PROJECTION OF GREENHOUSE GAS EMISSIONS 2010 TO 2030

NERI Technical Report no. 841 2011

NATIONAL ENVIRONMENTAL RESEARCH INSTITUTE
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Data sheet

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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 2030 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

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Preface

This report contains a description of models and background data for projection of CO_2, CH_4, N_2O, HFCs, PFCs and SF_6 for Denmark. The emissions are projected to 2030 using a basic scenario, which includes the estimated effects of policies and measures implemented by April 2011 on Denmark's greenhouse gas (GHG) emissions ('with existing measures' projections).

The Department of Policy Analysis of the National Environmental Research Institute (NERI), 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 NERI are Erik Rasmussen and Ole-Kenneth Nielsen, respectively.

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

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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 2030 using a scenario, which includes the estimated effects of policies and measures implemented by April 2011 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 (22 %), Agriculture (16 %) and Other Sectors (11 %). For the latter sector the most important sources are fuel use in the residential sector. GHG emissions show a decreasing trend in the projection period from 2010 to 2030. 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 60 351 ktonnes CO_2 equivalents and 51 595 ktonnes in 2030, corresponding to a decrease of about 15 %. From 1990 to '2010' the emissions are estimated to decrease by about 11 %.

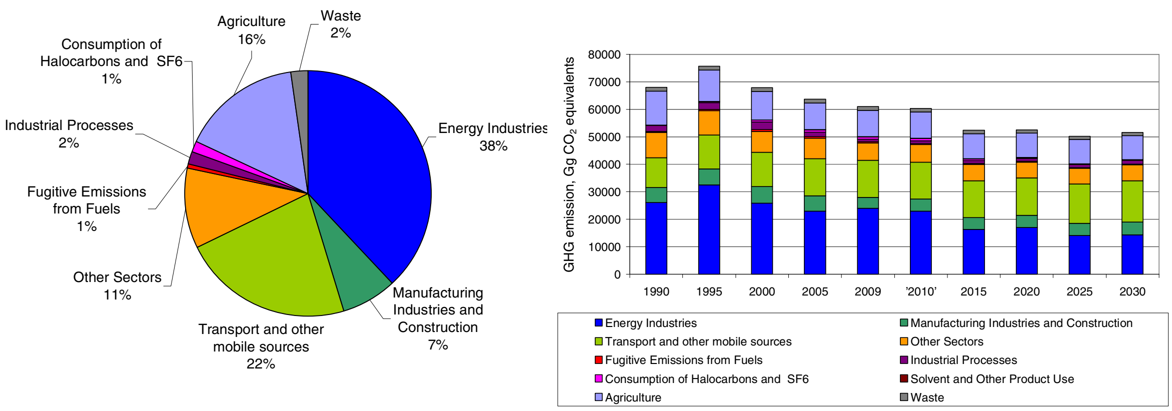


Figure S.1 Total GHG emissions in CO_2 equivalents. Distribution according to main sectors in '2010' and time-series for 1990 to 2030.

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 (63 %), are estimated to decrease significantly in the period from 2010 to 2030 due to a partial shift in fuel type from coal to wood and municipal waste. Also, for residential combustion plants a significant decrease in emissions is projected; the emissions decrease by 68 % from 1990 to 2030. 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 almost 200 % from 1990 to '2010' and by more than 30 % from '2010' to 2030.

Fugitive emissions from fuels

The GHG emissions from the sector Fugitive emissions from fuels increased in the years 1990-2000 where a maximum was reached. The emissions are estimated to decrease in the projection years 2010-2030, mainly from 2010-2015. 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 2010-2030 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 2010-2030.

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 is cement production, which contributes 82 % 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 MSW 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 2009 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 33 % from 1990 to 2030 due to a forecasted growth in traffic. The emission shares for the remaining mobile sources are small compared with road transport, and from 1990 to 2030 the total share for these categories reduces from 32 % to 25 %. For industry, the emissions decrease by 35 % from 1990-2030. 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 2009, the emission of GHGs in the agricultural sector decreased from 12 384 ktonnes CO_2 equivalents to 9 606 ktonnes CO_2 equivalents, which corresponds to a 22 % reduction. This development is expected to continue and the emission by 2030 is expected to decrease further to 8 801 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 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 considered in the projections.

Waste

The total historical GHG emission from the waste sector has been slightly decreasing since 1990. The level predicted for 2010 and onwards is decreasing compared with the latest historic year. In '2010', CH_4 emission from landfill sites is predicted to contribute 78 % 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 11 %. The category waste incineration & other waste contributes 11 % 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.

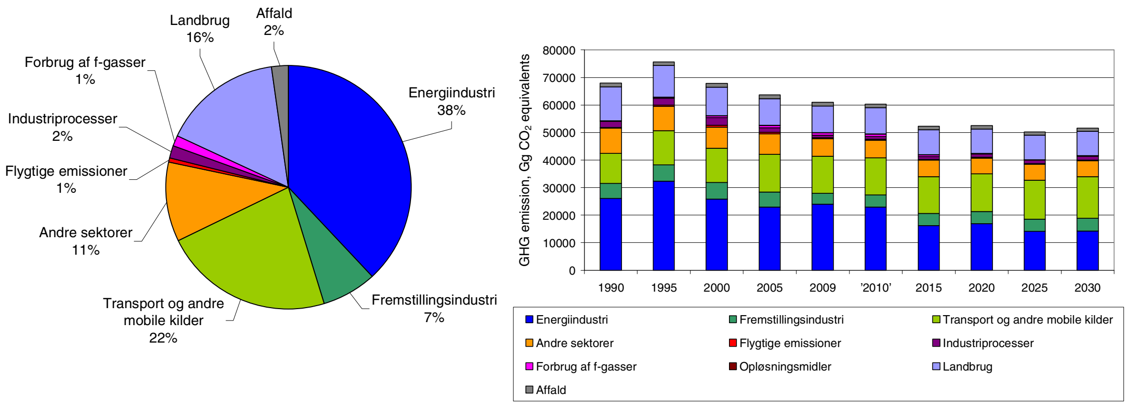
LULUCF

The overall picture of the LULUCF sector is a net source of 3 155 Gg CO_2 eqv. in 1990. In 2009 it was turned into a net sink of 1 118 Gg CO_2 eqv. In the future it is expected that the whole LULUCF sector will be a net source of 1 500 Gg CO_2 eqv. in 2015 increasing to 1 800 Gg CO_2 eqv. in 2019. Until 2030 a further increase is expected. 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 1 900 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 approx. 1 300 Gg CO_2 eqv. per year. 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 2030 på baggrund af et scenarie, som medtager de estimerede effekter på Danmarks drivhusgasudledninger af virkemidler iværksat indtil april 2011 (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 2008-2012 (‘2010’) forventes at være energiproduktion og -konvertering (38 %), transport (22 %), landbrug (16 %), og andre sektorer (11 %). For andre sektorer er den vigtigste kilde husholdninger (Figur R.1). Fremskrivningerne af drivhusgasemissionerne viser en faldende tendens i prognoseperioden fra 2010 til 2030. Generelt falder emissionsandelen for energisektoren, mens emissionsandelen for transportsektoren stiger. De totale emissioner er beregnet til 60.351 ktons CO_2-ækvivalenter i ’2010’ og til 51.595 ktons i 2030 svarende til et fald på omkring 15 %. Fra 1990 til ‘2010’ er emissionerne beregnet til at ville falde med ca. 11 %.



Figur R.1 Totale drivhusgasemissioner i CO_2-ækvivalenter fordelt på hovedsektorer for ’2010’ og tidsserier fra 1990 til 2030.

Stationær forbrænding

Stationær forbrænding omfatter Energiindustri, Fremstillingsindustri og Andre sektorer. Andre sektorer dækker over handel/service, husholdninger samt landbrug/gartneri. Drivhusgasemissionen fra kraft- og kraftvarmeværker, som er den største kilde i ‘2010’ (63 %), er beregnet til at falde markant i perioden 2010 til 2030 grundet et delvis brændselsskift fra kul til træ og affald. Emissionerne fra husholdningers forbrændingsanlæg falder ifølge fremskrivningen også og bliver mere end halveret i perioden 1990 til 2030. Drivhusgasemissionerne fra andre sektorer er næsten konstante i hele perioden med undtagelse af off-shoresektoren, hvor emissioner fra anvendelse af energi til udvinding af olie og gas stiger med næsten 200 % fra 1990 til '2010' og med mere end 30 % fra '2010' til 2030.

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 er beregnet til at falde i fremskrivningsperioden 2010-2030. Faldet skyldes hovedsageligt at offshore flaring i forbindelse med udvinding af olie og naturgas er faldet. Desuden kan faldet tilskrives tekniske forbedringer på råolie terminalen og dermed faldende emissioner fra lagring af i råolietanke på terminalen samt i mindre grad fra lastning af skibe i havneanlægget. Emissionerne fra udvinding af olie og naturgas er beregnet til at falde i perioden 2010-2030 som følge af forventning om faldende udvundne mængder af olie og naturgas. Emissionerne af drivhusgasser fra de øvrige kilder er beregnet til at være konstante eller næsten konstante i fremskrivningsperioden 2010-2030.

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 82 % af den procesrelaterede drivhusgasemission. 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 33 % pga. vækst i trafikken. Den samlede emission for andre mobile kilder er noget lavere end vejtransporten totalt, og fra 1990 til 2030 falder andre mobile kilders emissionsandel fra 32 % til 25 %. For industri falder emissionerne med 35 % fra 1990 til 2030. 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 har maksimum i 2008-2009 og derefter er 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 2009 faldt emissionen af drivhusgasser fra 12.384 ktons CO_2-ækvivalenter til 9.606 ktons CO_2-ækvivalenter, hvilket svarer til en reduktion på 22 %. Denne udvikling forventes at fortsætte og emissionen forudses at falde yderligere til 8.801 ktons CO_2-ækvivalenter i 2030. 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 mindre fald siden 1990. Fremskrivningen viser, at de samlede emissioner er faldende. I '2010' forventes CH_4 fra lossepladser stadig at dominere sektoren og udgøre 78 % 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 11 %. Kategorien affaldsforbrænding og anden affaldshåndtering bidrager med 11 % 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 3.155 Gg CO_2-ækvivalenter. I 2009 er dette opgjort til en nettobinding på 1.118 Gg CO_2-ækvivalenter. Fremover er der forventet at hele LULUCF-sektoren vil være en nettokilde på 1.500 Gg CO_2-ækvivalenter i 2015 og stigende til 1.800 Gg CO_2-ækvivalenter i 2019. Frem til 2030 forventes en stadig stigende emission fra sektoren. Årsagen 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 1.900 hektar per år. Sammen med en forventet lille skovrydning vil kulstofmængden i de danske skove stige fremover. Dyrkning af de organiske landbrugsjorde medfører en årlig emission på ca. 1.300 Gg CO_2- ækvivalenter per år. 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) and "Projection of Greenhouse Gas Emissions 2009 to 2030" (Nielsen et al., 2010). The purpose of the present project, "Projection of greenhouse gas emissions 2010 to 2030" 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 April 2011 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).

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 2009 (Nielsen et al., 2011). 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 2009 was approximately 2 % of the total emission in CO_2 equivalents. The national total GHG emission in CO_2 equivalents excluding LULUCF has decreased by 10.3 % from 1990 to 2009 and decreased 15.9 % including LULUCF.

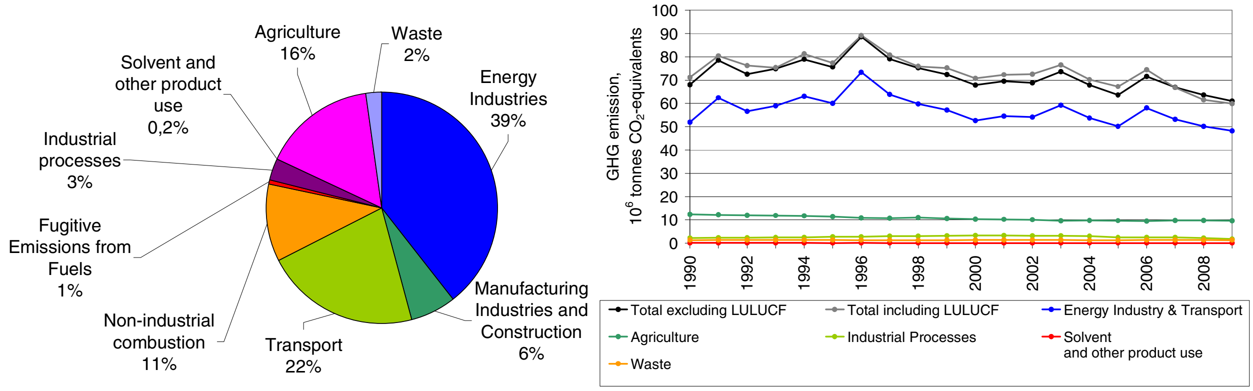


Figure 1.1 Greenhouse gas emissions in CO_2 equivalents distributed on main sectors for 2009 and time-series for 1990 to 2009.

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 49 % of the emissions. About 27 % come from the transport sector. In 2009, the actual CO_2 emission was about 8.3 % lower than the emission in 1990.

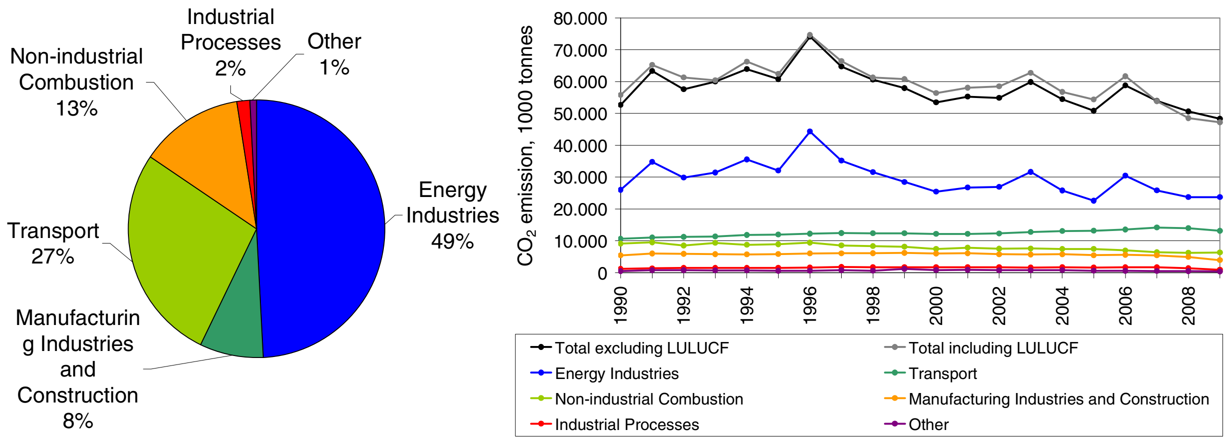


Figure 1.2 CO_2 emissions. Distribution according to the main sectors (2009) and time-series for 1990 to 2009.

1.3.2 Nitrous oxide

Agriculture is the most important N_2O emission source in 2008 contributing 91.3 % (Figure 1.3) of which N_2O from soil dominates (84.2 %). 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 32.4 % from 1990 to 2009 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 6.2 %. The N_2O emission from transport contributes by 2.2 % in 2009. 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.

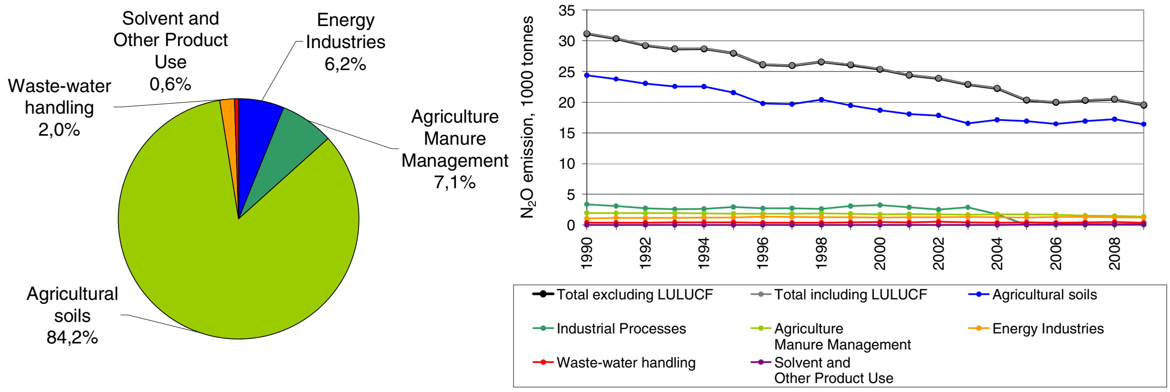


Figure 1.3 N_2O emissions. Distribution according to the main sectors (2009) and time-series for 1990 to 2009.

1.3.3 Methane

The largest sources of anthropogenic CH_4 emissions are agricultural activities contributing in 2009 with 70.4 %, waste (20.6 %), public power and district heating plants (3.2 %), see Figure 1.4. The emission from agriculture derives from enteric fermentation (49.2 %) and management of animal manure (21.2 %). 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 2009, 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 25.8 % 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 3.3 % from 1990 to 2009. The emission of CH_4 from waste disposal has decreased slightly due to an increase in the incineration of waste.

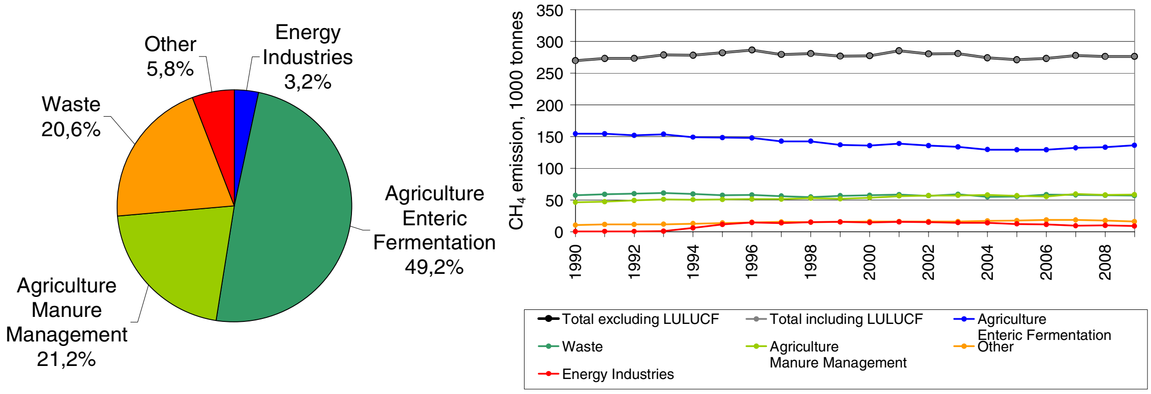


Figure 1.4 CH_4 emissions. Distribution according to the main sectors (2009) and time-series for 1990 to 2009.

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 2009 the emission of F-gases expressed in CO_2 equivalents decreased. The increase in emission from 1995 to 2009 is 161 %. 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 4.3 %. 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 2009. 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.

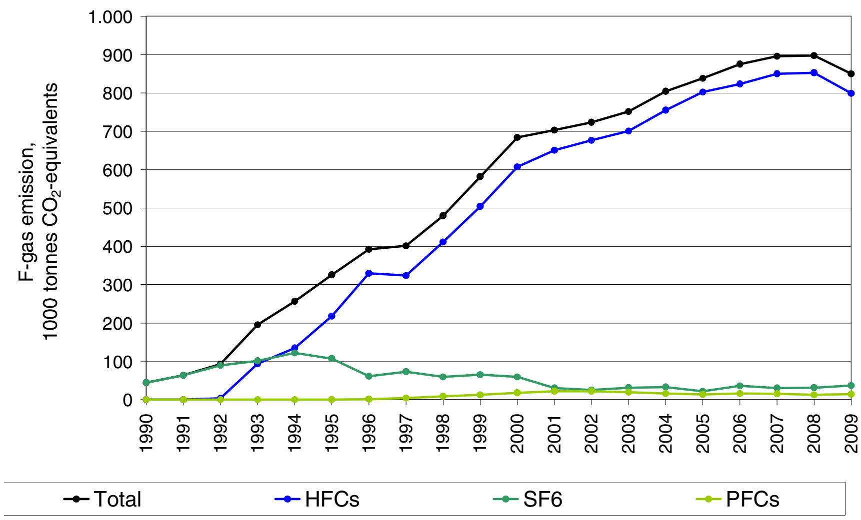


Figure 1.5 F-gas emissions. Time-series for 1990 to 2009.

