																	
D. Other																	
7. Other																	
Memo Items (not included above):																	
International Bunkers																	
Aviation																	
Marine																	
Multilateral Operations																	
CO_2 Emissions from Biomass																	

Notes:

(1): Military mobile combustion of fuels

(2): Glass production, production of bricks and clay products

(4): PFC used as detergent

(5): Window plate production, research laboratories and running shoes

NO: Not occurring

NE: Not estimated

NA: Not Applicable

IE: Included elsewhere

Table 14.13 Historic and projected perfluorocarbons (PFCs) emissions in ktonnes CO_2 equivalents.

PFCs emissions and projections (Gg CO_2 equivalents)		KP Base year	1990	1995	2000	2005	2008	2009	2010	2011	2012	2008-12	2015	2020	2025	2030	2035
Denmark's total emissions excluding net emissions/removals from LU-LUCF		1		1	18	14	13	14	13	13	12	13	10	9	7	6	6
1. Energy																	
A. Fuel Combustion (Sectoral Approach)																	
1. Energy Industries																	
a Public Electricity and Heat Production																	
b Petroleum Refining																	
c Manufacture of Solid Fuels and Other Energy Industries																	
2. Manufacturing Industries and Construction																	
3. Transport																	
a Civil Aviation																	
b Road Transport																	
c Railways																	
d Navigation																	
4. Other Sectors																	
a Commercial and Institutional																	
b Residential																	
c Agriculture/Forestry/Fisheries																	
5. Other																	
B. Fugitive Emissions from Fuels																	
1. Solid Fuels																	
2. Oil and Natural Gas																	
a Oil																	
b Natural Gas																	
c Flaring																	
2. Industrial Processes		1		1	18	14	13	14	13	13	12	13	10	9	7	6	6
A. Mineral Products																	
1 Cement Production																	
2 Lime Production																	
3 Limestone and Dolomite Use																	
4 Soda Ash Production and Use	NO																
5 Asphalt Roofing																	

Table 14.13 Historic and projected perfluorocarbons (PFCs) emissions in ktonnes CO_2 equivalents.

PFCs emissions and projections (Gg CO_2 equivalents)		KP Base year	1990	1995	2000	2005	2008	2009	2010	2011	2012	2008-12	2015	2020	2025	2030	2035
6 Road Paving with Asphalt																	
7 Other																	
B. Chemical Industry																	
2 Nitric Acid Production																	
5 Other																	
C. Metal Production																	
1 Iron and Steel Production																	
4 SF_6 Used in Aluminium and Magnesium Foundries																	
D. Other Production																	
E. Production of Halocarbons and SF_6	NO																
F. Consumption of Halocarbons and SF_6		1		1	18	14	13	14	13	13	12	13	10	9	7	6	6
1. Refrigeration and Air Conditioning Equipment		1		1	16	14	9	8	7								
2 Foam Blowing		NA		NA	NA	NO	NO	NO	NO								
3 Fire Extinguishers		NO		NO	NO	NO	NO	NO	NO								
4 Aerosol/Metered Dose Inhalers		NA		NA	NA	NO	NO	NO	NO								
8 Electrical Equipment		NA		NO	NO	NO	NO	NO	NO								
9 Other		NA,NO		NO	2	NO	4	6	6								
C_3F_8	(4)	NA,NO		NO	2	NO	4	6	6								
SF_6																	
G. Other																	
3. Solvent and Other Product Use																	
A Paint Application																	
B Degreasing and Dry Cleaning																	
C Chemical Products, Manufacture and Processing																	
D Other																	
1 Use of N_2O for Anaesthesia																	
5 Other																	
4. Agriculture																	
A Enteric Fermentation																	
1 Cattle																	
Dairy Cattle																	

Table 14.13 Historic and projected perfluorocarbons (PFCs) emissions in ktonnes CO_2 equivalents.