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:

(1.1) $$E = \sum_s A_s(t) \cdot \overline{EF_s}(t)$$

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 know-ledge 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:

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

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).

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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/CORINAIR, 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 2030 (Danish Energy Agency, 2011a) and energy projections for individual plants (Danish Energy Agency, 2011b).

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 MWe, 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	2010	2015	2020	2025	2030
Natural gas	184 078	148 116	140 081	135 449	138 356
Steam coal	171 662	98 266	107 352	78 775	77 949
Wood and simil.	70 485	77 142	84 370	95 205	107 419
Municipal waste	38 733	42 279	42 932	46 613	48 520
Gas oil	31 235	27 783	26 191	25 364	26 915
Agricultural waste	20 920	19 038	18 731	18 443	18 124
Refinery gas	15 419	15 419	15 419	15 419	15 419
Residual oil	12 188	9455	10 669	10 227	11 100
Petroleum coke	5341	5821	6056	6220	6633
Biogas	4480	8224	17 788	17 657	17 556
LPG	1628	1726	1772	1815	1891
Coke	616	601	616	626	659
Kerosene	117	117	117	118	120
Total	556 903	453 987	472 097	451 931	470 661

Through 2020, natural gas and coal are the most important fuels, followed by wood and municipal waste. From 2024 wood overtakes coal as the second most important fuel. The largest variations are seen for coal use and renewable energy use. Coal use peaks in 2010 and decreases significantly until 2030. For wood the projected consumption increases throughout the period as a whole and from 2024 onwards the consumption of wood is projected to be higher than the consumption of coal.

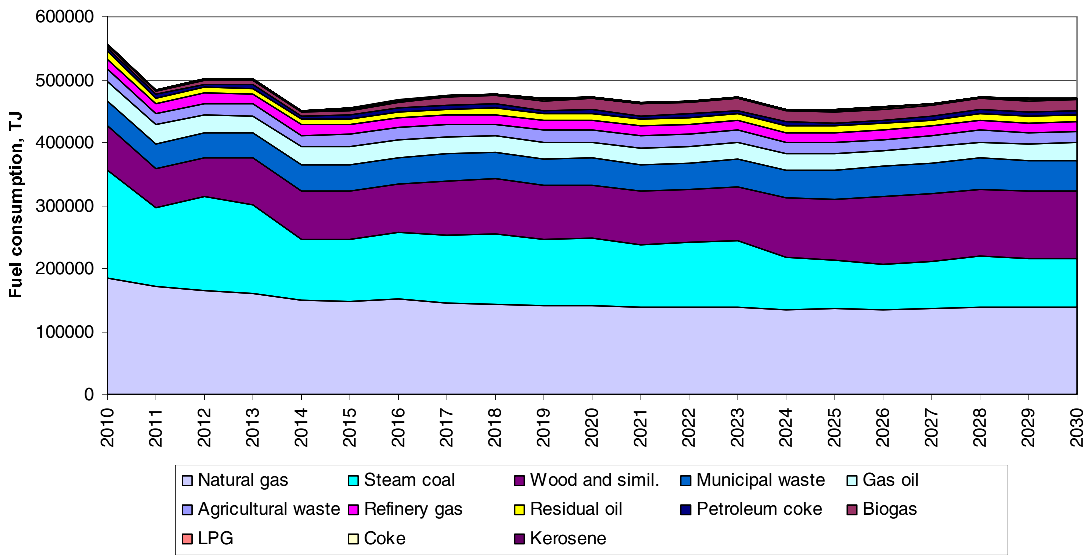

Figure 2.1 Projected energy consumption by fuel type.

Fuel use by sector is shown in Figure 2.2. The sectors consuming the most fuel are public power, residential, manufacturing industries, off-shore and district heating. According to the energy projection the fuel consumption in the off-shore sector will increase by almost 39 % from 2010 to 2030.

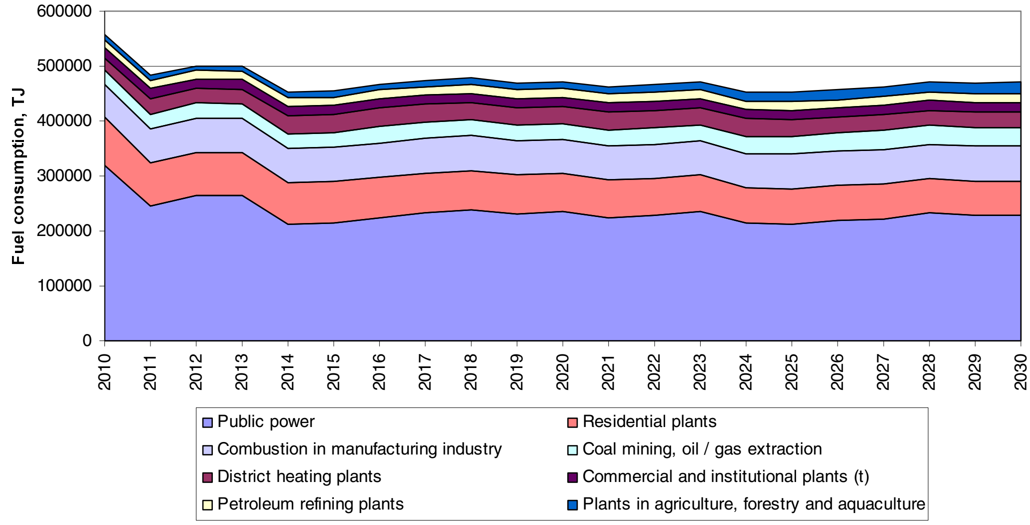

Figure 2.2 Energy use by sector.

Power plants larger than 25 MWe use between 36 % and 50 % of total fuel, the fuel consumption in these sources decline from 2010 to 2014, thereafter the consumption increases slightly and then remain relatively stable. 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 0.6-7.6 % of total fuel consumption over the period 2010 to 2030 (Figure 2.4).

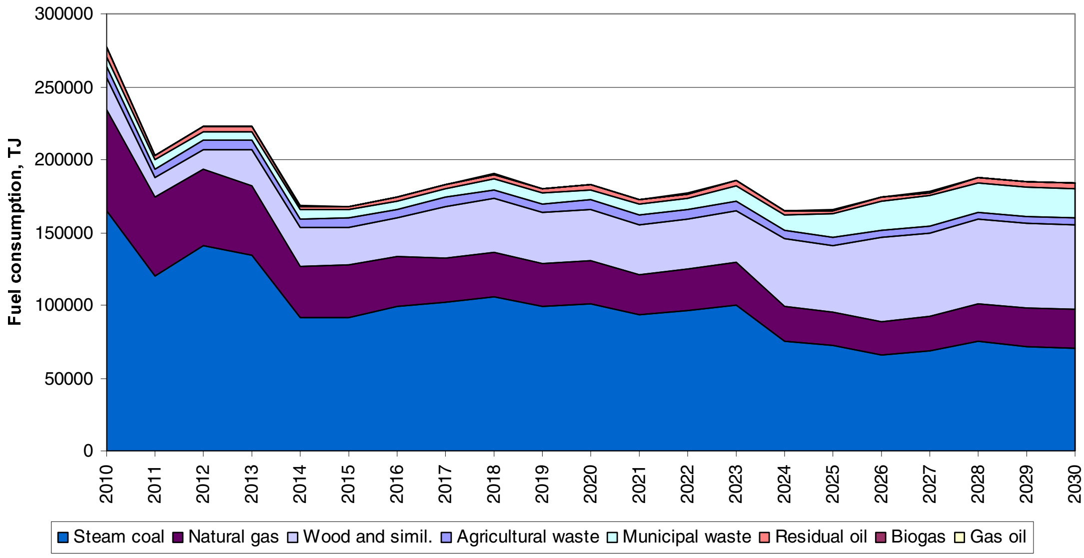

Figure 2.3 Energy consumption for plants > 25 MWe.

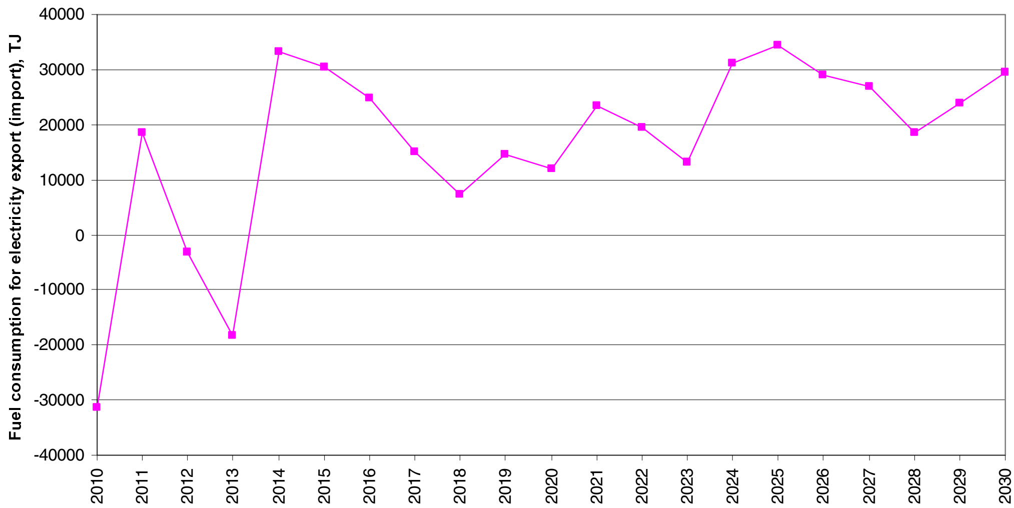

Figure 2.4 Fuel consumption associated with electricity export.

2.4 Emission factors

2.4.1 Area sources

In general, emission factors for areal sources refer to the 2009 emission factors (Nielsen et al., 2011).

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 2005-2009 emission factors have been applied rather than including only the 2009 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 emission CH_4 and N_2O 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 2010-2030. The applied IEFs are shown in Table 2.3. The IEFs are assumed to remain unchanged over the period 2010-2030.

The fuel consumption in natural gas fuelled engines been projected separately and 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.

Table 2.2 Implied emission factors (IEF) for CH_4 and N_2O. Calculation of implied emission factors are based on emission factors from 2009 and fuel consumption in 2009.

SNAP	Fuel	GHG	IEF
0101	Residual oil	CH_4	1.7
0101	Gas oil	CH_4	1.8
0101	Biogas	CH_4	431
0203	Gas oil	CH_4	21
0203	Biogas	CH_4	263
03	Gas oil	CH_4	0.9
03	Biogas	CH_4	242
0101	Gas oil	N_2O	0.5
0101	Biogas	N_2O	1.6
0103	Refinery gas	N_2O	0.21
0201	Gas oil	N_2O	0.4
0201	Biogas	N_2O	1
0202	Gas oil	N_2O	0.6
0203	Gas oil	N_2O	1.8
0203	Biogas	N_2O	1
03	Gas oil	N_2O	0.5
03	Biogas	N_2O	0.93

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. Some plants come under other SNAP categories:

- For gas turbines, the emission factors for SNAP 010104 are applied.
- For gas engines, the emission factors for SNAP 010105 are applied.

2.5 Emissions

Emissions for the individual GHGs are calculated by means of Equation 2.1, where A 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	1995	2000	2005	2009	'2010'	'2015'	2020	2025	2030
Public power	22 751	29 068	22 813	19 835	20 700	19 659	13 822	13 276	10 212	10 446
District heating plants	1855	1191	543	526	803	803	1177	1230	915	881
Petroleum refining plants	908	1387	1001	939	934	902	884	884	884	884
Oil/gas extraction	534	751	1475	1636	1561	1575	1699	1696	1895	2062
Commercial and institutional plants	1411	1160	930	989	830	947	973	962	963	968
Residential plants	5057	5081	4103	3786	3115	3027	2373	2092	1807	1617
Plants in agriculture, forestry and aquaculture	615	744	789	663	353	401	454	555	785	1026
Combustion in industrial plants	4619	5021	5067	4485	3085	3609	3803	3790	3861	3978
Total	37 750	44 403	36 721	32 859	31 380	30 923	25 182	24 484	21 321	21 862

The projected emissions in 2008-2012 are approximately 6800 ktonnes (CO_2 eqv.) lower than the emissions in 1990. From 1990 to 2030, the total emission falls by approximately 15 900 ktonnes (CO_2 eqv.) or 42 % 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, 1995, 2000, 2005 and 2009 (Nielsen et al. 2011).

2.5.1 CO_2 emissions

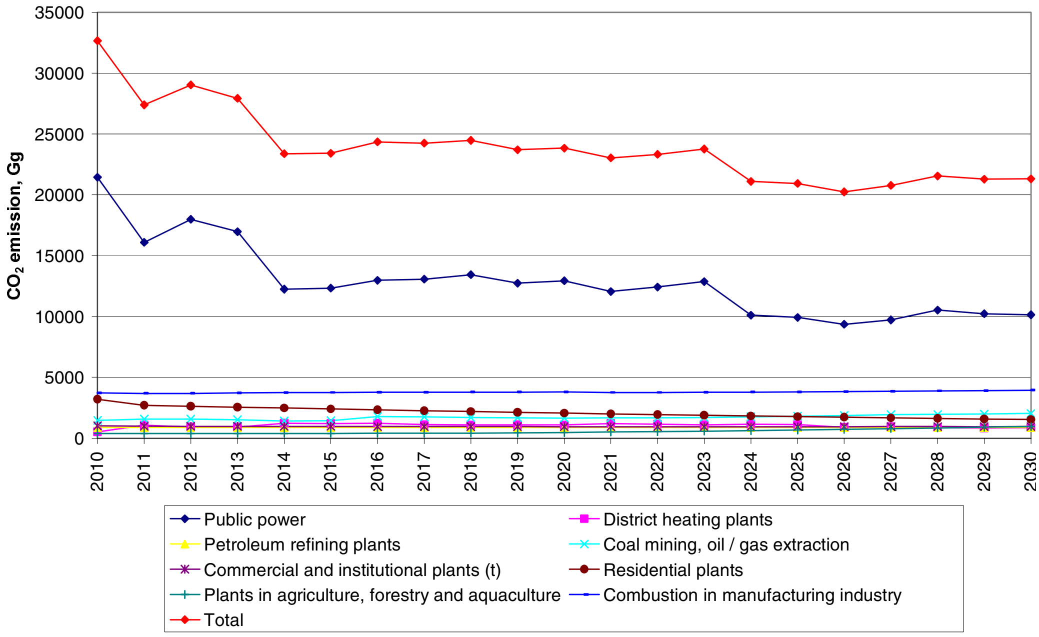

Figure 2.5 CO_2 emissions by sector.

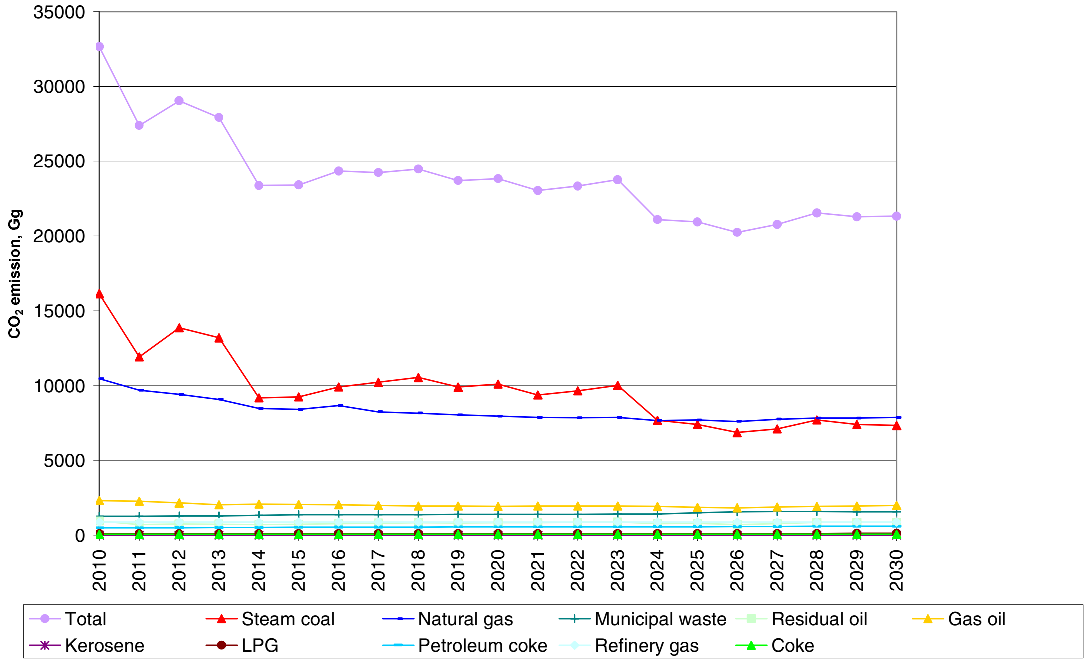

Figure 2.6 CO_2 emissions by fuel.

Table 2.5 CO_2 emissions, Gg.

Sector	1990	1995	2000	2005	2008	2009	'2010'	'2015'	2020	2025	2030
Public power	22685	28749	22433	19508	20554	20447	19308	13525	12949	9923	10138
District heating plants	1833	1171	526	505	611	777	779	1141	1086	1112	856
Petroleum refining plants	906	1384	998	938	926	933	901	882	882	882	882
Oil/gas extraction	527	741	1457	1615	1614	1542	1556	1590	1649	1814	2037
Commercial and institutional plants	1402	1136	903	961	849	806	928	967	950	949	955
Residential plants	4944	4945	3960	3602	2795	2925	2851	2408	2067	1777	1537
Plants in agriculture, forestry and aquaculture	586	704	734	615	386	324	373	397	465	674	964
Combustion in industrial plants	4570	4981	5011	4438	3746	3051	3579	3754	3795	3808	3950
Total	37454	43812	36023	32181	31480	30804	30276	24664	23842	20938	21320

CO_2 is the dominant GHG for stationary combustion and comprises, in 2010, approximately 97 % 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 and oil/gas extraction. The emission of CO_2 decreases by 35 % from 2010 to 2030 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

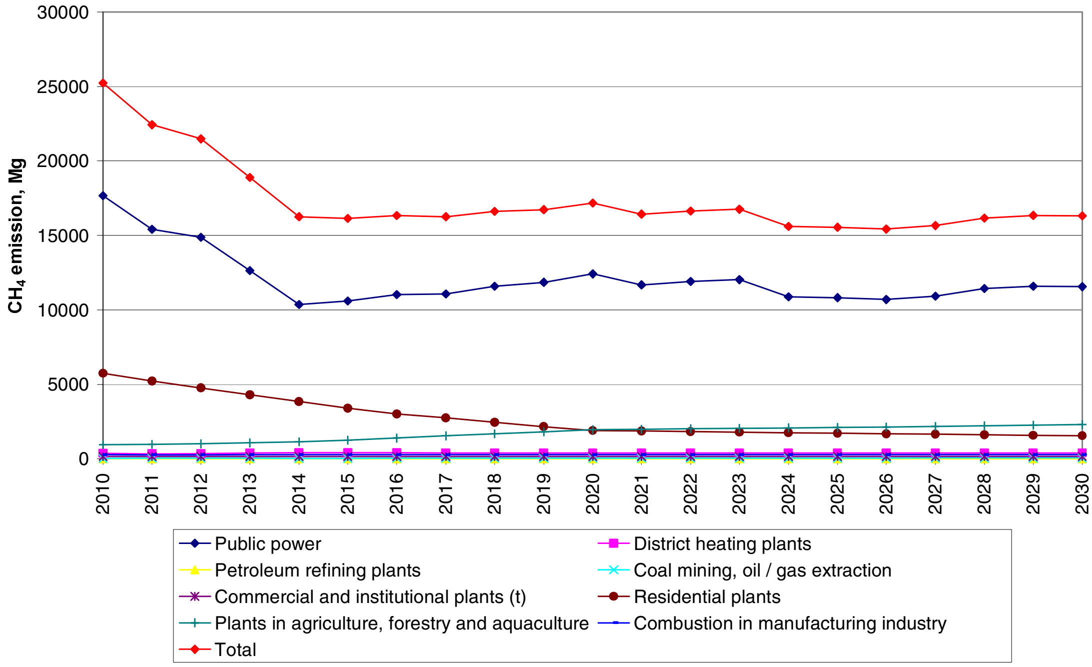

Figure 2.7 CH_4 emissions by sector.

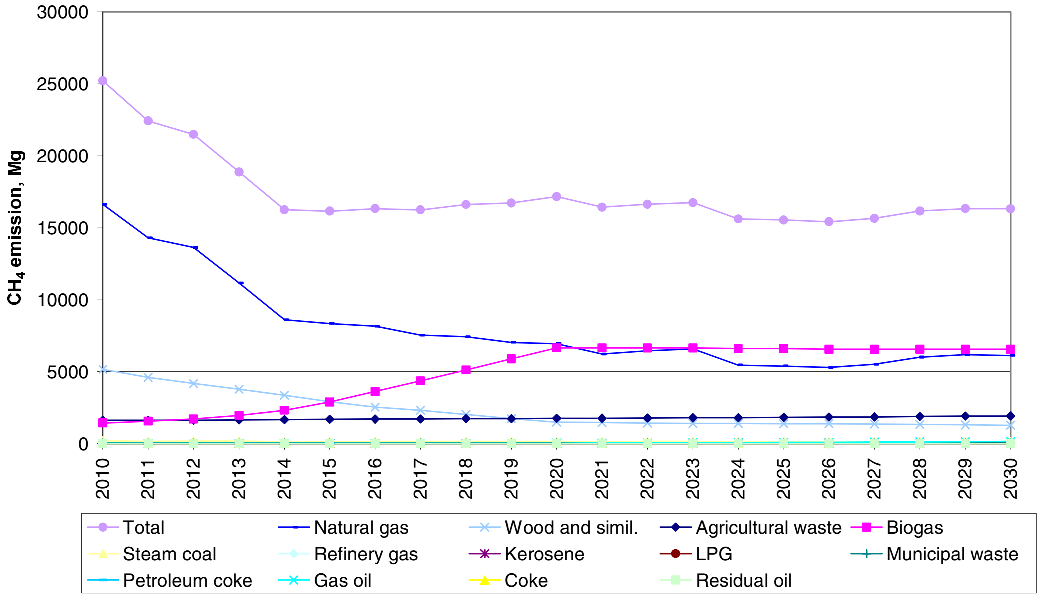

Figure 2.8 CH_4 emissions by fuel.

Table 2.6 CH_4 emissions, Mg.

Sector	1990	1995	2000	2005	2008	2009	'2010'	'2015'	2020	2025	2030
Public power	248	11 110	14 357	12 036	9 757	8 432	13 228	11 136	12 419	10 818	11 559
District heating plants	221	235	239	311	357	385	359	402	396	402	398
Petroleum refining plants	18	26	2	1	4	4	11	16	16	16	16
Oil/gas extraction	14	19	38	48	48	46	46	47	49	54	60
Commercial and institutional plants	54	688	920	858	718	729	380	148	147	146	146
Residential plants	4057	5 055	5 413	6 791	7 421	6 722	5 975	3 460	1 905	1 719	1 550
Plants in agriculture, forestry and aquaculture	1061	1 583	2337	2 001	1 188	1 130	1 048	1 283	1 955	2 106	2 302
Combustion in industrial plants	336	415	1 134	1 014	698	655	438	283	285	282	288
Total	6008	19 131	24 438	23 060	20 192	18 102	21 485	16 775	17 171	15 543	16 318

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 wood 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 apparent increase from the historic inventory for 2009 and the projected emission for '2010' is due to higher estimated fuel consumption in natural gas fuelled gas engines in 2010-2012 than for 2008 and 2009, also all gas engines are included under public power in the projections, which is the reason for the apparent decrease for e.g. commercial and institutional plants. The increase in emission from residential plants is due to an increase in wood combustion. A significant increase in CH_4 emission from biogas is also noticeable; this is due to increased 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.

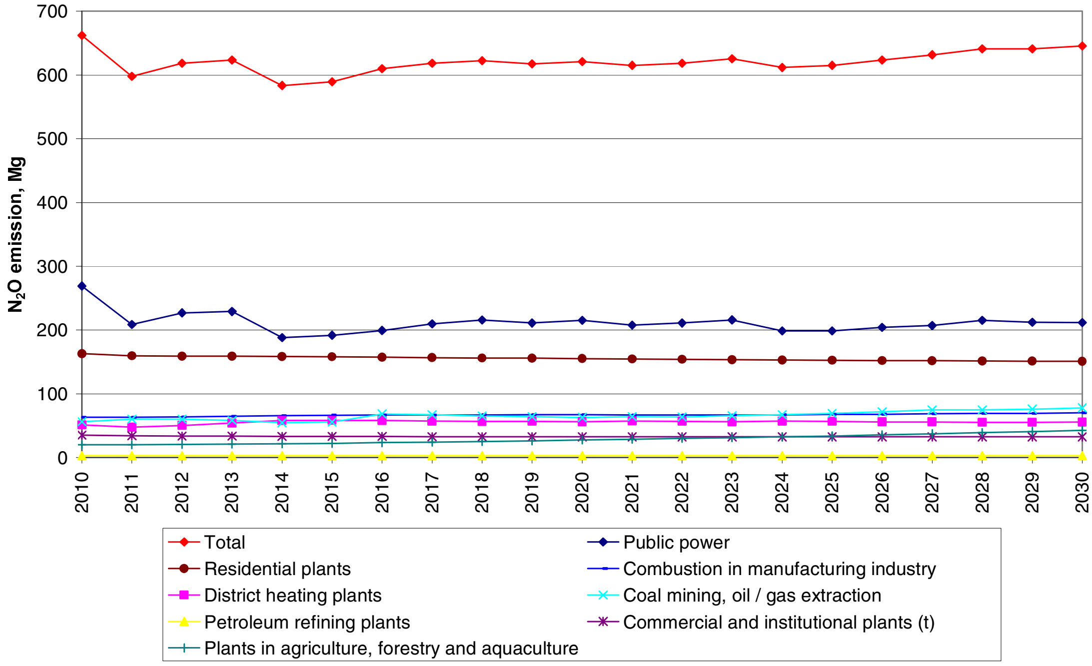

Figure 2.9 N_2O emissions by sector.

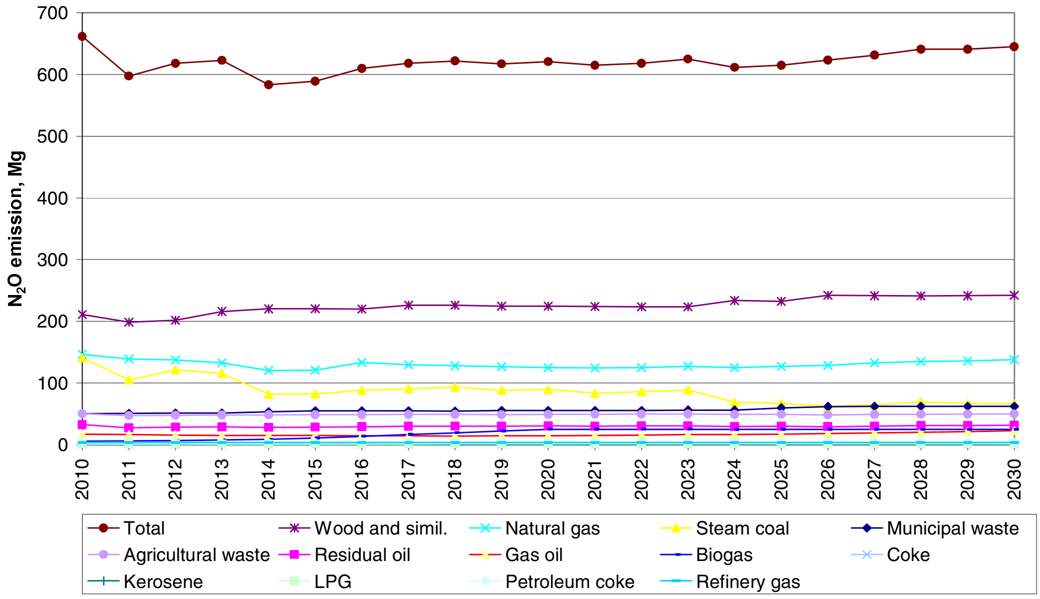

Figure 2.10 N_2O emissions by fuel.

Table 2.6 N_2O emissions, Mg.

Sector	1990	1995	2000	2005	2008	2009	'2010'	'2015'	2020	2025	2030
Public power	197	279	252	240	241	244	238	204	215	199	212
District heating plants	56	47	40	47	55	58	52	57	56	57	56
Petroleum refining plants	2	8	7	5	4	4	3	3	3	3	3
Oil/gas extraction	20	28	56	62	62	59	60	61	63	69	78
Commercial and institutional plants	25	30	25	33	30	29	32	33	33	32	33
Residential plants	90	94	93	136	163	159	161	158	155	153	151
Plants in agriculture, forestry and aquaculture	24	22	20	19	16	16	19	23	28	34	43
Combustion in industrial plants	134	102	103	83	77	64	66	66	67	68	70
Total	548	611	596	625	648	632	631	605	621	615	645

2.6 Model description

The software used for the energy model is Microsoft Access 2003, which is a Relational Database Management System (RDBMS) for creating databases. The database is called the 'Fremskrivning2010-2030 model' 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 'Fremskrivning2010-2030 model'.

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
qEmissionArea	Calculation of the emissions from small combustion plants. Input: tblActArea and qEmfArea
qEmissionPoint	Calculation of the emissions from large combustion plants. Input: tblActPoint and qEmfPoint
qEmissionAll_a	Union of qEmissionArea and qEmissionPoint

Based on some of the queries a large number of summation queries are available in the 'Fremskrivning2010-2030 model' (Figure 2.12). The outputs from the summation queries are Excel tables.

Table 2.3 Summation queries.

Name	Output
qxlsEmissionAll	Table containing emissions for SNAP groups, Years and Pollutants
qxlsEmissionArea	Table containing emissions for small combustion plants for SNAP groups, Years and Pollutants
qxlsEmissionPoint	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.

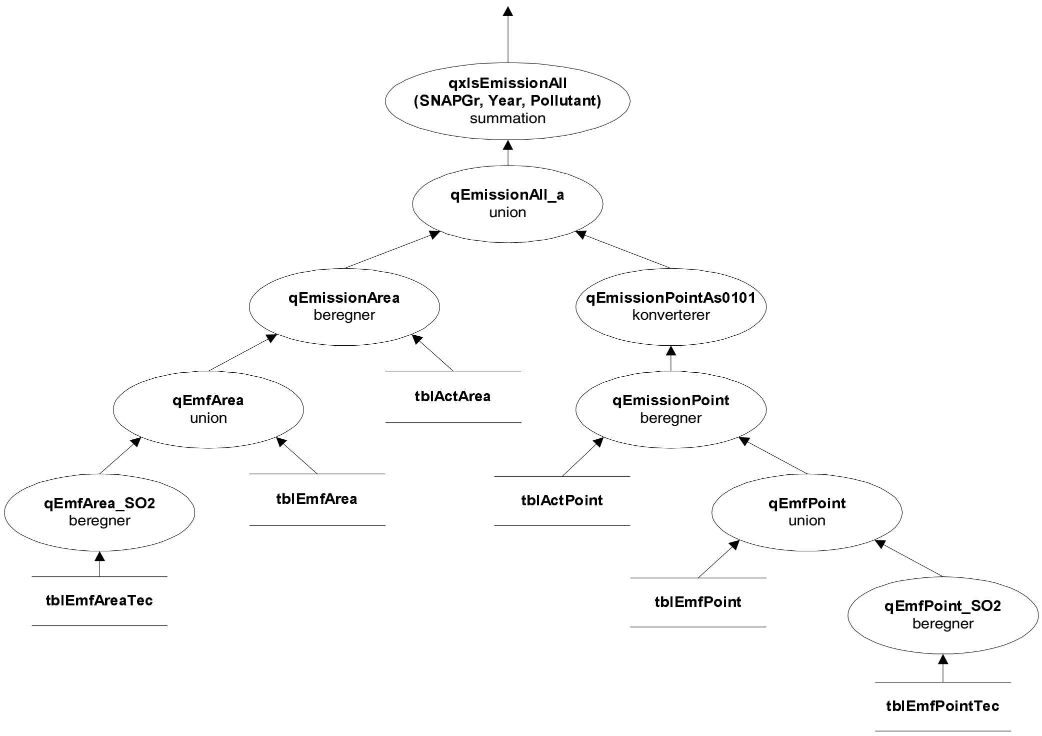

Figure 2.11 The overall construction of the database.

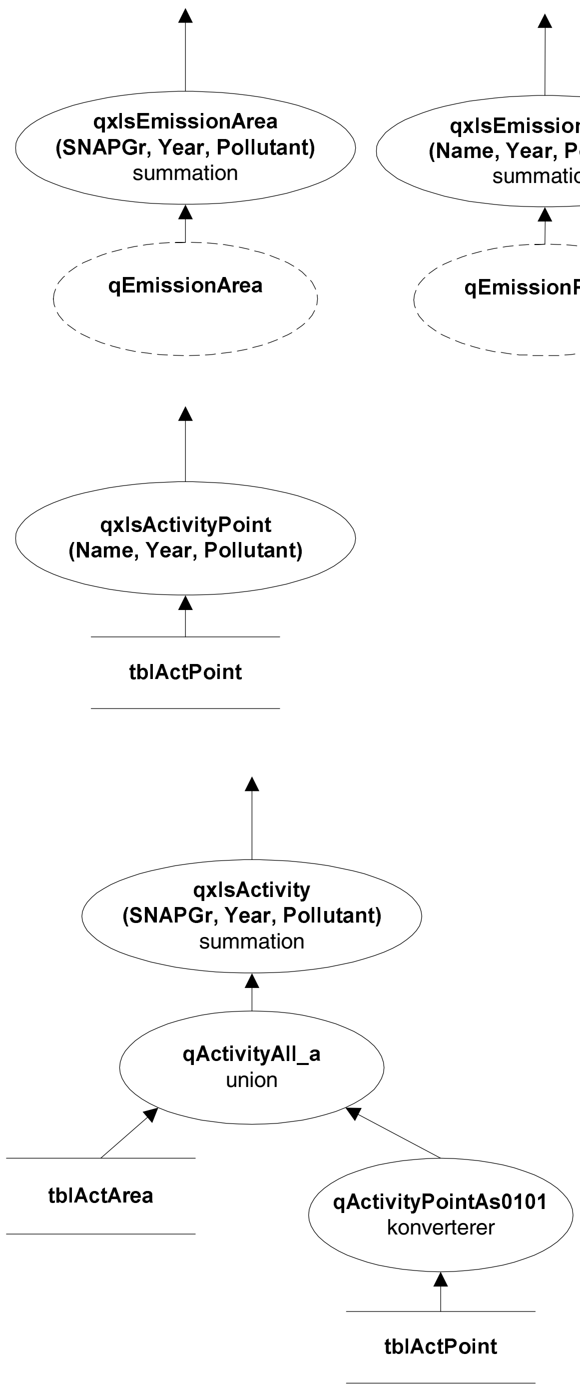

Figure 2.12 Summation queries.

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Danish Energy Agency, 2011b: Energy projections 2010-2030 of individual plants, RAMSES, April 2011.

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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

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 3.5.1. 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 correspond 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, 2011b) 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.

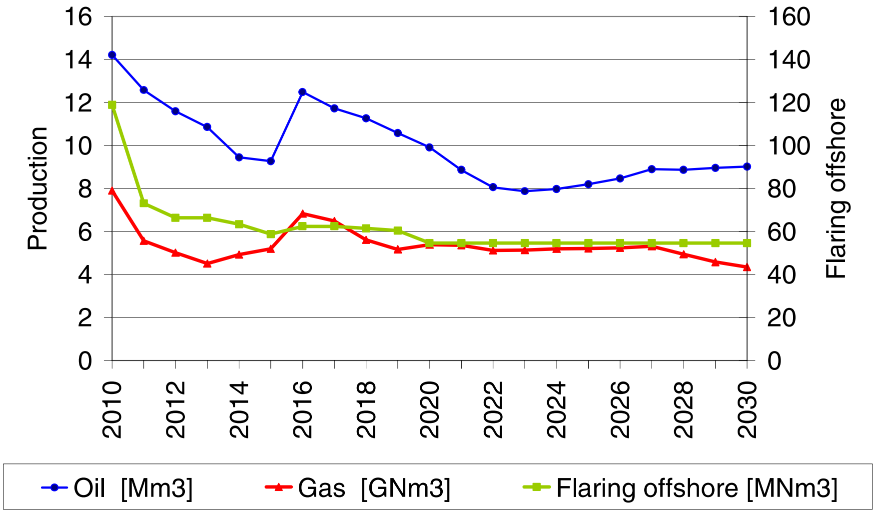

Figure 3.1 Prognosis for the production of oil and gas (DEA, 2011).

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 (2011a) 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 a number of 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 79 % from 2010 due to introduction of new vapour recovery unit (VRU) at the Danish oil terminal (Spectrasyne Ltd, 2010). Further, a new degassing system has been built and taken into use in 2009. This has reduced the CH_4 emissions from oil tanks by 53 % (Spectrasyne Ltd, 2010). The CH_4 emission factors for the projection years 2010 to 2030 are listed in Table 3.2.

Table 3.2 Emission factors for 2010-2030.

	CH_4	Unit	Ref.
Ships offshore	0.00005	Fraction of loaded	EMEP/CORINAIR, 2009
Ships onshore	0.0000079	Fraction of loaded	EMEP/CORINAIR, 2007 and Spectrasyne Ltd, 2010
Oil tanks	10,7	G pr 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 in refineries the average emission factor based on EU-ETS data for 2006-2009 are applied. The same approach are made for off-shore flaring but based on data for 2008-2009 as these are the only years with a complete dataset.

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 both flaring offshore and in refineries.

The fuel consumption and flaring amounts for refineries in the DEA prognosis (DEA, 2011a) equal the values for the latest historical year, and correspondingly the emissions for 2009 are applied for the projection years 2010-2030.

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.

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 and projection years. The total fugitive CH_4 emission is expected to decrease in the projection period. The decrease reflects the environmental regulation and technical improvements related to emissions from storage of oil in tanks and onshore loading of ships at the raw oil terminal. Further, decreasing extraction of oil and gas contribute to lower the CH_4 emissions. It has been assumed that the number of platforms falls in line with the decline in extraction. Emissions of CH_4 are shown in Figure 3.2 for selected years in the time-series 1990-2030.

Table 3.3 CH_4 emissions, Mg.