PFCs emissions and projections (Gg CO_2 equivalents)		KP Base year	1990	1995	2000	2005	2008	2009	2010	2011	2012	2008-12	2015	2020	2025	2030	2035
Non-Dairy Cattle																	
2 Buffalo	NO																
3 Sheep																	
4 Goats																	
5 Camels and Llamas	NO																
6 Horses																	
7 Mules and Asses	NO																
8 Swine																	
9 Poultry																	
10 Other																	
Fur farming & Deer																	
B. Manure Management																	
1 Cattle																	
Dairy Cattle																	
Non-Dairy Cattle																	
2 Buffalo	NO																
3 Sheep																	
4 Goats																	
5 Camels and Llamas	NO																
6 Horses																	
7 Mules and Asses	NO																
8 Swine																	
9 Poultry																	
10 Other livestock																	
Fur farming																	
11 Anaerobic Lagoons	NO																
12 Liquid Systems																	
13 Solid Storage and Dry Lot																	
14 Other AWMS																	
C. Rice Cultivation	NO																
D. Agricultural Soils																	
1 Direct Soil Emissions																	

Table 14.13 Historic and projected perfluorocarbons (PFCs) emissions in ktonnes CO_2 equivalents.

PFCs emissions and projections (Gg CO_2 equivalents)		KP Base year	1990	1995	2000	2005	2008	2009	2010	2011	2012	2008-12	2015	2020	2025	2030	2035
2 Pasture, Range and Paddock Manure																	
3 Indirect Emissions																	
4 Other																	
Industrial waste used as fertilizer																	
Use of sewage sludge as fertilizers																	
E. Prescribed Burning of Savannas	NO																
F. Field Burning of Agricultural Residues																	
G. Other	NO																
6. Waste																	
A. Solid Waste Disposal on Land																	
B. Waste-water Handling																	
C. Waste Incineration																	
D. Other																	
7. Other																	
Memo Items (not included above):																	
International Bunkers																	
Aviation																	
Marine																	
Multilateral Operations																	
CO_2 emissions from Biomass																	

Notes:

(1): Military mobile combustion of fuels

(2): Glass production, production of bricks and clay products

(3): Catalysts/Fertilizers, Pesticides and Sulphuric acid

(4): PFC used as detergent

(5): Window plate production, research laboratories and running shoes

(6): Other products, manufacture and processing such as vessels, vehicles, wood, food and graphic

NO: Not occurring

NE: Not estimated

NA: Not Applicable

IE: Included elsewhere

Table 14.14 Historic and projected sulphur hexafluoride (SF_6) emissions in ktonnes CO_2 equivalents.

SF_6 emissions and projections (Gg CO_2 equivalents)	KP Base year	1990	1995	2000	2005	2008	2009	2010	2011	2012	2008-12	2015	2020	2025	2030	2035
Denmark's total emissions excluding net emissions/removals from LULUCF	107		107	59	21	31	36	38	71	117	59	125	61	14	8	8
1. Energy																
A. Fuel Combustion (Sectoral Approach)																
1. Energy Industries																
a Public Electricity and Heat Production																
b Petroleum Refining																
c Manufacture of Solid Fuels and Other Energy Industries																
2. Manufacturing Industries and Construction																
3. Transport																
a Civil Aviation																
b Road Transport																
c Railways																
d Navigation																
4. Other Sectors																
a Commercial and Institutional																
b Residential																
c Agriculture/Forestry/Fisheries																
5. Other																
B. Fugitive Emissions from Fuels																
1. Solid Fuels																
2. Oil and Natural Gas																
a Oil																
b Natural Gas																
c Flaring																
2. Industrial Processes	5		107	59	21	31	36	38	71	117	59	125	61	14	8	8
A. Mineral Products																
1 Cement Production																
2 Lime Production																
3 Limestone and Dolomite Use																
4 Soda Ash Production and Use																
5 Asphalt Roofing																

Table 14.14 Historic and projected sulphur hexafluoride (SF_6) emissions in ktonnes CO_2 equivalents.

SF_6 emissions and projections (Gg CO_2 equivalents)		KP Base year	1990	1995	2000	2005	2008	2009	2010	2011	2012	2008-12	2015	2020	2025	2030	2035
6 Road Paving with Asphalt																	
7 Other																	
B. Chemical Industry																	
2 Nitric Acid Production																	
5 Other																	
C. Metal Production		36		36	21	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1 Iron and Steel Production																	
4 SF_6 Used in Aluminium and Magnesium Foundries		36		36	21	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
D. Other Production																	
E. Production of Halocarbons and SF_6	NO																
F. Consumption of Halocarbons and SF_6		71		71	37	21	31	36	38	71	117	59	125	61	14	8	8
1. Refrigeration and Air Conditioning Equipment		0		NA	NA	NO	NO	NO	NO								
2 Foam Blowing		NA		NA	NA	NO	NO	NO	NO								
3 Fire Extinguishers		NO		NO	NO	NO	NO	NO	NO								
4 Aerosol/Metered Dose Inhalers		NA		NA	NA	NO	NO	NO	NO								
8 Electrical Equipment		4		4	11	13	16	15	14								
9 Other		68		68	26	9	15	22	24								
C_3F_8																	
SF_6	(5)	68		68	26	9	15	22	24								
G. Other																	
3. Solvent and Other Product Use																	
A Paint Application																	
B Degreasing and Dry Cleaning																	
C Chemical Products, Manufacture and Processing																	
D Other																	
1 Use of N_2O for Anaesthesia																	
5 Other																	
4. Agriculture																	
A Enteric Fermentation																	
1 Cattle																	
Dairy Cattle																	

Table 14.14 Historic and projected sulphur hexafluoride (SF_6) emissions in ktonnes CO_2 equivalents.

SF_6 emissions and projections (Gg CO_2 equivalents)		KP Base year	1990	1995	2000	2005	2008	2009	2010	2011	2012	2008-12	2015	2020	2025	2030	2035
Non-Dairy Cattle																	
2 Buffalo	NO																
3 Sheep																	
4 Goats																	
5 Camels and Llamas	NO																
6 Horses																	
7 Mules and Asses																	
8 Swine																	
9 Poultry																	
10 Other																	
Fur farming & Deer																	
B. Manure Management																	
1 Cattle																	
Dairy Cattle																	
Non-Dairy Cattle																	
2 Buffalo	NO																
3 Sheep																	
4 Goats																	
5 Camels and Llamas	NO																
6 Horses																	
7 Mules and Asses	NO																
8 Swine																	
9 Poultry																	
10 Other livestock																	
Fur farming																	
11 Anaerobic Lagoons	NO																
12 Liquid Systems																	
13 Solid Storage and Dry Lot																	
14 Other AWMS																	
C. Rice Cultivation	NO																
D. Agricultural Soils																	
1 Direct Soil Emissions																	

Table 14.14 Historic and projected sulphur hexafluoride (SF_6) emissions in ktonnes CO_2 equivalents.

SF_6 emissions and projections (Gg CO_2 equivalents)		KP Base year	1990	1995	2000	2005	2008	2009	2010	2011	2012	2008-12	2015	2020	2025	2030	2035
2 Pasture, Range and Paddock Manure																	
3 Indirect Emissions																	
4 Other																	
Industrial waste used as fertilizer																	
Use of sewage sludge as fertilizers																	
E. Prescribed Burning of Savannas	NO																
F. Field Burning of Agricultural Residues																	
G. Other	NO																
6. Waste																	
A. Solid Waste Disposal on Land																	
B. Waste-water Handling																	
C. Waste Incineration																	
D. Other																	
7. Other																	
Memo Items (not included above):																	
International Bunkers																	
Aviation																	
Marine																	
Multilateral Operations																	
CO_2 Emissions from Biomass																	

Notes:

(1): Military mobile combustion of fuels

(2): Production of glass, bricks and clay products

(3): Catalysts/Fertilizers, Pesticides and Sulphuric acid

(4): PFC used as detergent

(5): Window plate production, research laboratories and running shoes

(6): Other products, manufacture and processing such as vessels, vehicles, wood, food and graphic

NO: Not occurring

NE: Not estimated

NA: Not Applicable

IE: Included elsewhere

Table 14.15 Trends in greenhouse gas (GHG) emissions and distributions by gases and sectors.