	1990	1995	2000	2005	2008	2009	
Refining	37	62	50	612	2 184	2 137	
Oil, onshore activities	817	1 271	1 809	2 225	1 744	1 386	
Oil, offshore activities	708	990	1 566	1 775	1 777	1 775	
Gas, transmission and distribution	424	834	401	380	172	144	
Venting and flaring	86	169	144	114	175	112	
Total	2 072	3 327	3 970	5 105	6 052	5 554	
Continued	2010	2011	2012	2015	2020	2025	2030
Refining	2 137	2 137	2 137	2 137	2 137	2 137	2 137
Oil, onshore activities	1 282	1 198	1 121	921	679	495	371
Oil, offshore activities	1 662	1 459	1 343	1 085	1 158	965	1 049
Gas, transmission and distribution	143	141	136	124	109	98	92
Venting and flaring	138	129	127	126	125	125	125
Total	5 362	5 064	4 864	4 393	4 207	3 820	3 773

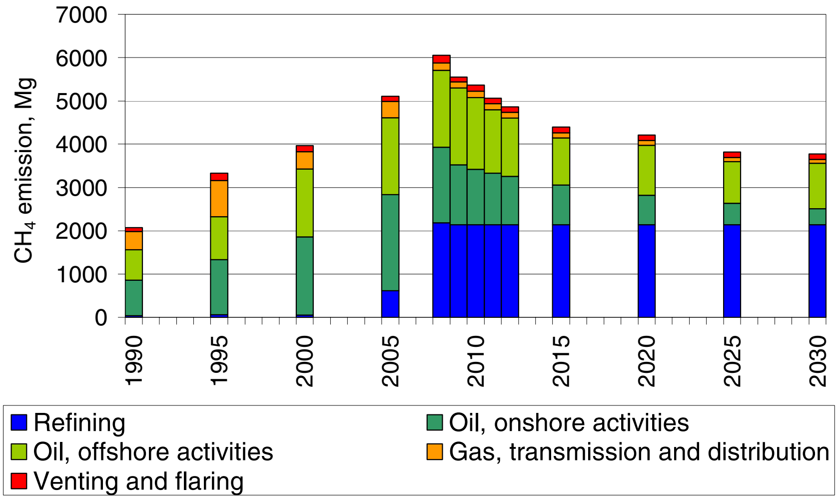

Figure 3.2 CH_4 emissions in the projection period by sector.

The summarised greenhouse gas emissions for selected historical and projection years are shown in Figure 3.3 on sub-sector level. Flaring is the only source contributing emissions of CO_2 and CH_4 for fugitive emissions. The GHG emissions from flaring and venting dominate the summarised GHG emissions. The GHG emissions reached a maximum in 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.

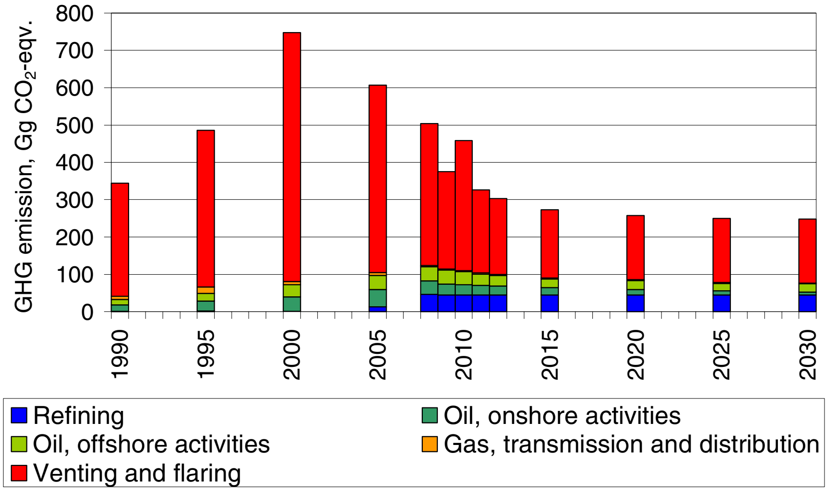

Figure 3.3 GHG emissions in selected historical and projection years.

The only source of CO_2 and 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 3.4 for the projection period.

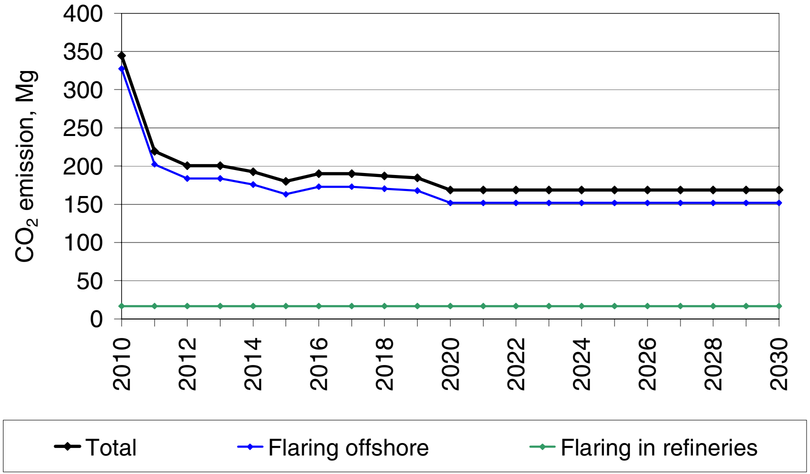

Figure 3.4 CO_2 emissions in the projection period by sector.

3.5 Model description

The model for projection of fugitive emissions from fuels, the “Fugitive emissions model”, is created in Microsoft Excel. Refineries and transmission/distribution of gas are treated in separate workbooks (“Refineries” and “Gas losses”) and the results are imported to the workbook “Exploration” holding the remaining part of the fugitive sector. The names and content of the sub models are listed in Table 3.4.

Table 3.4 Tables in the 'Fugitive emissions model'.

Name	Content
Refineries	Activity data and emission factors for refining and flaring in refineries for the historical years 1990-2009.
Gas losses	Activity data and emission factors for transmission and distribution of natural gas and town gas for the historical years 1990-2009.
Exploration	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 2009 plus prognosis and projected activity rates and emission factors for the projection years 2010 to 2030. Further, the resulting emission the projection years for all sources in the fugitive sector are stored in the worksheet "Projected emissions".

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.

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4 Industrial processes

4.1 Sources

A range of sources is covered in the projection of process emissions to 2030 (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., 2011).

4.2 Projections

The results of projection of the GHG emission are presented in Table 4.3. The projections are generally based on energy projections related to specific sectors (Danish Energy Agency, 2011); the applied extrapolation factors are presented in Table 4.2. The methodologies used within the different sectors - especially the estimate on 2010 activity - are described below.

Production of building materials i.e. cement, yellow bricks, expanded clay products, glass and stone wool contributes significantly to industrial process emissions. However the building sector has been influences by the economical crises. The activity in 2010 is therefore assumed to be at the same level as in 2009 according to the prognosis for building activities by Dansk Byggeri (2011). The emission for 2011-2030 is estimated by extrapolation with a factor based on expected energy consumption within the sector “production of cement and bricks etc.”; see Table 4.2.

Lime is used for a number of different applications. 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 the sector "other production"; see Table 4.2.

Glass is mainly produced for packaging and 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 the sector "production of glass and ceramics etc."; 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 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 consumption of "coal and coke" and "waste"; see Table 4.2.

Table 4.2 Extrapolation factors for estimation of CO_2 emissions from industrial processes (based on energy projections by (Danish Energy Agency (2011)).

	QJONF Food and beverage	QJONK Chemical industry	QJONQ Other production	QJOCE Cement, bricks etc.	QJOGL Glass, ceramics etc.	Coal & coke	Waste
2010[1]	1	1	1	1	1	1	1
2011	0.98	0.97	0.99	1.03	1.03	0.73	1.01
2012	0.97	0.96	0.98	1.06	1.06	0.85	1.02
2013	0.96	0.94	0.99	1.11	1.10	0.81	1.03
2014	0.95	0.93	0.99	1.14	1.14	0.55	1.07
2015	0.95	0.92	1.00	1.17	1.18	0.56	1.10
2016	0.95	0.89	1.00	1.19	1.22	0.60	1.09
2017	0.94	0.87	0.99	1.21	1.25	0.62	1.10
2018	0.94	0.84	0.99	1.23	1.29	0.64	1.09
2019	0.94	0.81	0.98	1.25	1.32	0.60	1.12
2020	0.94	0.78	0.97	1.27	1.35	0.61	1.11
2021	0.95	0.74	0.95	1.26	1.36	0.56	1.12
2022	0.95	0.71	0.93	1.28	1.38	0.58	1.12
2023	0.95	0.68	0.92	1.30	1.40	0.61	1.13
2024	0.96	0.65	0.91	1.32	1.43	0.45	1.13
2025	0.96	0.62	0.91	1.35	1.46	0.44	1.22
2026	0.97	0.60	0.90	1.37	1.49	0.40	1.26
2027	0.98	0.58	0.90	1.40	1.53	0.42	1.27
2028	0.98	0.55	0.90	1.43	1.57	0.45	1.27
2029	0.99	0.52	0.89	1.44	1.60	0.44	1.27
2030	1.00	0.50	0.89	1.48	1.64	0.43	1.27

1) Emission in 2010 is based on sector specific assumptions.

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.

Consumption of lime for sugar refining 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 food and beverage industry; see Table 4.2.

Consumption of lubricants and the resulting emission of CO_2 2010 is assumed to be at the average level for 2006-8. The emission for 2011-2030 is assumed to be constant at the 2010 level.

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

	2A	2B	2C	2D	2G	
	Mineral Products	Chemical Industry	Metal Production	Food and drink	Lubricants	Total
1990	1068	0.80	28.4	4.45	49.7	1151
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	1467
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	923	2.24	0	2.19	36.5	964
2011	936	2.18	0	2.14	36.5	977
2012	961	2.15	0	2.12	36.5	1002
2013	998	2.12	0	2.10	36.5	1039
2014	1013	2.09	0	2.09	36.5	1054
2015	1038	2.06	0	2.07	36.5	1079
2016	1057	2.00	0	2.07	36.5	1098
2017	1075	1.94	0	2.06	36.5	1115
2018	1092	1.88	0	2.06	36.5	1133
2019	1107	1.81	0	2.06	36.5	1147
2020	1124	1.74	0	2.06	36.5	1164
2021	1111	1.65	0	2.07	36.5	1152
2022	1126	1.59	0	2.07	36.5	1166
2023	1139	1.52	0	2.08	36.5	1179
2024	1150	1.46	0	2.09	36.5	1190
2025	1172	1.40	0	2.10	36.5	1212
2026	1191	1.35	0	2.12	36.5	1231
2027	1216	1.29	0	2.13	36.5	1256
2028	1237	1.24	0	2.15	36.5	1277
2029	1250	1.18	0	2.16	36.5	1290
2030	1278	1.13	0	2.18	36.5	1317

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	1995	2000	2005	2009	'2010' 2008-2012	'2015' 2013-2017	2020	2025	2030
2A	Mineral Products	1068	1405	1616	1544	881	1004	1036	1124	1172	1278
2B	Chemical Industry	0.80	0.80	0.65	3.01	2.13	2.22	2.04	1.74	1.40	1.13
2C	Metal Production	28.4	38.6	40.7	15.6	0	0	0	0	0	0
2D	Food and drink	4.45	3.91	3.90	4.46	1.92	2.21	2.08	2.06	2.10	2.18
2G	Lubricants	49.7	48.8	39.7	37.6	31.2	34.9	36.5	36.5	36.5	36.5
	Total	1151	1497	1701	1604	916	1044	1077	1164	1212	1317

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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 – 2009 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. (2011).

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 2009 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 49 %, 15 % 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 2009 NMVOC emission in Gg from CRF 3 Solvents and other product use and its sub-categories.

SNAP	Category description	NMVOC emission 2009 (Gg)	Fraction of total 2009 emission
060101	Manufacture of Automobiles	0.0414	0.0015
060102	Car Repairing	0.277	0.010
060103	Constructions and Buildings	0.622	0.023
060104	Domestic Use	0.397	0.015
060105	Coil Coating	0.0185	0.00068
060106	Boat Building	0.541	0.020
060107	Wood	0.0785	0.0029
060108	Other Industrial Paint Applications	1.26	0.046
060109	Other Non-Industrial Paint Application	0.0834	0.0030
	Paint Application (sum of above SNAP sub-categories)	**3.32**	**0.12**
060201	Metal Degreasing	0	0
060202	Dry Cleaning	1.31E-05	4.8E-07
060203	Electronic Components Manufacturing	0	0
060204	Other Industrial Dry Cleaning	0	0
	Degreasing and Dry Cleaning (sum of above SNAP sub-categories)	**1.31E-05**	**4.8E-07**
060301	Polyester Processing	0	0
060302	Polyvinylchlorid Processing	5.28E-08	1.9E-09
060303	Polyurethan Foam Processing	0.188	0.0069
060304	Polystyrene Foam Processing	0.894	0.033
060305	Rubber Processing	0	0
060306	Pharmaceuticals Products Manufacturing	0	0
060307	Paints Manufacturing	0.000264	9.7E-06
060308	Inks Manufacturing	0.000212	7.8E-06
060309	Glues Manufacturing	0	0
060310	Asphalt Blowing	0	0
060311	Adhesive, Magnetic Tapes, Film & Photographs Manufacturing	3E-06	1.1E-07
060312	Textile Finishing	0	0
060313	Leather Tanning	0	0
060314	Other	3.82	0.14

Continued			
	Chemical Products Manufacturing & Processing (sum of above SNAP sub-categories)	**4.90**	**0.18**
060401	Glass Wool Enduction	4.89E-06	1.8E-07
060402	Mineral Wool Enduction	0.000521	1.9E-05
060403	Printing Industry	0.00911	0.00033
060404	Fat, Edible and Non-Edible Oil Extraction	0	0
060405	Application of Glues and Adhesives	1.54	0.056
060406	Preservation of Wood	0	0
060407	Underseal Treatment and Conservation of Vehicles	0	0
060408	Domestic Solvent Use (Other Than Paint Application)	4.11	0.15
060409	Vehicles Dewaxing	0	0
060411	Domestic Use of Pharmaceutical Products	0	0
060412	Other (Preservation of Seeds a.o)	13.5	0.49
	Other use (sum of above SNAP sub-categories)	**19.1**	**0.70**
	Total	27.4	1.0

The processes and activities that are covered by BEK 350 and the associated fraction of the total 2009 NMVOC emissions are shown in Table 5.2. They cover 9.1 % of the total NMVOC emissions in CRF 3.

NMVOC emission threshold values that these categories must comply with refer to single installations and 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 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 1995-2009 emissions.

For N_2O historic emissions are available for 2005 to 2009 and are approximately constant during 2006 to 2009 with a mean value and standard deviation of 0.11 ± 0.015 Gg N_2O per year. The gas is used for anaesthesia and 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 2009 emissions.

Table 5.2 Processes and activities (categories) that are covered by BEK 350, associated SNAP sub-categories, NMVOC emissions in 2009 and fraction of 2009 emissions from BEK 350 category.

Categories in BEK 350	Corresponding SNAP categories	NMVOC emission 2009 (Gg)	Fraction of total 2009 emission
Adhesive coating	060405	1.54	0.056 (also includes diffuse use)
Coating activity and vehicle refinishing	060101, 060102, 060106, 060107	0.94	0.034
Coil coating and winding wire coating	060105	0.0185	0.00068
Dry cleaning	060202	0.000013	0.00000048
Footwear manufacture	nd	Nd	nd
Manufacturing of coating preparations, varnishes, inks and adhesives	060307, 060308, 060309, 060311	0.00048	0.000018
Manufacture of pharmaceutical products	060306	0	0
Printing	060403	0.0091	0.00033
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		2.5	0.091

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 categories in Statistics Denmark (2011) and SPIN (2011) 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 1995 to 2009 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 3D5 Other. An exponential fit gives the best approximation with R^2 values of 0.85, 0.75, 0.72 and 0.93 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 three years of the historic emissions; i.e. the four CRF categories show approximately constant emissions during the latest three years (2007 to 2009). 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 1995 to 2009 emissions, and constant mean historic 2007 to 2009 emissions. N_2O projections are constant mean historic 2006 to 2009 emissions.

	Unit	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
NMVOC emissions											
3A Paint Application	Gg	3.40	3.29	3.20	3.11	3.02	2.94	2.86	2.79	2.73	2.67
3B Degreasing and Dry Cleaning	Gg	1.4E-05	1.3E-05	1.3E-05	1.2E-05	1.2E-05	1.1E-05	1.1E-05	1.1E-05	1.0E-05	1.0E-05
3C Chemical Products, Manufacturing and Processing	Gg	5.24	5.15	5.06	4.98	4.91	4.83	4.76	4.69	4.62	4.56
3D5 Other Use	Gg	17.5	17.1	16.8	16.5	16.2	16.0	15.7	15.4	15.9	14.9
Total NMVOC	Gg	26.1	25.6	25.1	24.6	24.2	23.7	23.3	22.9	22.5	22.2
N_2O emissions											
3D1 Use of N_2O for Anaesthesia	Gg	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11
	Unit	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
NMVOC emissions											
3A Paint Application	Gg	2.61	2.55	2.50	2.45	2.41	2.37	2.33	2.29	2.25	2.22
3B Degreasing and Dry Cleaning	Gg	1.0E-05	9.8E-06	9.7E-06	9.5E-06	9.4E-06	9.3E-06	9.2E-06	9.1E-06	9.0E-06	8.9E-06
3C Chemical Products, Manufacturing and Processing	Gg	4.49	4.43	4.37	4.32	4.26	4.21	4.16	4.11	4.07	4.02
3D5 Other Use	Gg	14.7	14.5	14.3	14.1	13.9	13.7	13.5	13.3	13.2	13.0
Total NMVOC	Gg	21.8	21.5	21.2	20.9	20.6	20.3	20.0	19.7	19.5	19.3
N_2O emissions											
3D1 Use of N_2O for Anaesthesia	Gg	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11
	Unit	2030									
NMVOC emissions											
3A Paint Application	Gg	2.19									
3B Degreasing and Dry Cleaning	Gg	8.8E-06									
3C Chemical Products, Manufacturing and Processing	Gg	3.98									
3D5 Other Use	Gg	12.9									
Total NMVOC	Gg	19.0									
N_2O emissions											
3D1 Use of N_2O for Anaesthesia	Gg	0.11									

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 3 and CO_2 conversion factors.

	Unit	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
CO_2 eqv. emissions											
3A Paint Application	Gg	8.68	8.41	8.16	7.92	7.70	7.49	7.30	7.12	6.95	6.79
3B Degreasing and Dry Cleaning	Gg	7.3E-06	7.0E-06	6.7E-06	6.5E-06	6.2E-06	6.0E-06	5.9E-06	5.7E-06	5.6E-06	5.4E-06
3C Chemical Products, Manufacturing and Processing	Gg	13.0	12.7	12.5	12.3	12.1	12.0	11.8	11.6	11.5	11.3
3D5 Other Use	Gg	40.4	39.6	38.9	38.2	37.5	36.8	36.2	35.6	35.0	34.4
Total CO_2 eqv. emissions from NMVOC	Gg	62.0	60.8	59.6	58.4	57.3	56.3	55.3	54.3	53.4	52.5
CO_2 eqv. emissions											
3D1 Use of N_2O for Anaesthesia	Gg	34.0	34.0	34.0	34.0	34.0	34.0	34.0	34.0	34.0	34.0
Total CO_2 eqv. emissions	Gg	96.0	94.7	93.5	92.4	91.3	90.2	89.2	88.3	87.3	86.5

	Unit	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
CO_2 eqv. emissions											
3A Paint Application	Gg	6.63	6.49	6.36	6.24	6.12	6.01	5.91	5.81	5.72	5.64
3B Degreasing and Dry Cleaning	Gg	5.3E-06	5.2E-06	5.1E-06	5.1E-06	5.0E-06	4.9E-06	4.9E-06	4.8E-06	4.8E-06	4.7E-06
3C Chemical Products, Manufacturing and Processing	Gg	11.1	11.0	10.8	10.7	10.6	10.4	10.3	10.2	10.1	10.0
3D5 Other Use	Gg	33.9	33.4	32.9	32.4	31.9	31.5	31.1	30.7	30.3	29.9
Total CO_2 eqv. emissions from NMVOC	Gg	51.7	50.9	50.1	49.3	48.6	48.0	47.3	46.7	46.1	45.5
CO_2 eqv. emissions											
3D1 Use of N_2O for Anaesthesia	Gg	34.0	34.0	34.0	34.0	34.0	34.0	34.0	34.0	34.0	34.0
Total CO_2 eqv. emissions	Gg	85.6	84.8	84.0	83.3	82.6	81.9	81.3	80.7	80.1	79.5

	Unit	2030
CO_2 eqv. emissions		
3A Paint Application	Gg	5.56
3B Degreasing and Dry Cleaning	Gg	4.7E-06
3C Chemical Products, Manufacturing and Processing	Gg	9.87
3D5 Other Use	Gg	29.5
Total CO_2 eqv. emissions from NMVOC	Gg	45.0
CO_2 eqv. emissions		
3D1 Use of N_2O for Anaesthesia	Gg	34.0
Total CO_2 eqv. emissions	Gg	78.9

In the previous emission projection (Nielsen et al., 2010) 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 2009 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 near future. For composite and PUR there are ongoing 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 2010 to 2030 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 31 % decrease in total NMVOC emissions from 2009 (Table 1) to 2030. CFR 3A, 3C and 3D5 show a 34 %, 19 % and 32 % 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.