GHG emissions and projections	KP Base year	1990	1995	2000	2005	2008	2009	2010	2011	2012	2008-12	2015	2020	2025	2030	2035
Distribution by gases (%):																
CO_2	76.0 %	77.0 %	80.1 %	78.8 %	80.0 %	79.8 %	79.7 %	79.9 %	78.3 %	78.2 %	79.2 %	76.7 %	76.6 %	76.3 %	76.9 %	77.3 %
CH_4	8.2 %	8.8 %	8.1 %	8.6 %	8.8 %	8.8 %	9.1 %	9.1 %	9.7 %	9.7 %	9.3 %	10.5 %	11.0 %	11.2 %	11.1 %	10.9 %
N_2O	15.3 %	14.2 %	11.4 %	11.6 %	9.8 %	9.9 %	9.8 %	9.7 %	10.5 %	10.6 %	10.1 %	11.6 %	12.1 %	12.3 %	11.9 %	11.6 %
HFCs	0.3 %	NA	0.3 %	0.9 %	1.3 %	1.3 %	1.3 %	1.3 %	1.3 %	1.2 %	1.3 %	0.9 %	0.2 %	0.1 %	0.1 %	0.1 %
PFCs	0.0 %	NA	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %
SF_6	0.2 %	NA	0.1 %	0.1 %	0.0 %	0.0 %	0.1 %	0.1 %	0.1 %	0.2 %	0.1 %	0.3 %	0.1 %	0.0 %	0.0 %	0.0 %
Total	100 %	100 %	100 %	100 %	100 %	100 %	100 %	100 %	100 %	100 %	100 %	100 %	100 %	100 %	100 %	100 %
Industrial gases (HFCs+PFCs+SF_6)	0.5 %	NA	0.4 %	1.0 %	1.3 %	1.4 %	1.4 %	1.4 %	1.5 %	1.4 %	1.4 %	1.2 %	0.3 %	0.2 %	0.2 %	0.2 %
Trends relative to the KP base year 1990/95:																
CO_2	100	100	116	102	97	96	92	93	83	82	89	70	65	63	65	67
CH_4	100	106	108	103	99	99	97	97	96	94	96	89	86	86	87	88
N_2O	100	92	82	74	59	60	56	56	55	55	56	53	51	51	50	50
HFCs	100	NA	100	279	368	392	367	368	340	307	355	201	33	29	28	28
PFCs	100	NA	100	3562	2768	2547	2823	2642	2495	2365	2574	2055	1723	1354	1234	1234
SF_6	100	NA	100	55	20	29	34	35	66	109	55	116	57	13	7	7
Total	100	99	110	98	92	92	88	88	81	80	85	70	65	63	65	66
Industrial gases (HFCs+PFCs+SF_6)	100	NA	100	210	257	275	261	262	253	245	259	176	44	25	23	23
Distribution by IPCC main sector categories:																
Energy	75.2 %	76.0 %	79.1 %	77.6 %	78.9 %	79.0 %	79.5 %	79.9 %	77.8 %	77.8 %	78.9 %	75.8 %	75.4 %	75.0 %	75.6 %	76.1 %
Industrial Processes	3.6 %	3.2 %	3.6 %	5.0 %	3.8 %	3.6 %	2.9 %	2.8 %	3.3 %	3.3 %	3.2 %	3.4 %	3.0 %	3.0 %	3.1 %	3.2 %
Solvent and Other Product Use	0.2 %	0.1 %	0.1 %	0.2 %	0.1 %	0.1 %	0.1 %	0.1 %	0.1 %	0.1 %	0.1 %	0.1 %	0.1 %	0.1 %	0.1 %	0.1 %
Agriculture	18.8 %	18.2 %	15.1 %	15.3 %	15.3 %	15.6 %	15.7 %	15.6 %	17.0 %	17.0 %	16.1 %	18.9 %	19.8 %	20.3 %	19.8 %	19.4 %
Waste	2.2 %	2.5 %	2.0 %	2.0 %	1.8 %	1.8 %	1.7 %	1.6 %	1.7 %	1.7 %	1.7 %	1.8 %	1.7 %	1.5 %	1.4 %	1.3 %
Total	100 %	100 %	100 %	100 %	100 %	100 %	100 %	100 %	100 %	100 %	100 %	100 %	100 %	100 %	100 %	100 %
Trends relative to the KP base year 1990/95:																
Energy	100	100	115	101	97	96	93	94	83	82	90	70	65	63	65	67
Industrial Processes	100	89	110	137	99	91	71	68	75	74	76	67	54	54	56	59
Solvent and Other Product Use	100	68	80	75	64	57	60	56	56	55	54	52	49	46	44	42
Agriculture	100	96	88	80	75	76	73	73	73	72	73	70	68	68	68	68
Waste	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Total	100	99	110	98	92	92	88	88	81	80	85	70	65	63	65	66
Economic sector categories* Gg COs eqv.:																

Table 14.15 Trends in greenhouse gas (GHG) emissions and distributions by gases and sectors.

GHG emissions and projections	KP Base year	1990	1995	2000	2005	2008	2009	2010	2011	2012	2008-12	2015	2020	2025	2030	2035
Energy	26620	26615	33036	26770	23857	24724	24507	24379	20401	20021	22805	14619	13665	12596	13267	13459
Transport	10650	10905	12392	12477	13614	14134	13454	13356	13123	12745	13362	13005	12796	13198	13957	14901
Agriculture, forestry, fisheries	15780	15007	14001	12827	12240	12165	11645	11748	11362	11300	11642	11089	10747	10727	10715	10706
Business	9518	9233	9994	10540	9076	8366	6903	7349	7112	7168	7376	6388	5050	4857	4747	4703
Domestic sector	5208	5089	5110	4133	3822	3045	3116	3237	2912	2969	3056	2507	1891	1684	1522	1389
Waste	1547	1711	1517	1344	1130	1121	1058	995	964	934	1014	854	749	671	615	574
Total	69323	68560	76050	68090	63740	63554	60683	61065	55874	55137	59255	48463	44898	43733	44822	45731
Distribution by economic sector ():																
Energy	38.4 %	38.8 %	43.4 %	39.3 %	37.4 %	38.9 %	40.4 %	39.9 %	36.5 %	36.3 %	38.5 %	30.2 %	30.4 %	28.8 %	29.6 %	29.4 %
Transport	15.4 %	15.9 %	16.3 %	18.3 %	21.4 %	22.2 %	22.2 %	21.9 %	23.5 %	23.1 %	22.6 %	26.8 %	28.5 %	30.2 %	31.1 %	32.6 %
Agriculture, forestry, fisheries	22.8 %	21.9 %	18.4 %	18.8 %	19.2 %	19.1 %	19.2 %	19.2 %	20.3 %	20.5 %	19.6 %	22.9 %	23.9 %	24.5 %	23.9 %	23.4 %
Business	13.7 %	13.5 %	13.1 %	15.5 %	14.2 %	13.2 %	11.4 %	12.0 %	12.7 %	13.0 %	12.4 %	13.2 %	11.2 %	11.1 %	10.6 %	10.3 %
Domestic sector	7.5 %	7.4 %	6.7 %	6.1 %	6.0 %	4.8 %	5.1 %	5.3 %	5.2 %	5.4 %	5.2 %	5.2 %	4.2 %	3.9 %	3.4 %	3.0 %
Waste	2.2 %	2.5 %	2.0 %	2.0 %	1.8 %	1.8 %	1.7 %	1.6 %	1.7 %	1.7 %	1.7 %	1.8 %	1.7 %	1.5 %	1.4 %	1.3 %
Total	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %
Trends relative to the KP base year 1990/95:																
Energy	100	100	124	101	90	93	92	92	77	75	86	55	51	47	50	51
Transport	100	102	116	117	128	133	126	125	123	120	125	122	120	124	131	140
Agriculture, forestry, fisheries	100	95	89	81	78	77	74	74	72	72	74	70	68	68	68	68
Business	100	97	105	111	95	88	73	77	75	75	77	67	53	51	50	49
Domestic sector	100	98	98	79	73	58	60	62	56	57	59	48	36	32	29	27
Waste	100	111	98	87	73	72	68	64	62	60	66	55	48	43	40	37
Total	100	99	110	98	92	92	88	88	81	80	85	70	65	63	65	66