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.

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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	IPCC 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

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. 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 NERI, 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 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, 2009). For information on the historical vehicle stock and annual mileage, please refer to Nielsen et al. (2011).

In addition new data prepared by DTU Transport for the Danish Infrastructure Commission has given information of the total mileage driven by foreign trucks on Danish roads for rigid trucks and truck-trailer/articulated truck combinations, respectively. This mileage contribution has been added to the total mileage for Danish trucks on Danish roads, for trucks in comparable gross vehicle weight size classes. The data from DTU Transport was estimated for the years 1999-2009 and by using appropriate assumptions the mileage has been back-casted to 1985 and forecasted to 2030.

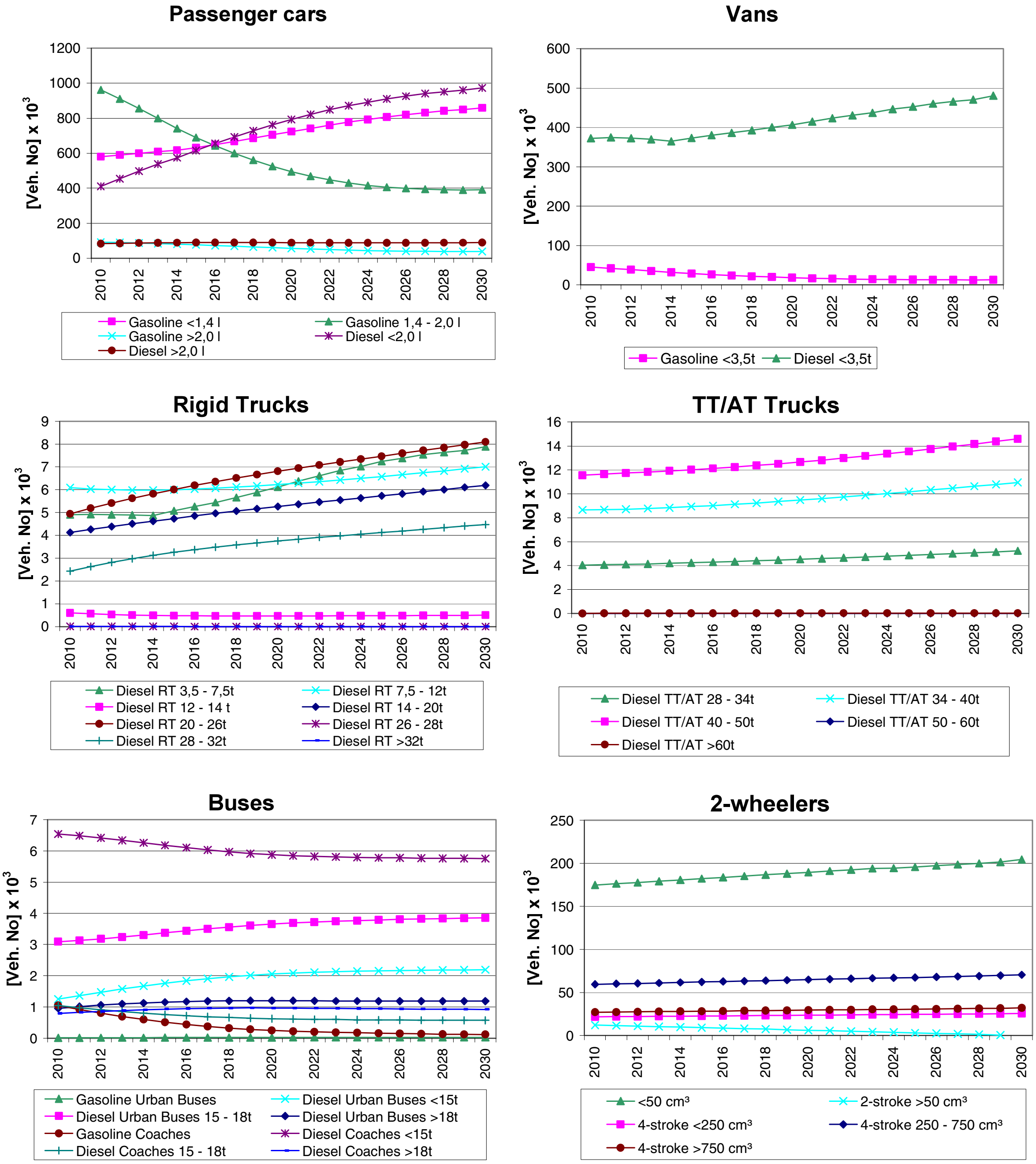

Figure 6.1 Number of vehicles in sub-classes from 2010-2030.

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 2010-2030. The trends in vehicle numbers per EU layer are also shown in Figure 6.2 for the 2010-2030 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.

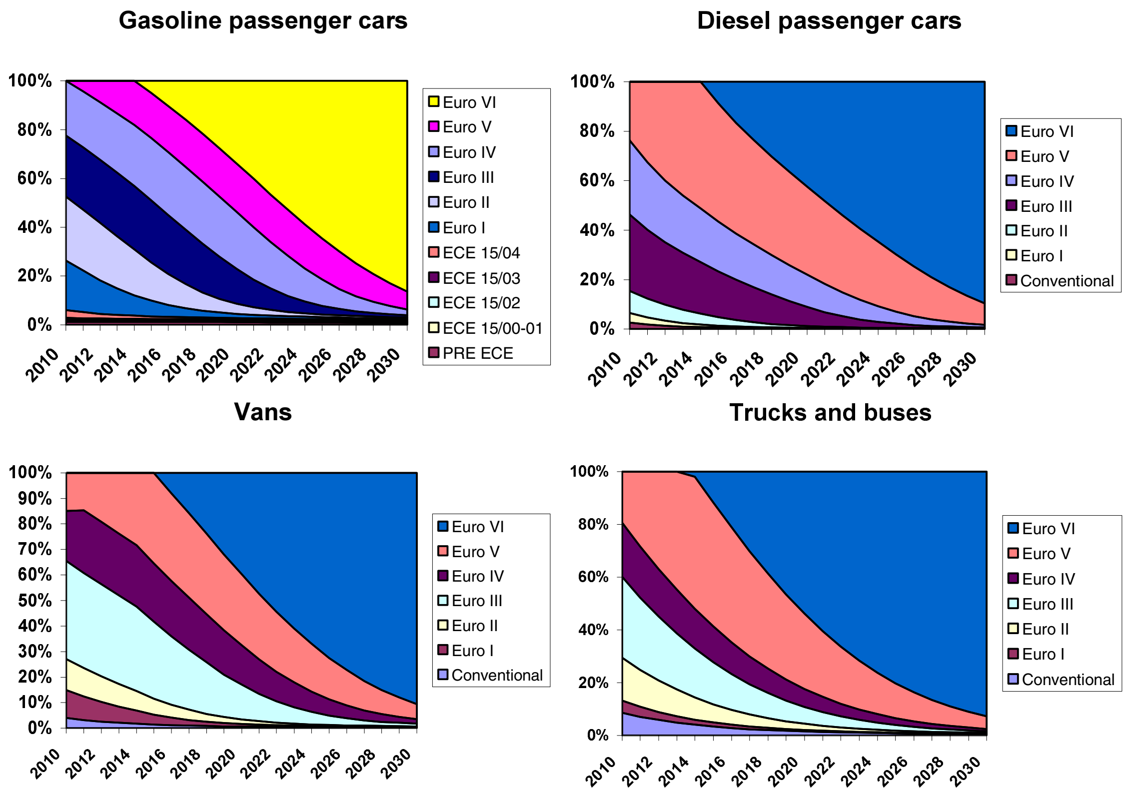

Figure 6.2 Layer distribution of vehicle numbers per vehicle type in 2010-2030.

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 grams per kilometre (g pr 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**: 65 % of each manufacturer's newly registered cars must comply on average with the limit value curve set by the legislation in 2012. 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 pr km of exceedance, 15 € for the second g pr km, 25 € for the third g pr km, and 95 € for each subsequent g pr km. From 2019, already the first g pr km of exceedance will cost 95 €.
- **Long-term targe**t: a target of 95 g pr 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 7 g pr km of emission credits on average for their fleet if they equip vehicles with innovative technologies, based on independently verified data.

On 28 October 2009 the European Commission adopted a new legislative proposal to reduce CO_2 emissions from light commercial vehicles (vans). The main content of the proposal is given below in bullet points:

- Target dates: the EU fleet average for all new light commercial vehicles (vans) of 175 g pr km will apply as of 2014. The requirement will be phased-in as of 2014 when 75 % of each manufacturer's newly registered vans must comply on average with the limit value curve set by the legislation. This will rise to 80 % in 2015, and 100 % from 2016 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 over-

all fleet average. Only the fleet average is regulated, so manufacturers will still be able to make vehicles with emissions above the limit value curve provided these are balanced by other vehicles which are below the curve.

- Vehicles affected: the vehicles affected by the legislation are vans, which account for around 12 % of the market for light-duty vehicles. This includes vehicles used to carry goods weighing up to 3.5 t (vans and car-derived vans, known as N1) and which weigh less than 2610 kg when empty.
- Long-term target: a target of 135 g pr km is specified for the year 2020. Confirmation of the target with the updated impact assessment, 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.
- 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 pr km of exceedance, 15 € for the second g pr km, 25 € for the third g pr km, and 120 € for each subsequent g pr km. From 2019, already the first g pr km of exceedance will cost 120 €. This value is higher than the one for cars (95 €) because of the differences in compliance costs.
- Super-credits: vehicles with extremely low emissions (below 50 g pr km) will be given additional incentives whereby one low-emitting van will be counted as 2.5 vehicles in 2014, as 1.5 vehicles in 2015, and one vehicle from 2016.
- 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 7 g pr 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 pr 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 pr h. More information regarding the fuel measurement procedure can be found in the EU Directive 80/1268/EØF.

For NO_x, VOC (NMVOC + CH_4), CO and PM, the emissions from road transport vehicles have to comply with the different EU directives listed in Table 5.3. In the latter table, EU directive starting dates for vehicles new registrations are also listed. The specific emission limits can be seen in Winther (2008b).

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		0
	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	0
	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	0
	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	1.10.2014
Mopeds		Conventional	0
	Euro I	97/24	2000
	Euro II	2002/51	2004
Motor cycles		Conventional	0
	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 pr 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 pr kWh from emission approval tests cannot be directly used for inventory work. Instead, emission factors used for national estimates must be transformed into g pr 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, 2008b). 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 2009 has been calculated from type approval values incorporated in the DTU Transport fleet and mileage statistics. This value is used in combination with the overall EU target of 130 g CO_2 pr km in 2015 and 95 g CO_2 pr km in 2020 in order to calculate an interpolated time series of type approval related CO_2 emission factors for the years 2010-2020.

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 CO_2 emission factor and the CO_2 emission factor for 2009.

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.

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 (2008b).

Fuel consumption and emission results per layer and vehicle type, respectively, are shown in Annex 5.1 from 2010-2030. 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 2001-2009, 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 (2011) 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 5.4.

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
Household/ gardening	-	Riders, lawn movers, chain saws, cultivators, shrub clearers, hedge cutters, trimmers, other

A Danish research project has provided updated information of the number of different types of machines, their load factors, engine sizes and annual working hours (Winther et al., 2006). Please refer to the latter report for detailed information about activity data for non road machinery types.

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 NERI 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 NERI sector "Industry (gasoline/diesel/LPG)". In cases for industrial non road where NERI bottom-up estimates are smaller than DEA reported values, the fuel difference is transferred to industrial stationary sources.

The DEA gasoline fuel data for households are used as an input for the fuel balance for the NERI sector "Household/gardening".

National sea transport

An internal NERI 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, 2008a; Nielsen et al., 2011).

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 1990-2009. For these ferry routes and the years 1990-2005, the following detailed traffic and technical data have been gathered by Winther (2008a): Ferry name, year of service, engine size (MCR), engine type, fuel type, average load factor, auxiliary engine size and sailing time (single trip).

For 2006-2009, the above mentioned traffic and technical data for specific ferries have been provided by Kristensen (2010) in the case of Mols-Linien (Sjællands Odde-Ebeltoft, Sjællands Odde-Århus, Kalundborg-Århus), by Hjortberg (2010) for Bornholmstrafikken (Køge-Rønne) and by Simonsen (2010) for Langelandstrafikken A/S (Tårs-Spodsbjerg). For Esbjerg-Torshavn and Hanstholm-Torshavn traffic and technical data have been provided by Dávastovu (2010) 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, 1999-2009
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 (2011). 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 2010-2030 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 pr 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	
						EU directive	Implement. date Transient	Constant	EU directive	Implement. date
	[g pr kWh]									
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 pr kWh]	HC [g pr kWh]	NO_X [g pr kWh]	$HC+NO_X$ [g pr kWh]	Implementation date
	Stage I						
Hand held	SH1	S<20	805	295	5.36	-	1/2 2005
	SH2	20=<S<50	805	241	5.36	-	1/2 2005
	SH3	50=<S	603	161	5.36	-	1/2 2005
Not hand held	SN3	100=<S<225	519	-	-	16.1	1/2 2005
	SN4	225=<S	519	-	-	13.4	1/2 2005
	Stage II						
Hand held	SH1	S<20	805	-	-	50	1/2 2008
	SH2	20=<S<50	805	-	-	50	1/2 2008
	SH3	50=<S	603	-	-	72	1/2 2009
Not hand held	SN1	S<66	610	-	-	50	1/2 2005
	SN2	66=<S<100	610	-	-	40	1/2 2005
	SN3	100=<S<225	610	-	-	16.1	1/2 2008
	SN4	225=<S	610	-	-	12.1	1/2 2007

For recreational craft, Directive 2003/44 comprises the 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 pr kWh]	HC [g pr kWh]	NO_X [g pr kWh]	HC+NO_X [g pr kWh]	PM [g pr 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 manufactured up to 31.12.1999	Engines first produced after 31.12.1995 & for engines manufactured 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 pr kWh, n < 130 RPM
- 45 x n-0.2 g pr kWh, 130 ≤ n < 2000 RPM
- 9,8 g pr kWh, n ≥ 2000 RPM

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[1]: 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 NOx emission limits for ship engines (amendments to MARPOL Annex VI).

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

[1] 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, 2010) 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 2010-2030.

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 2006).

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 (2011), though slightly modified for fisheries based on the findings from Winther (2008a).

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 ‘2015’ results are the average figures for the years 2013-2017.

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

		2010	2015	"2015"	2020	2025	2030
Energy	Industry - Other (1A2f)	8	7	7	8	8	9
	Civil Aviation (1A3a)	2	2	2	3	3	3
	Road (1A3b)	163	173	173	175	183	196
	Railways (1A3c)	3	3	3	3	3	3
	Navigation (1A3d)	10	10	10	10	10	10
	Residential (1A4b)	4	4	4	4	4	4
	Ag./for./fish. (1A4c)	21	23	23	25	25	25
	Military (1A5)	2	2	2	2	2	2
	Navigation int. (1A3d)	22	22	22	22	22	22
	Civil Aviation int. (1A3a)	33	38	39	44	45	43
CO_2	Industry - Other (1A2f)	566	549	548	576	620	664
	Civil Aviation (1A3a)	154	170	171	195	202	189
	Road (1A3b)	11941	11999	11977	12152	12714	13581
	Railways (1A3c)	230	230	230	230	230	230
	Navigation (1A3d)	757	757	757	757	757	757
	Residential (1A4b)	286	271	271	271	271	271
	Ag./for./fish. (1A4c)	1564	1678	1680	1821	1861	1879
	Military (1A5)	160	160	160	160	160	160
	Navigation int. (1A3d)	1645	1645	1645	1645	1645	1645
	Civil Aviation int. (1A3a)	2402	2765	2782	3158	3271	3063
CH_4	Industry - Other (1A2f)	23	21	21	21	22	23
	Civil Aviation (1A3a)	5	6	6	7	7	7
	Road (1A3b)	703	493	496	391	365	348
	Railways (1A3c)	6	3	3	0	0	0
	Navigation (1A3d)	18	18	18	18	18	19
	Residential (1A4b)	272	256	258	256	256	256
	Ag./for./fish. (1A4c)	32	29	29	28	27	27
	Military (1A5)	5	4	4	3	3	3
	Navigation int. (1A3d)	40	41	41	42	43	43
	Civil Aviation int. (1A3a)	49	56	57	64	67	62
N_2O	Industry - Other (1A2f)	24	23	23	25	27	28
	Civil Aviation (1A3a)	5	6	6	7	7	6
	Road (1A3b)	379	381	382	395	440	486
	Railways (1A3c)	6	6	6	6	6	6
	Navigation (1A3d)	46	46	46	46	46	45
	Residential (1A4b)	5	5	5	5	5	5
	Ag./for./fish. (1A4c)	76	81	81	88	90	90
	Military (1A5)	6	6	6	6	6	6
	Navigation int. (1A3d)	104	104	104	104	104	104
	Civil Aviation int. (1A3a)	106	122	123	139	144	135
GHG-eq.	Industry - Other (1A2f)	574	557	556	584	628	673
	Civil Aviation (1A3a)	155	172	173	197	204	191
	Road (1A3b)	12073	12128	12106	12283	12858	13739
	Railways (1A3c)	232	232	232	232	232	232
	Navigation (1A3d)	771	771	771	771	771	771
	Residential (1A4b)	293	278	278	278	278	278
	Ag./for./fish. (1A4c)	1588	1704	1705	1849	1889	1908
	Military (1A5)	162	162	162	162	162	162
	Navigation int. (1A3d)	1678	1678	1678	1678	1678	1678
	Civil Aviation int. (1A3a)	2436	2804	2821	3203	3317	3106

6.3.1 Road transport

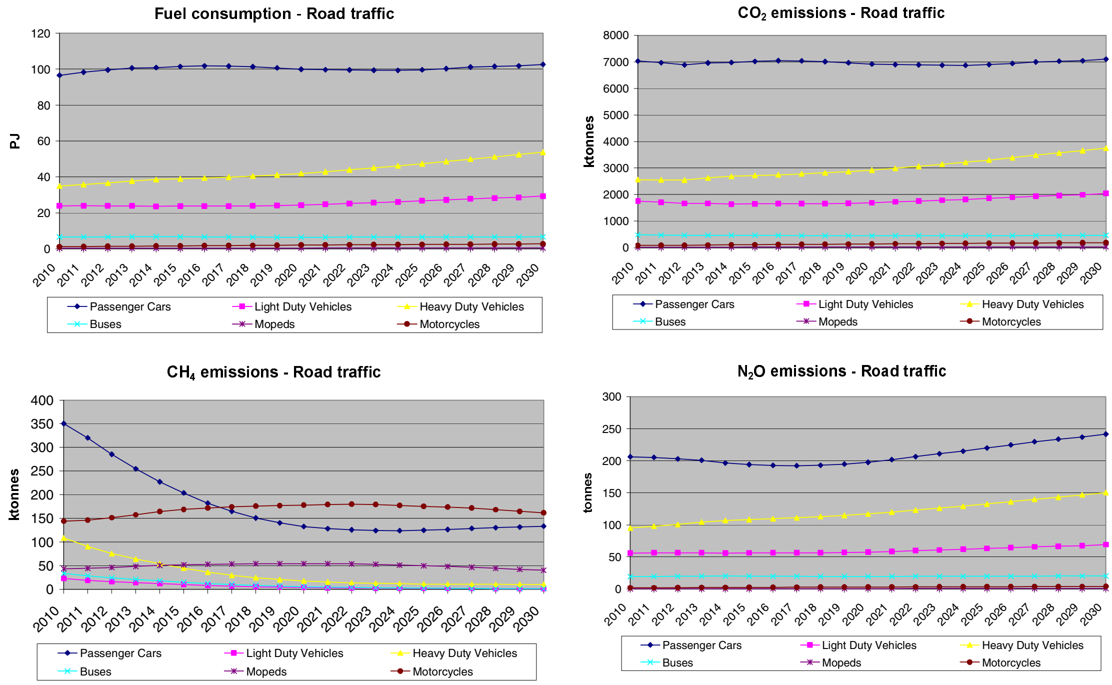

Figure 6.3 Fuel consumption, CO_2, CH_4 and N_2O emissions from 2010-2030 for road traffic.