Table 14.16 Emission estimates for 1990 to 2035 for the LULUCF sector.

	1990	2000	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
5. Land Use, Land-Use Change and Forestry, Total	4422.6	5893.6	2788.1	-876.4	-2170.7	2836.0	3267.0	3266.3	3243.7	3203.9	3174.4	3224.4	3209.1	3241.3	3230.2
A. Forest Land	-819.8	1928.5	-1005.2	-3590.5	-5676.9	-868.1	-436.5	-449.2	-458.1	-485.5	-483.4	-477.8	-442.8	-404.1	-405.7
1. Forest Land remaining Forest Land	-828.2	2245.0	-691.6	-3048.4	-5677.3	-124.6	199.2	184.6	177.2	166.2	162.5	360.5	393.5	415.4	415.4
2. Land converted to Forest Land	8.4	-316.5	-313.6	-542.1	0.4	-743.6	-635.7	-633.7	-635.3	-651.6	-645.9	-838.2	-836.2	-819.5	-821.2
B. Cropland	4645.2	3424.9	3482.8	2390.2	3185.9	3372.6	3333.0	3341.6	3324.5	3308.7	3273.8	3314.7	3261.0	3251.2	3238.4
1. Cropland remaining Cropland	4607.0	3380.1	3463.9	2370.5	3165.3	3350.9	3299.7	3307.5	3289.6	3273.0	3237.3	3277.3	3222.9	3212.2	3198.7
2. Land converted to Cropland	38.2	44.7	18.9	19.7	20.6	21.6	33.3	34.1	34.9	35.7	36.6	37.4	38.2	39.0	39.7
C. Grassland	405.9	370.0	190.3	188.4	185.9	187.2	209.9	210.7	211.5	212.3	213.1	213.9	214.6	215.4	216.1
1. Grassland remaining Grassland	188.7	165.5	144.6	141.9	138.3	138.3	139.3	139.3	139.3	139.3	139.3	139.3	139.3	139.3	139.3
2. Land converted to Grassland	217.2	204.5	45.7	46.5	47.6	48.9	70.6	71.4	72.2	73.0	73.8	74.6	75.3	76.0	76.8
D. Wetlands	86.8	33.9	-6.3	5.1	0.0	5.8	8.3	7.1	6.0	4.7	3.5	2.3	1.2	0.0	-1.2
1. Wetlands remaining Wetlands	86.2	54.5	33.3	47.0	39.1	44.7	44.7	44.8	44.8	44.6	44.6	44.6	44.6	44.6	44.6
2. Land converted to Wetlands	0.6	-20.6	-39.6	-42.0	-39.1	-39.0	-36.4	-37.6	-38.8	-39.9	-41.1	-42.3	-43.4	-44.6	-45.8
E. Settlements	104.4	136.4	126.5	130.4	134.4	138.6	152.3	156.1	159.9	163.7	167.5	171.3	175.0	178.8	182.5
1. Settlements remaining Settlements	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2. Land converted to Settlements	104.4	136.4	126.5	130.4	134.4	138.6	152.3	156.1	159.9	163.7	167.5	171.3	175.0	178.8	182.5
F. Other Land	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1. Other Land remaining Other Land	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2. Land converted to Other Land	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
5. Land Use, Land-Use Change and Forestry, Total	3223.5	3172.5	3180.9	3174.7	3162.3	3152.9	3121.2	3116.3	3099.9	3093.2	3085.6	3096.4	3086.7	3070.2	3066.9
A. Forest Land	-407.4	-409.0	-410.7	-412.3	-414.0	-415.6	-417.3	-418.9	-420.6	-422.3	-423.9	-425.6	-427.2	-428.9	-430.5
1. Forest Land remaining Forest Land	415.4	415.4	415.4	415.4	415.3	415.3	415.3	415.3	415.3	415.2	415.2	415.2	415.2	415.2	415.2