The total fuel consumption for road traffic increases by 20 % from 2010 to 2030. 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 14 % from 2010-2030.

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 50 % from 2010 to 2030 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

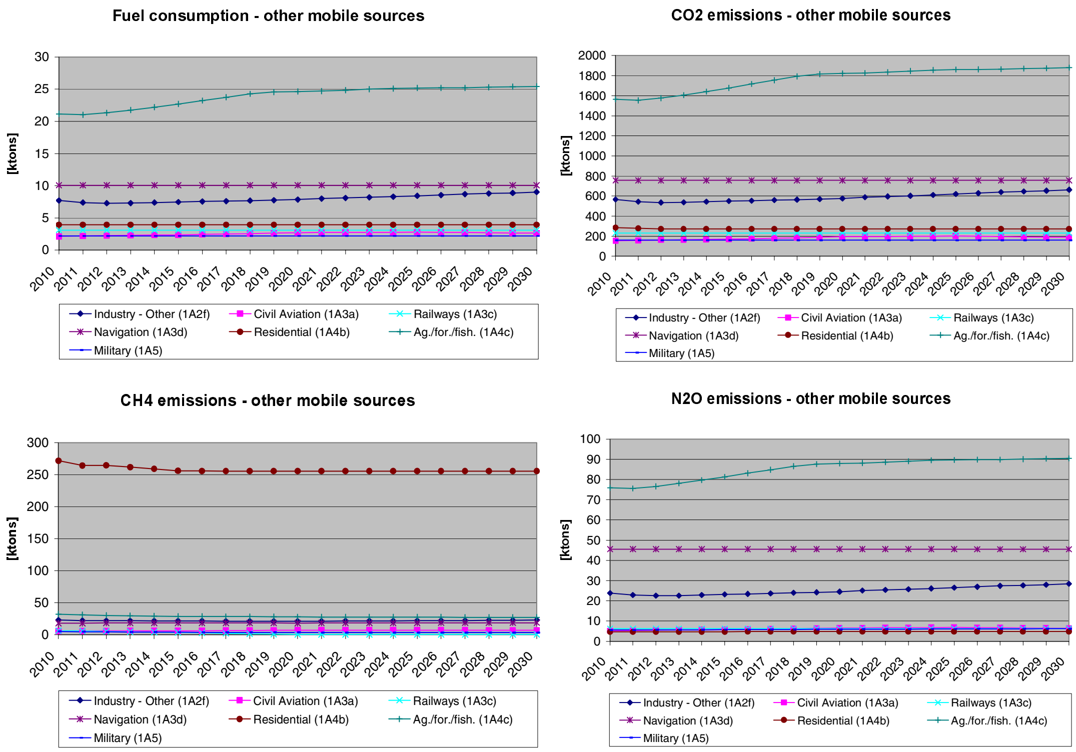

Figure 6.4 Fuel consumption, CO_2, CH_4 and N_2O emissions from 2010-2030 for other mobile sources.

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 Navigation (1A3d), Industry (1A2f), Residential (1A4b), Railways (1A3c), Domestic aviation (1A3a) and Military (1A5) in this consecutive order.

Agriculture/forestry/fisheries (1A4c) is the most important source of N_2O emissions, followed by Navigation (1A3d) and Industry (1A2f). 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 (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 NERI transport models

More detailed emission models for transport comprising road transport, air traffic, non road machinery and sea transport have been developed by NERI. 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 NERI report, along with flow-chart diagrams.

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7 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, 2011). 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 2030.

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 2009 emission inventories the total contribution from F-gases, converted into CO_2 equivalents, constituted 0.9 % 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, 2009 (Nielsen et al., 2011). As a result, the model corresponds with the guidelines produced for this purpose. The model is built in Microsoft Excel, combining an Excel spreadsheet 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 1995-2009, as well as projected values for the period 2010-2020 as calculated for DEPA. 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 2009 report prepared for DEPA (Poulsen & Werge, 2011). Moreover, these data has been based on detailed spreadsheets, 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 2030; see Figure 7.1.

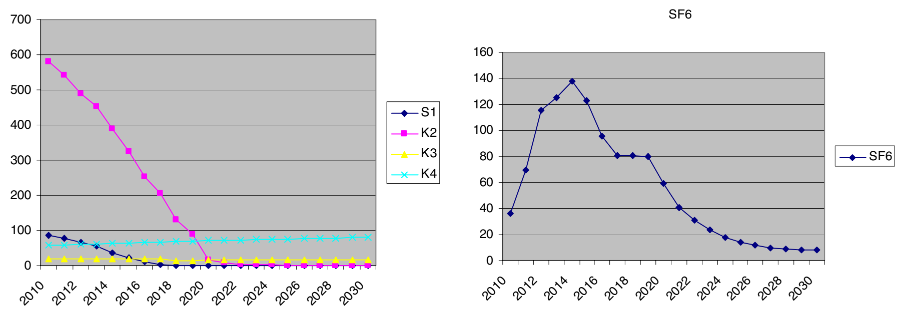

Figure 7.1 Graphical projections for the years 2010 to 2030. A: S1 Foam blowing, K2 Commercial refrigerant, K3 Transport refrigerant, K4 Mobile A/C. B SF_6

Table 7.2 Total F-gas emissions in CO_2 eqv. (1 000 tonnes). Historic data: 1995-2009. Projections: 2010-2030.

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	65.4	582
2000	607	17.9	59.2	684
2001	650	22.1	30.4	703
2002	676	22.2	25.0	723
2003	701	19.3	31.4	751
2004	755	15.9	33.1	804
2005	802	13.9	21.8	838
2006	823	15.7	36.0	875
2007	850	15.4	30.3	896
2008	853	12.8	31.6	897
2009	798	14.2	36.7	848
2010	773	13.3	36.1	823
2011	725	12.5	69.3	807
2012	661	11.9	115	788
2013	615	11.3	125	752
2014	533	10.8	138	681
2015	458	10.3	123	591
2016	375	9.91	95.5	481
2017	319	9.54	80.5	409
2018	239	9.21	81.0	329
2019	197	8.92	80.1	286
2020	125	8.65	59.6	193
2021	119	8.40	41.0	168
2022	114	8.00	31.0	153
2023	113	7.60	24.0	145
2024	113	7.20	18.0	139
2025	114	6.80	14.0	135
2026	114	6.40	12.0	133
2027	115	6.20	10.0	131
2028	116	6.20	9.00	131
2029	117	6.20	8.00	131
2030	118	6.20	8.00	132

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

		1995	2000	2005	2009	'2010' 2008-2012	'2015' 2013-2017	2020	2025	2030
2F	HFC	218	607	802	798	762	460	125	114	118
2F	PFC	0.50	17.9	13.9	14.2	12.9	10.4	8.65	6.80	6.20
2F	SF6	107	59.2	21.8	36.7	57.8	112	59.6	14.0	8.00
2F	F-gas total	326	684	838	848	833	583	193	135	132

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 2009. 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.

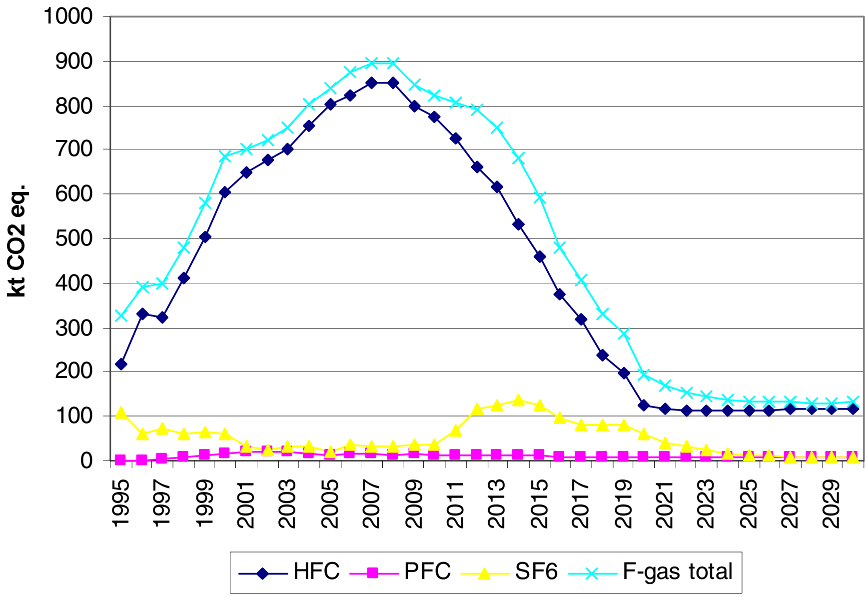

Figure 7.1 Time-series for F-gas emissions, divided into HFCs, PFCs and SF_6.

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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 are mainly related to the livestock production and includes CH_4 emission from enteric fermentation and manure management, N_2O emission from manure management and agricultural soils and emission of CH_4 and N_2O from burning of straw on field. The effect of lower emission from biogas treated slurry is also taken into account.

In this projection is the latest official reporting from Denmark including emission until 2009. Thus, the projection comprises an assessment of the greenhouse gas emissions from the agricultural sector from 2010 to 2030 – the emissions during 2020-2030 are, however for several of the variables, retained at the same level.

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 2010 - 2030

Assessment of future greenhouse gas emissions from the agricultural sector 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. 793 (Nielsen et al., 2010).

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 lead to more legislation in connection with approvals and establishment of new animal houses. This projection includes several objectives formulated in agreement on Green Growth (2009 and 2010) as extension of the biogas production, establishment of non-cultivated area along water streams and reduction in N-loss to the aquatic environment. Among other issues which are included in projection, following can be mentioned; expected change in livestock production, change in N-excretion, improved production efficiency for dairy cattle and sows and expected change in housing system.

The emission of greenhouse gases has been decreased from 12.4 million tonnes CO_2 equivalents in 1990 to 9.6 million tonnes CO_2 equivalents in 2009, which correspond to a 22 % reduction (Table 8.1). Based on the given assumptions the projected emission it is expected to be decreased further by 8 % in 2020, which mean to 8.9 million tonnes CO_2 equivalents.

Result of changes in conditions from 2020 to 2030 expects to reduce the emission slightly with 1 % and in this way has no significant effects given in total agricultural greenhouse gas emission. The decreased emission is mainly a result of decrease in N_2O emission from synthetic fertiliser, N_2O emission from N-leaching and emission from manure management.

The decreased emission from synthetic fertiliser from 3.86 Gg N_2O in 2009 to 3.05 Gg N_2O in 2030 is due to a combination of reduction in agricultural area and lower nitrogen requirement in crops. Furthermore, this development of lower emission from synthetic fertiliser is also the main reason for the decrease in emission from N-leaching.

The decrease in both CH_4- and N_2O emission from manure management is in particular due to the increasing amount of biogas treated slurry. The decrease until 2020 is also a consequence of reduction in the number of dairy cattle until 2013 and change in housing system with the phasing out of the deep litter systems.

The implementations of technologies in housings primarily result in a reduction of ammonia emission, but also lead to a reduction on greenhouse gases. It has to be mentioned that some of this reduction, not only is caused by the technology, but also is a result of change in housing system e.g. from deep litter system to slurry based system.

Table 8.1 Expected development in the emission of greenhouse gases from the agricultural sector from 2009-2030.

	CRF category	1990	2000	2005	2009	2010	2015	2020	2025	2030	Ave. 2008-12	Ave. 2013-17
CH_4, Gg	4A - Enteric Fermentation	154.69	135.80	129.08	136.14	134.68	129.79	130.13	133.01	135.89	133.69	129.85
	4B - Manure Management											
	Manure	46.56	54.23	57.72	59.58	57.89	56.26	55.91	56.20	56.49	58.16	56.26
	Biogas treatment - slurry	-0.09	-0.54	-0.90	-1.11	-1.18	-1.66	-4.23	-5.57	-6.91	-1.13	-1.18
	4F - Field burning of agricultural residue	0.09	0.13	0.14	0.14	0.13	0.13	0.13	0.13	0.13	0.13	0.13
	CH_4, total	201.26	189.61	186.05	194.75	191.52	184.52	181.94	183.78	185.59	190.86	185.07
N_2O, Gg	4B - Manure Management											
	Manure	1.95	1.78	1.79	1.44	1.43	1.27	1.15	1.16	1.16	1.42	1.27
	Biogas treatment - slurry	-0.01	-0.03	-0.05	-0.06	-0.07	-0.09	-0.24	-0.31	-0.39	-0.06	-0.07
	4D.1 - Direct Soil Emissions											
	Synthetic fertiliser	7.72	4.86	3.98	3.86	3.89	3.51	3.39	3.22	3.05	3.88	3.52
	Animal manure applied to soil	3.54	3.41	3.82	3.75	3.73	3.68	3.70	3.80	3.89	3.74	3.68
	N-fixing crops	0.87	0.75	0.67	0.80	0.80	0.77	0.76	0.75	0.73	0.77	0.77
	Crop residues	1.17	1.09	1.07	1.01	1.01	0.97	0.96	0.95	0.93	1.00	0.98
	Cultivation of histosols	0.55	0.54	0.53	0.53	0.53	0.52	0.51	0.51	0.50	0.53	0.52
	Sewage sludge and industrial waste used as fertiliser	0.09	0.17	0.24	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26
	4D.2 - Animal Production											
	Grazing	1.00	1.00	0.76	0.69	0.67	0.65	0.65	0.65	0.65	0.67	0.65
	4D.3 - Indirect Soil Emissions											
	Atmospheric Deposition	1.50	1.15	1.04	0.96	1.13	1.03	0.97	0.95	0.92	1.05	1.03
	Nitrogen Leaching and Runoff	7.92	5.69	4.77	4.57	4.53	4.26	4.18	4.13	4.09	4.59	4.27
	4F - Field burning of agricultural residue	0.002	0.003	0.004	0.004	0.003	0.003	0.003	0.003	0.003	0.003	0.003
	N_2O, total	26.31	20.42	18.63	17.79	17.92	16.83	16.30	16.06	15.82	17.85	16.89
CO_2 eqv., million tonnes												
	4. GHG – Agriculture, total											
	CH_4	4.23	3.98	3.91	4.09	4.02	3.88	3.82	3.86	3.90	4.01	3.89
	N_2O	8.16	6.33	5.77	5.52	5.55	5.22	5.05	4.98	4.90	5.53	5.24
	CO_2 eqv. - total	12.38	10.31	9.68	9.61	9.58	9.09	8.87	8.84	8.80	9.54	9.12

8.2 Assumptions for the livestock production

In this section is given a short overview of the assumptions which are taken into account in the projection. The overview includes assumptions provided for the livestock production, use of synthetic fertilizer, changes in the agricultural area and establishment of emission reducing technologies. These are the most important variables due to the prediction of greenhouse gas emission until 2030.

The main part of the greenhouse gas emission is related to the livestock production and particularly the production and pigs and dairy cattle. All other livestock categories have a minor effect of the total emission and the population are therefore until 2030, kept at a level equivalent to production conditions in 2009.

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

8.2.1 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 2030 the number of dairy cattle is kept constant, while the assumption of increased efficiency will give rise to an increased milk production.

Dairy cattle

In the projection continuing increase production efficiency is expected in form of improved milk yield per cow. From 2009 to 2020 an increase of dairy yield of 150 kg milk per cow per year is assumed, which is based on an assessment provided by the Knowledge Centre for Agriculture (Aaes, 2010). From 2020 to 2030, the rate of increase is not expected to be as high and is assumed to be 80 kg milk per cow per year. The increase in the efficiency gives an average dairy yield of approximately 10 900 kg milk per cow per year in 2020 and 11 700 kg milk per cow per year in 2030.

Table 8.2 Number of dairy cattle and milk yield - figures used in the projection to 2030.

	2009	2015	2020	2025	2030
Dairy cattle, 1000 unit	563	525	525	525	525
Milk yield, kg milk per cow per year	9 100	10 100	10 900	11 300	11 700

N-excretion – dairy cattle

The N-excretion is closely related to the level of milk yield. According to the default values, N-excretion in 2009 for dairy cattle (large breed) was 140.9 kg N per animal per year (Poulsen, 2010). An increase of milk yield to 10 900 kg milk per cow in 2020 assumed to result in an N-excretion of 144 kg N per animal per year (large breed) and 154 kg N per animal per year in 2030 based on an assessment provided by the Knowledge Centre for Agriculture (Aaes, 2010). The N-excretion for the years between 2009-2020 and 2020-2030 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 2009. Table 8.3 shows the N-excretion figures used in the projection.

Table 8.3 N-excretion for dairy cows – figures used in the projection to 2030.

N-excretion dairy cattle	2009	2015	2020	2025	2030
	kg N per animal per year				
Large breed	140.6	142.4	143.6	148.9	154.2
Jersey	119.7	120.6	121.7	126.2	130.6

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 2030. Thus, the changes in number of dairy cattle reflect the number of non-dairy cattle.

The historic normative data for N-excretion for all cattle subcategories 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 2007-2009. In the projection no significant changes in N-excretion is expected and therefore kept at the same level as in 2009.

Housing system

In 2009, according to Statistics Denmark, there were 563 000 dairy cows and 526 000 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 housings for cattle is for dairy cattle a phasing out of both tethering and deep litter housings 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 housings 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.

8.2.2 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. 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.

Sows

During the period 1990-2009 is seen a constant increase in the number of weaners per sow of 0.3 piglets per year in average 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 2020-2030 equalling to 0.1 piglets per sow per year. This results in an average production of nearly 30 piglets per sow in 2030.

Weaners and fattening pigs

The number of sows and the production efficiency in form of 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 export of weaners from 2004. This trend is expected continue and thus the export is assumed to increase from 7 million weaners in 2009 to 12 million in 2020/2030. This result in a rise of produced number of weaners from 28.5 million in 2010 to 31.8 in 2020 and 32.9 in 2030, which correspond to an increase of 18 % from 2009 to

2030. Because of the rising export of weaners, the production level for fattening pigs assumed to be nearly unaltered.

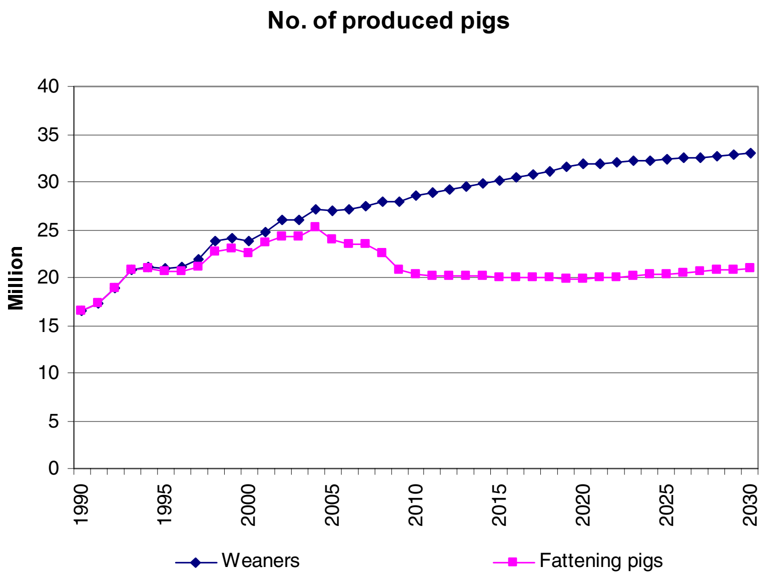

Figure 8.1 Number of produced weaners and fattening pigs.

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

Pigs, million produced	2009	2015	2020	2025	2030
Sows	1.1	1.1	1.1	1.1	1.1
Weaners	27.9	30.2	31.8	32.4	32.9
Fattening pigs	20.9	20.0	19.8	20.4	20.9

Nearly 90 % of Danish pig meat is exported and the production is therefore closely related to the conditions on the export market. Thus, it could be interesting to compare the assumption in this projection with an estimate based on an economic model. Institute of Food and Resource Economics has in 2010 (Dubgaard et al., 2010) provided an estimate for the pig production in 2020 based on a model called "Agricultural Member State Modelling for the EU and Eastern European Countries" (AGMEMOD), which is grounded on world marked prices on the most important agricultural products. The AGMEMOD predict a pig production given in annual average population at 13.5 million in 2020 and this are actually in consistent to the assumption in the projection, when the number of produced pigs in the projection is converted to annual average population. However, the AGMEMOD are based on the 2007 situation and predict no significant changes in production from 2007-2020. But it has to be noted that the development in year 2008 and 2009 shows a considerable decrease in the pig production (Statistics Denmark) as a result of the economic crises. AGMEMOD has not yet been tested with the latest population data and the question is how this will affects the development to 2020. It could indicate a potential scenario with a lower pig production.

Table 8.5 Number of pigs given as annual average production.

	2007	2008	2009	2020
AGMEMOD[1]	13.7	13.4	13.6	13.5
NERI, BF2011	13.7	12.7[2]	12.4[2]	13.5

[1] Dubgaard et al., 2010. Figure 2.2.3.

[2] Statistics Denmark.

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 25.16 kg N per sow per year, which corresponds to 3 % reduction compared to 2009. For fattening pigs, N-excretion is expected to decrease from 2.94 to 2.65 kg N per pig produced per year and this means a reduction of 10 %. For weaners an N-excretion is assumed at the same level as in 2009.

In Table 8.6, the figures for N-excretion used in the projection are given.

Table 8.6 N-excretion for pigs – figures used in the projection to 2030.

N-excretion for swine	2009	2015	2020	2025	2030
	kg N per pig per year				
Sows	25.97	25.53	25.16	25.16	25.16
Weaners	0.51	0.51	0.51	0.51	0.51
Fattening pigs	2.94	2.78	2.65	2.65	2.65

Housing system

In 2009 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 and all fattening pigs are expected to be housed in systems with partially slatted or drained floor in 2020. For sows is also estimated a phasing out of systems with fully slatted floor but over a longer period; all phased out in 2030. But for sows it is assumed that systems with deep layer of bedding will continue at almost the same level as in 2009.

8.2.3 Technology

In Denmark most of the environmental requirements due to the agricultural production have been focused on reducing nitrogen loss to the aquatic environment, protection of nitrogen exposed areas and reduction of the ammonia emission. These, has not a direct impacted on greenhouse gas emissions. It does, however, have an indirect impacted 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 Danish Law on environmental approval of animal holdings (LBK No. 1486 of 04/12/2009). Other decisions, which are related to the greenhouse gases may obviously by the Kyoto Protocol, but also in the EU Decision No 406/2009/EC are relevant. In sectors which is 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 as transport, buildings, agriculture and waste.

Present projection includes the effect of lower emission from biogas treated slurry. From 2009 to 2030 an increase in biogas treated slurry is expected. Implementation of ammonia emission reducing technologies in animal housings is also taken into account. These technologies cover air cleaning and slurry acidification systems.

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.

Emission reducing technologies in animal housings

Until now, requirements to handling of animal manure during storage and application to the field implementation has been brought into focus to reduce the nitrogen loss. In future reducing technology 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 technologies suppliers these technologies seems 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 housingss 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, as mention before this indirectly impacts 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.

Acidification of slurry

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 %. Acidification of slurry will mean that a greater proportion of the nitrogen in the slurry will be retained in ammonium-form, which is by far less volatile than ammonia. This means that ammonia evaporation is also reduced under storage and under application of animal manure. Acidification of slurry is in the projection implemented for dairy cattle, heifers > ½ year, sows and fattening pigs.

Cleaning of air output

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

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

Estimation of technology

In Agreement of Green Growth is established a requirement of 30 % reduction of Nex Animal in 2020, which is specified in Law on environmental approval of animal holdings (LBK No. 1486 of 04/12/2009 + BEK No 294 of 31/03/2009). Some of the reduction is assumed to be reached due to improvements of feed efficiency and change in the distribution of housing types. For dairy cattle is assumed that Nex housing is reduced with around 5 % by feed efficiency and distribution of housing types and for fattening pigs is this reduction assumed to be 3 %. 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.

For cattle production is one technology included in the projection, acidification of slurry. This technology has an average reduction factor of 60 % and therefore is it estimated that around 40 % of the dairy cattle have implemented this technology in 2020. For the pig production two technologies are included acidification of slurry and air cleaning. The average reduction factors for these technologies are 60 % and 70 %, respectively and the total average reduction factor for pigs is therefore 65 %. For fattening pigs is, on the basis of this, estimated that around 40 % have implemented this technology in 2020.

Table 8.7 Predictions regarding establishment of ammonia reducing technology in housings.

	2020 Share of production with reducing technology	2030 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 %

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 2009, 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 (DEA, 2010).

In Agreement of Green Growth composed by the government an aim of 50 % biogas treated animal husbandry is specified and 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, a conservative assumption is supposed in the projection due to the large economic costs which are related to the establishments of biogas plants. Until 2020 25 % of the slurry is assumed to be biogas treated and further extended to 40 % in 2030. As a result of the slurry used in the biogas production the emission of CH_4 and N_2O is calculated to be reduced by 0.16 million CO_2 eqv. in 2020 and 0.27 CO_2 eqv. in 2030 (Table 8.8).

Table 8.8 Expected development in biogas treated slurry.

			Reduced emission		
	Pct. of biogas treated slurry	Million tonnes slurry biogas treated	Gg CH_4	Gg N_2O	Million tonnes CO_2 eqv.
2009	7	2.4	1.11	0.06	0.04
1015	10	3.6	1.66	0.09	0.06
2020	25	9.1	4.23	0.24	0.16
2025	33	12	5.58	0.31	0.21
2030	40	14.9	6.92	0.39	0.27

8.3 Additional assumptions

Besides the described assumptions for the livestock production a series of conditions are predicted for the other emission sources. The most important ones are described in the following sections.

8.3.1 Agricultural area

Developments from 1985 to 2009 show a total reduction in agricultural land area of 210 000 ha, which correspond to 8 800 ha each year. This is a result of urban development and infrastructure, but also due to removal of marginal land due to EUs set-a-side scheme from 1992 and other legislation as Action Plan on the Aquatic Environment, Nitrates Directive and the Habitats directive. In future, this trend in extension of rural areas, infrastructure and protection of vulnerable habitats is expected to be continued. In the projection the agricultural land area is assumed to fall 130 000 ha from 2009-2020 and further 80 000 ha from 2020-2030.

From 2009 to 2020 it is estimated a removal of around 7 300 ha per year to development in the form of rural development and infrastructure. A further decrease in cultivated area is expected as a result of the Agreement on Green Growth represented in 2009 and followed up in form of a second version Green Growth 2.0 in April 2010. This agreement include among other measurements a removal of 50 000 ha near water streams with the purpose to reduce the nitrogen loss to the aquatic environment.

The removal of these 50 000 ha is assessed to be implemented in 2013 and 2014.

Assumptions for 2009-2020:

Reduction in agricultural land area of 130 000 ha:
- Reduction of around 7 300 ha per year = 80 000 ha.
- Agreement on Green Growth = 50 000 ha.

Assumption for 2020-2030:

Reduction in agricultural land area of 80 000.

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

Table 8.9 Agricultural land area in 2009 and in the projection.

	2009	2015	2020	2025	2030
Agricultural land area, 1 000 ha	2 624	2 530	2 494	2 454	2 414

8.3.2 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. In the projection, it is assumed that there is no significant change in the distribution of different crops types compared to the conditions in 2009. The nitrogen requirement in crops is estimated to 130 kg N per ha on average. It is assumed that 50 000 is area, which has no need for fertilisation.

Use of nitrogen in synthetic fertilisers is predicted to decrease by 21 %. The two main reasons to this fall, is a decrease in the agricultural area and implementation of ammonia-reducing technology. These technologies reduce the ammonia emission from the housings and thereby increase the content of N in the animal manure (N ex storage).

Table 8.10 Expected development in consumption of synthetic fertilisers.

	2009	2015	2020	2025	2030
			Gg N		
N in animal manure (N ex storage)	209	203	204	209	213
N which is included in the farmers' fertiliser accounts	144	140	142	145	149
N in synthetic fertilisers	200	182	176	167	159

8.3.3 N-leaching

Nitrogen which is transported trough 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 2005-2009. The weighted N_2O emission factor is estimated to 0.02 %kg N_2O-N pr Kg N and the same factor is used for all years 2010 -2030.

The N-leaching to the ground water is expected to decrease from 155 Gg N in 2009 to approx. 135 Gg N in 2020 and 133 Gg N in 2030 and this due to reduction of nitrogen in synthetic fertiliser. This impacts the N_2O emission, which decrease from 4.57 Gg N_2O in 2009 to 4.18 Gg N_2O in 2020 and further to 4.09 Gg N_2O in 2030, corresponding to a reduction by 10 % until 2030.

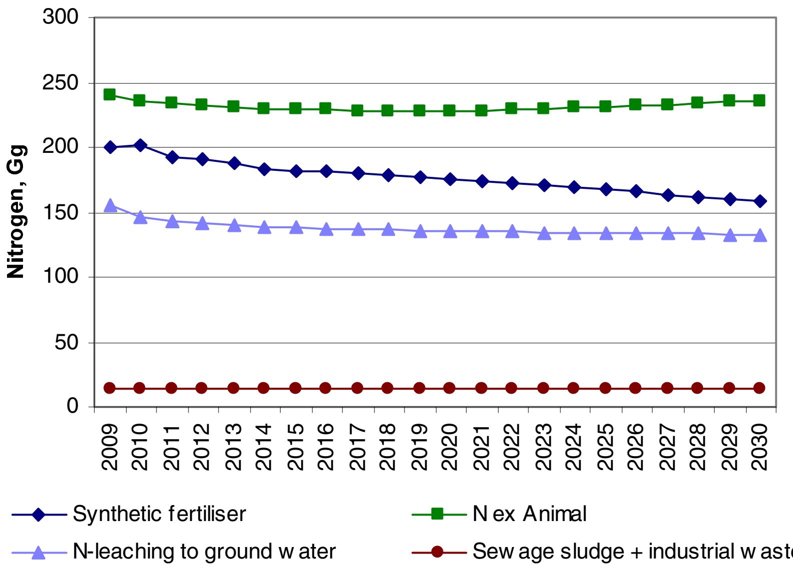

Figure 8.2 Nitrogen from synthetic fertiliser, animal excretions, N-leaching and sewage sludge + industrial waste.

8.3.4 Field burning of agricultural residue

There are two deferent sources of agricultural residue which is burned in Denmark, straw from grass seed production and straw which wet or in broken bales.

The area of fields with repeated grass seed production is assumed not to change significantly until 2030 and the amount of straw which is burned from this production is assumed to be at the same level (15 %) as in the historical years. The area of fields with repeated grass seed production used in the projection is an average of the area for 2005 to 2009.

The amount of straw burned from wet or broken bales of straw is in the historical years estimated to be 0.1 % of the total amount of straw. This amount is also used in the projection. It is assumed that the total amount of straw vary concurrently with the area of agricultural land and therefore will also the amount of straw burned from wet or broken bales vary concurrently with the area of agricultural land.

8.4 Sensitivity test

What is the effect on the total GHG emission in 2030 if we change the assumptions for some selected variables? It has to be pointed out that the effect of the different measures provided in Table 8.11 can not be considered as additive. The calculation of the emission is based on a series of different correlations between the variables. As an example can be mention; the agricultural area influence the use of synthetic fertiliser; establishment of ammonia reducing technology reduce the ammonia emission in housings but at the same time increases the nitrogen in animal manure in storage and applied on soil.

In Table 8.11 is given five examples of change in assumptions:

<u>1. Without technology:</u> This include no implementation of ammonia reducing technology in animal housings and the amount of biogas treated slurry is maintained as 7 % which corresponds to the 2009 situation.

<u>2. 100 % technology in 2020:</u> The effect of implementation of ammonia reducing technology in all housings for dairy cattle and fattening pigs in 2020/2030.

<u>3. Pig production reduced by 10 % in 2020:</u> The pig production is closely related to the conditions on the export market, that's way it is interesting to check the effect of change in the pig production, which are set at 10 % lower compared to 2020 in the basis projection (BP2011).

<u>4. Cattle production reduced 10 % in 2020:</u> The effect of 10 % lower cattle production 2020 compared to the assumptions given in the BP2011.

<u>5. Agricultural area:</u> BP2011 includes a reduction in the agricultural area of 210 000 hectare. What is the effect if the agricultural area only decrease with 100 000 hectare?

Table 8.11 Effect on the total GHG emission by changing in different variable.

CO_2 eqv., million tonnes	2015	2020	2030	Difference from 2030 emission calculated in BP2011
Basis projection (BP2011)	9.09	8.87	8.80	
1. Without technology	9.22	9.18	9.23	+0.43
2. 100 % technology in 2020 (dairy cattle and fattening pigs)	8.98	8.53	8.47	-0.33
3. Pig production 10 % reduction in 2020	9.00	8.71	8.65	-0.25
4. Cattle production 10 % reduction in 2020	8.98	8.53	8.47	-0.33
5. Agricultural area (100 000 hectare 2009-2030)	9.17	8.96	8.93	-0.13

A projection where the technology effect is not included expects to increase the 2030 emission with 0.43 million tonnes CO_2 eqv. compared to the BP2011. This corresponds to an increase of 5 %. If the implementation rate for emission reducing technology is enhanced to 100 % in 2020 for production of dairy cattle and fattening pigs, the 2030 emission except to be reduced with additionally 0.33 million tonnes CO_2 eqv.

A reduced production of pigs and cattle are estimated to result in a further decline in 2030 emission of 0.25 and 0.33 million tonnes CO_2 eqv., respectively.

The change in the agricultural area affects the total 2030 emission with 0.13 million tonnes CO_2 eqv.

The sensitivity test shows that change in the selected variables result in a variation of total GHG emission given in million tonnes CO_2 eqv. between +0.43 to -0.33, which is equal to around ±5 %.

8.5 Summary

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

There is no doubt that the emission of both ammonia and greenhouse gases from the agricultural sector will be reduced over time, but 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, developments within environmental regulation, especially for larger farm units. EU agricultural policy also plays a deciding role and, of course, the conditions for export and import of agricultural products.

This projection of greenhouse gases replaces the latest basic projection published in NERI Technical Report No. 793 (Nielsen et al., 2010). The present projection includes several objectives formulated in the agreement on Green Growth (2009 and 2010) and implementation of ammonia reducing technologies in housing system as a consequence of increasing environmental requirements provided in recent legislation (LBK No. 1486 of 04/12/2009 and BEK No 294 of 31/03/2009).

The agricultural area is expected to decrease 210 000 hectare from 2009 to 2030. Concerning the livestock production a reduction in the number of cattle is assumed until 2013 as a result of fixed EU milk quota. From 2013 to 2030 the number of dairy cattle are maintained in the projection, which increase the total milk production as a consequence of improved milk yield. Despite the economic crises the production of pigs is expected to continue. However, production of fattening pigs and sows are assumed to be fixed nearly at the same level as in 2010, while the production of weaners is assumed to increase for the purpose of export.

Based on these assumptions in the projection, the greenhouse gas emission is expected to decrease from 9.6 million tonnes CO_2 equivalents in 2009 to 8.9 million tonnes CO_2 equivalents in 2020 and further reduced to 8.8 million tonnes CO_2 equivalents in 2030, which corresponds to a decrease of 9 %. The decreased emission is mainly a result of a decrease in N_2O emission from synthetic fertiliser, N_2O emission from N-leaching and emission from manure management.

The emission from use of synthetic fertiliser is expected to decrease from 1.20 million tonnes CO_2 eqv. in 2009 to 0.95 million tonnes CO_2 eqv. in

2030, which corresponds to a 21 % reduction. The reduction is mainly caused by a decrease in the agricultural land – removal of 50 000 hectares defined in the Agreement of Green Growth and 130 000 hectares to infrastructure and urban development. The reduction is also due to a lower nitrogen requirement in crops, which is assumed to amount to 130 kg N per hectare in average. The decrease in use of synthetic fertiliser is also the main reason for the 10 % decrease in emission from N-leaching from 1.42 million tonnes CO_2 eqv. in 2009 to 1.27 million tonnes CO_2 eqv. in 2030.

The reduced emission from manure management 2009-2030 covers a decrease in CH_4 emission of 0.19 million tonnes CO_2 eqv. and N_2O emission of 0.21 million tonnes CO_2 eqv. The lower emission from biogas treated slurry is the most important explanation of this development. The decrease in the number of dairy cattle until 2013 and change in housing system are additional reasons for the emission reduction. A phasing out of housing systems with deep litter is assumed from 2009 to 2020, which will reduce the CH_4 emission as a consequence of no emission from straw bedding. The N_2O emission is expected to decrease as a result of a lower emission factor for slurry (0.001 kg N_2O-N pr kg N excreted) compared with deep litter (0.02 kg N_2O-N pr kg N excreted).

Establishment of ammonia reducing technology in animal housings and expansion of biogas production are also taken into account. The sensitivity test shows that changes in the selected variables result in a variation of total GHG emission given in million tonnes CO_2 eqv. between +0.43 to -0.33, which is equal to around ±5 %.

Apart from the biogas treatment of slurry, no other technical solutions exist in agriculture today specifically aimed towards limiting of greenhouse gas emission. 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 could be interesting in case further emission reduction requirements would be raised.

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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., 2011.

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 2010-2030, as presented in Table 9.1.

Table 9.1 Historical and projected amounts of waste [Gg].

1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
3175	3032	2890	2747	2604	1957	2507	2083	1859	1467	1482
2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
1300	1174	966	1000	957	975	956	1045	753	970	1006
2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
1041	1039	1036	1034	1031	1034	1037	1040	1043	1050	1058
2023	2024	2025	2026	2027	2028	2029	2030			
1065	1073	1080	1086	1092	1098	1104	1110			

The FRIDA model still do not present the waste categories deposited at landfills which are included 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 2009 (Nielsen et al., 2011). The emission projection from 2010-2030 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 2009.

Table 9.2 Waste amounts according to ISAG waste categories [Gg].

Year	Domestic Waste	Bulky Waste	Garden Waste	Commercial & office Waste	Industrial Waste	Building & construction Waste	Sludge	Ash & Slag	Waste Total
2009	12,81	88,31	2,63	121,51	336,53	126,22	25,10	39,65	752,8
Norm 2009	0,02	0,12	0,00	0,16	0,45	0,17	0,03	0,05	1
2010	17	114	3	157	434	163	32	51	970,1
2011	17	118	4	162	450	169	34	53	1005,7
2012	18	122	4	168	466	175	35	55	1041,4
2013	18	122	4	168	464	174	35	55	1038,8
2014	18	122	4	167	463	174	35	55	1036,3
2015	18	121	4	167	462	173	34	54	1033,8
2016	18	121	4	166	461	173	34	54	1031,2
2017	18	121	4	167	462	173	34	54	1034,1
2018	18	122	4	167	464	174	35	55	1037,0
2019	18	122	4	168	465	174	35	55	1039,9
2020	18	122	4	168	466	175	35	55	1042,8
2021	18	123	4	170	470	176	35	55	1050,3
2022	18	124	4	171	473	177	35	56	1057,7
2023	18	125	4	172	476	179	36	56	1065,2
2024	18	126	4	173	480	180	36	57	1072,7
2025	18	127	4	174	483	181	36	57	1080,1
2026	18	127	4	175	486	182	36	57	1086,1
2027	19	128	4	176	488	183	36	58	1092,0
2028	19	129	4	177	491	184	37	58	1098,0
2029	19	130	4	178	494	185	37	58	1104,0
2030	19	130	4	179	496	186	37	58	1109,9

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 2011 NIR report (Nielsen et al., 2011). In short, the model assumes that the carbon in the deposited waste decays and is converted to CH_4 according to first order degradation (FOD) kinetics. For a detailed description of the model and input parameters the reader is referred to Nielsen et al., 2011.

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 macro economic 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., 2011.