2. Land converted to Forest Land	-822.8	-824.4	-826.1	-827.7	-829.3	-831.0	-832.6	-834.2	-835.9	-837.5	-839.1	-840.8	-842.4	-844.0	-845.7
B. Cropland	3229.9	3218.8	3225.3	3217.4	3203.1	3194.8	3161.3	3154.6	3136.4	3127.9	3118.4	3127.5	3116.0	3097.7	3092.6
1. Cropland remaining Cropland	3189.3	3177.4	3183.1	3174.3	3159.2	3150.1	3115.8	3108.2	3089.2	3079.8	3069.5	3077.8	3065.4	3046.3	3040.4
2. Land converted to Cropland	40.6	41.4	42.2	43.1	43.9	44.7	45.6	46.4	47.2	48.1	48.9	49.7	50.5	51.4	52.2
C. Grassland	216.9	217.8	218.6	219.4	220.2	221.1	221.9	222.7	223.5	224.4	225.2	226.0	226.8	227.6	228.4
1. Grassland remaining Grassland	139.3	139.3	139.3	139.3	139.3	139.3	139.3	139.3	139.3	139.3	139.3	139.3	139.3	139.3	139.3
2. Land converted to Grassland	77.6	78.4	79.3	80.1	80.9	81.7	82.6	83.4	84.2	85.0	85.9	86.7	87.5	88.3	89.1
D. Wetlands	-2.3	-45.2	-46.3	-47.5	-48.7	-52.8	-54.0	-55.1	-56.3	-57.5	-58.6	-59.8	-61.0	-62.1	-63.3
1. Wetlands remaining Wetlands	44.6	2.9	2.9	3.0	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2. Land converted to Wetlands	-46.9	-48.1	-49.3	-50.5	-51.6	-52.8	-54.0	-55.1	-56.3	-57.5	-58.6	-59.8	-61.0	-62.1	-63.3
E. Settlements	186.4	190.2	194.0	197.8	201.6	205.4	209.2	213.0	216.8	220.7	224.5	228.3	232.1	235.9	239.7

Continued															
1. Settlements remaining Settlements	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2. Land converted to Settlements	186.4	190.2	194.0	197.8	201.6	205.4	209.2	213.0	216.8	220.7	224.5	228.3	232.1	235.9	239.7
F. Other Land	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1. Other Land remaining Other Land	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2. Land converted to Other Land	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

PROJECTION OF GREENHOUSE GASES 2011-2035

This report contains a description of models, background data and projections of CO_2, CH_4, N_2O, HFCs, PFCs and SF_6 for Denmark. The emissions are projected to 2035 using a scenario combined with the expected results of a few individual policy measures. Official Danish forecasts of activity rates are used in the models for those sectors for which forecasts are available, i.e. the latest official forecast from the Danish Energy Agency. The emission factors refer to international guidelines and some are country-specific and refer to Danish legislation, Danish research reports or calculations based on emission data from a considerable number of industrial plants. The projection models are based on the same structure and method as the Danish emission inventories in order to ensure consistency.

ISBN: 978-87-92825-87-2
ISSN: 2245-0203