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	3175	59,3	0,5	5,9	52,9	1111
1991	3032	60,9	0,7	6,1	54,2	1138
1992	2890	62,4	1,4	6,2	54,9	1153
1993	2747	63,7	1,7	6,4	55,8	1171
1994	2604	64,9	4,6	6,5	54,2	1138
1995	1957	65,8	7,4	6,6	52,6	1104
1996	2507	66,5	8,2	6,7	52,5	1103
1997	2083	67,1	11,1	6,7	50,3	1057
1998	1859	67,3	13,2	6,7	48,7	1023
1999	1467	67,5	11,5	6,8	50,4	1059
2000	1482	67,6	11,0	6,8	50,9	1069
2001	1300	67,6	10,0	6,8	51,8	1088
2002	1174	66,9	11,2	6,7	50,2	1053
2003	966	66,0	7,9	6,6	52,3	1097
2004	1000	64,8	11,0	6,5	48,4	1017
2005	957	63,6	9,7	6,4	48,5	1019
2006	975	62,6	5,5	6,3	51,4	1080
2007	956	61,7	5,4	6,2	50,6	1063
2008	1045	60,8	4,8	6,1	50,3	1057
2009	753	59,7	4,7	6,0	49,5	1039
2010	970	58,3	4,1	5,8	48,8	1024
2011	1006	57,4	4,0	5,7	48,0	1008
2012	1041	56,6	4,0	5,7	47,4	994
2013	1039	55,9	3,9	5,6	46,8	982
2014	1036	55,2	3,9	5,5	46,2	971
2015	1034	54,6	3,8	5,5	45,7	960
2016	1031	54,0	3,8	5,4	45,2	949
2017	1034	53,4	3,7	5,3	44,7	939
2018	1037	52,9	3,7	5,3	44,3	930
2019	1040	52,4	3,7	5,2	43,8	921
2020	1043	51,9	3,6	5,2	43,4	912
2021	1050	51,5	3,6	5,1	43,1	904
2022	1058	51,0	3,6	5,1	42,7	897
2023	1065	50,7	3,5	5,1	42,4	890
2024	1073	50,3	3,5	5,0	42,1	884
2025	1080	50,0	3,5	5,0	41,8	879
2026	1086	49,7	3,5	5,0	41,6	874
2027	1092	49,5	3,5	4,9	41,4	869
2028	1098	49,2	3,4	4,9	41,2	865
2029	1104	49,0	3,4	4,9	41,0	861
2030	1110	48,8	3,4	4,9	40,9	858

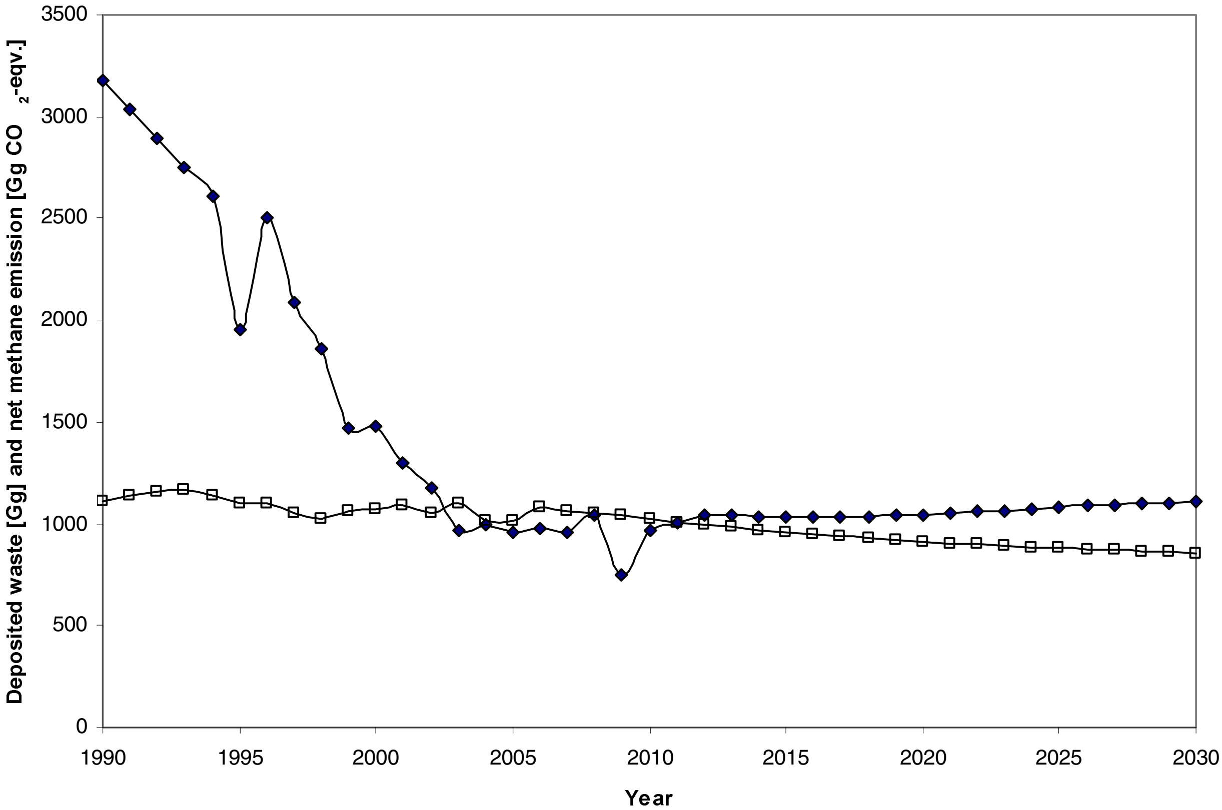

Figure 9.1 Historical and projected amounts of waste deposited (filled squares) at landfill and net CH_4 emissions (open squares). Historic data: 1993-2009. Projections: 2010-2030.

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 yearly fluctuation in the methane emission represents an aggregated of contributions from historical depositions according to a half-life of 14 years and a decreasing trend in the amounts of waste fraction with a high content of degradable organic matter. Overall the decrease in the total amount of deposited waste from 1990 to 2009 has decrease by 76 % accompanied by a decrease in the methane emission of only 6 %. For projection an overall increase in the deposited amounts of waste is 14 % 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, why the decrease a the methane emission of 16 % is estimated.

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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

Methane emission

Methane emissions from the municipal and private WWTPs 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., 2011. 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 pr yr].

1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
97	96	97	99	108	117	125	134	143	140	141
2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
144	156	160	153	150	147	149	145	148	150	150
2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
151	151	151	152	152	153	153	153	154	154	155
2023	2024	2025	2026	2027	2028	2029	2030			
155	155	156	156	157	157	158	158			

Historical data: 1999-2009, Projected data: 2010-2030.

Projection from 2009 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., 2011). From 2010 and forward, TOW increases according to population statistics (Table 10.2) assuming that only household contributes 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 percent of the population not being connected to the sewerage system (Nielsen et al., 2011).

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 are derived. The fugitive emission from anaerobic process, all with energy production, equals 1 % of the gross methane emissions (Nielsen et al., 2011). Methane emission projections are provided in Chapter 10.2, Table 10.5.

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., 2011) 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	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Population-Estimates (1000)	5140	5153	5170	5188	5208	5228	5248	5268	5287	5305	5322
Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Population-Estimates (1000)	5338	5351	5384	5398	5411	5427	5447	5476	5482	5535	5551
Year	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Population-Estimates (1000)	5567	5582	5597	5611	5626	5641	5656	5672	5688	5705	5722
Year	2023	2024	2025	2026	2027	2028	2029	2030			
Population-Estimates (1000)	5739	5756	5774	5791	5807	5824	5839	5854			

Historical data: 1999-2009, Projected data: 2010-2030.

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

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Total N, influent	17614	18477	17391	18012	23866	26808	27096	27891	30394	29686	32342
Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Total N, influent	32999	42224	33645	29989	38746	30481	37079	5137	30623	29209	29294
Year	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Total N, influent	29377	29457	29536	29614	29692	29771	29851	29934	30019	30106	30196
Year	2023	2024	2025	2026	2027	2028	2029	2030			
Total N, influent	30287	30378	30469	30559	30648	30733	30815	30894			

Historical data: 1999-2009, Projected data: 2010-2030.

For the total N in the effluents, the contribution from separate industries, rainwater conditioned effluents, scattered houses and mariculture and fish farming, a decreasing trend followed by a close to constant level are observed and the 2009 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	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Separate industries	-	-	-	2574	2737	2471	1729	1800	1428	863	897
Rainwater conditioned effluents	-	921	882	1025	1207	867	629	800	968	975	762
Scattered houses	-	-	-	1280	1210	1141	1143	1123	997	972	979
Mariculture and fish farming	-	-	-	1737	1684	1735	1543	1494	1241	1418	2714
Effluents from municipal and private WWTPs	16884	15111	13071	10787	10241	8938	6387	4851	5162	5135	4653
Years	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Separate industries	812	752	509	469	441	441	324	367	245	245	245
Rainwater conditioned effluents	758	1005	685	827	622	856	866	752	712	712	712
Scattered houses	1005	968	957	931	919,2475	907,495	907	907	907	907	907
Mariculture and fish farming	1757	1487	1162	1335	1225	1097	926	957	989	989	989
Effluents from municipal and private WWTPs	4221	4528	3614	4027	3831	3634	4358	3575	4025	3976	3988
Years	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Separate industries	245	245	245	245	245	245	245	245	245	245	245
Rainwater conditioned effluents	712	712	712	712	712	712	712	712	712	712	712
Scattered houses	907	907	907	907	907	907	907	907	907	907	907
Mariculture and fish farming	989	989	989	989	989	989	989	989	989	989	989
Effluents from municipal and private WWTPs	3999	4010	4020	4031	4042	4052	4063	4075	4086	4098	4110
Years	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	
Separate industries	245	245	245	245	245	245	245	245	245	245	
Rainwater conditioned effluents	712	712	712	712	712	712	712	712	712	712	
Scattered houses	907	907	907	907	907	907	907	907	907	907	
Mariculture and fish farming	989	989	989	989	989	989	989	989	989	989	
Effluents from municipal and private WWTPs	4098	4110	4123	4135	4147	4160	4172	4183	4195	4205	

Historical data: 1999-2009, Projected data: 2010-2030.

Implied emission factors, calculated as average emissions for the period 2004-2009 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	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Gross anaerobic processes	16,64	16,60	16,66	17,13	18,60	20,08	24,34	28,77	26,85	25,01	34,58
Recovered	16,48	16,44	16,49	16,95	18,41	19,88	24,10	28,48	26,58	24,76	34,24
Sewer system and WWTP	0,17	0,17	0,17	0,18	0,19	0,21	0,23	0,24	0,26	0,25	0,25
Emission from anaerobic treatment	0,17	0,17	0,17	0,17	0,19	0,20	0,24	0,29	0,27	0,25	0,35
Septic tanks	2,81	2,82	2,83	2,84	2,85	2,86	2,87	2,88	2,89	2,90	2,91
Net emission	3,15	3,16	3,17	3,19	3,23	3,27	3,34	3,41	3,42	3,41	3,51
Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Gross anaerobic processes	35,14	26,73	32,31	28,28	30,50	29,84	30,30	29,53	30,21	25,80	25,87
Recovered	34,78	26,47	31,99	28,00	30,19	29,54	30,00	29,24	29,90	25,54	25,61
Sewer system and WWTP	0,26	0,28	0,29	0,28	0,27	0,26	0,27	0,26	0,27	0,27	0,27
Emission from anaerobic treatment	0,35	0,27	0,32	0,28	0,30	0,30	0,30	0,30	0,30	0,26	0,26
Septic tanks	2,92	2,93	2,95	2,96	2,96	2,97	2,98	3,00	3,00	3,03	3,04
Net emission	3,53	3,48	3,56	3,51	3,54	3,53	3,55	3,55	3,57	3,56	3,57
Year	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Gross anaerobic processes	25,94	26,01	26,07	26,14	26,20	26,27	26,34	26,41	26,48	26,55	26,63
Recovered	25,68	25,75	25,81	25,88	25,94	26,01	26,07	26,14	26,21	26,28	26,36
Sewer system and WWTP	0,27	0,27	0,27	0,27	0,27	0,27	0,28	0,28	0,28	0,28	0,28
Emission from anaerobic treatment	0,26	0,26	0,26	0,26	0,26	0,26	0,26	0,26	0,26	0,27	0,27
Septic tanks	3,05	3,06	3,06	3,07	3,08	3,09	3,10	3,11	3,11	3,12	3,13
Net emission	3,58	3,59	3,60	3,61	3,62	3,63	3,64	3,65	3,66	3,67	3,68
Year	2023	2024	2025	2026	2027	2028	2029	2030			
Gross anaerobic processes	25,75	25,81	25,88	25,94	26,01	26,07	26,14	26,21			
Recovered	26,43	26,51	26,59	26,66	26,73	26,80	26,87	26,94			
Sewer system and WWTP	0,28	0,28	0,28	0,28	0,28	0,28	0,28	0,28			
Emission from anaerobic treatment	0,27	0,27	0,27	0,27	0,27	0,27	0,27	0,27			
Septic tanks	3,14	3,15	3,16	3,17	3,18	3,19	3,20	3,21			
Net emission	3,69	3,70	3,71	3,72	3,73	3,74	3,75	3,76			

Historical data: 1999-2009, Projected data: 2010-2030.

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 CH_4, Indirect and direct N_2O emission and the sectoral total emission [CO_2 eqv.].

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
N_2O	109,5	106,7	94,9	112,6	120,1	115,3	97,6	92,2	94,7	91,5	98,8
Net CH_4	66,2	66,4	66,6	67,0	67,9	68,7	70,2	71,7	71,8	71,5	73,8
Total Emission	175,7	173,1	161,5	179,6	188,0	184,0	167,8	163,9	166,6	163,1	172,6
Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
N_2O	92,7	107,9	85,8	83,4	94,2	80,9	93,3	111,4	80,9	57,3	57,4
Net CH_4	74,2	73,0	74,7	73,8	74,3	74,2	74,6	74,6	75,0	74,7	74,9
Total Emission	166,9	180,9	160,5	157,1	168,5	155,1	167,9	186,0	155,8	165,2	165,6
Year	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
N_2O	57,6	57,7	57,9	58,0	58,2	58,4	58,5	58,7	58,8	59,0	59,2
Net CH_4	75,1	75,3	75,5	75,7	75,9	76,1	76,3	76,6	76,8	77,0	77,2
Total Emission	166,1	166,5	166,9	167,3	167,7	168,1	168,5	168,9	169,4	169,8	170,3
Year	2023	2024	2025	2026	2027	2028	2029	2030			
N_2O	59,4	59,5	59,7	59,9	60,1	60,2	60,4	60,6			
Net CH_4	77,4	77,7	77,9	78,1	78,4	78,6	78,8	79,0			
Total Emission	170,8	171,2	171,7	172,2	172,6	173,1	173,5	173,9			

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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 considered to be biogenic.

Table 11.1a Projection of overall emission of greenhouse gases from the incineration of human bodies and animal carcasses.

	Unit	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
CO_2 emission from											
Human cremation	Gg	2.13	2.15	2.17	2.19	2.21	2.23	2.24	2.26	2.28	2.30
Animal cremation	Gg	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02
Total biogenic	Gg	3.15	3.17	3.19	3.20	3.22	3.24	3.26	3.28	3.30	3.32
CH_4 emission from											
Human cremation	Mg	0.50	0.51	0.51	0.51	0.52	0.52	0.53	0.53	0.54	0.54
Animal cremation	Mg	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24
Total	Mg	0.74	0.74	0.75	0.75	0.76	0.76	0.77	0.77	0.78	0.78
N_2O emission from											
Human cremation	Mg	0.63	0.63	0.64	0.64	0.65	0.65	0.66	0.66	0.67	0.68
Animal cremation	Mg	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30
Total	Mg	0.92	0.93	0.94	0.94	0.95	0.95	0.96	0.96	0.97	0.97
6C. Waste incineration											
Non-biogenic CO_2 equivalents	Gg	0.30	0.30	0.31	0.31	0.31	0.31	0.31	0.31	0.32	0.32

Continued

	Unit	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
CO_2 emission from											
Human cremation	Gg	2.32	2.34	2.36	2.38	2.40	2.43	2.45	2.47	2.49	2.51
Animal cremation	Gg	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02
Total biogenic	Gg	3.34	3.36	3.38	3.40	3.42	3.44	3.46	3.48	3.50	3.52
CH_4 emission from											
Human cremation	Mg	0.55	0.55	0.56	0.56	0.56	0.57	0.57	0.58	0.58	0.59
Animal cremation	Mg	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24
Total	Mg	0.78	0.79	0.79	0.80	0.80	0.81	0.81	0.82	0.82	0.83
N_2O emission from											
Human cremation	Mg	0.68	0.69	0.69	0.70	0.71	0.71	0.72	0.72	0.73	0.74
Animal cremation	Mg	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30
Total	Mg	0.98	0.99	0.99	1.00	1.00	1.01	1.02	1.02	1.03	1.04
6C. Waste incineration											
Non-biogenic CO_2 equivalents	Gg	0.32	0.32	0.32	0.33	0.33	0.33	0.33	0.33	0.34	0.34

Continued

	Unit	2030
CO_2 emission from		
Human cremation	Gg	2.53
Animal cremation	Gg	1.02
Total biogenic	Gg	3.54
CH_4 emission from		
Human cremation	Mg	0.59
Animal cremation	Mg	0.24
Total	Mg	0.83
N_2O emission from		
Human cremation	Mg	0.74
Animal cremation	Mg	0.30
Total	Mg	1.04
6C. Waste incineration		
Non-biogenic CO_2 equivalents	Gg	0.34

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 1990-2009.

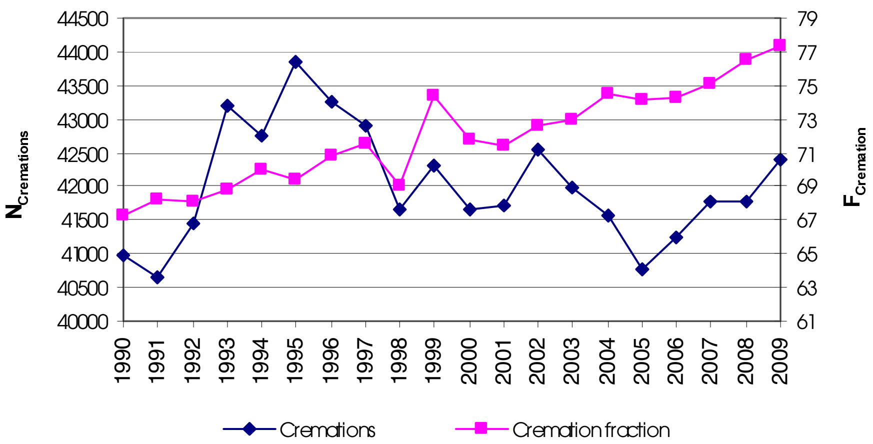

Figure 11.1 The development in the number of yearly cremations.

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 1990-2009 data. By comparing data for population with the yearly number of deceased for the years 1901-2009, 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

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Population	5534738	5550947	5566621	5581819	5596683	5611417	5626237	5641206	5656494	5672179
Deaths	55347	55509	55666	55818	55967	56114	56262	56412	56565	56722
Cremation fraction	76.9%	77.4%	77.8%	78.3%	78.8%	79.2%	79.7%	80.2%	80.6%	81.1%
Cremations	42561	42945	43327	43707	44086	44465	44846	45229	45617	46009

Continued

	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
Population	5688268	5704816	5721762	5738933	5756276	5773533	5790604	5807341	5823561	5839127
Deaths	56883	57048	57218	57389	57563	57735	57906	58073	58236	58391
Cremation fraction	81.6%	82.1%	82.5%	83.0%	83.5%	83.9%	84.4%	84.9%	85.3%	85.8%
Cremations	46406	46809	47216	47626	48040	48454	48869	49282	49693	50099

Continued

	2030
Population	5854021
Deaths	58540
Cremation fraction	86.3%
Cremations	50501

The projection of greenhouse gas emissions from human cremation shown in Table 11.1a-c are calculated by multiplying the estimated activity data from Table 11.2 with the emission factors known from Nielsen et al. (2011).

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 1998-2009.

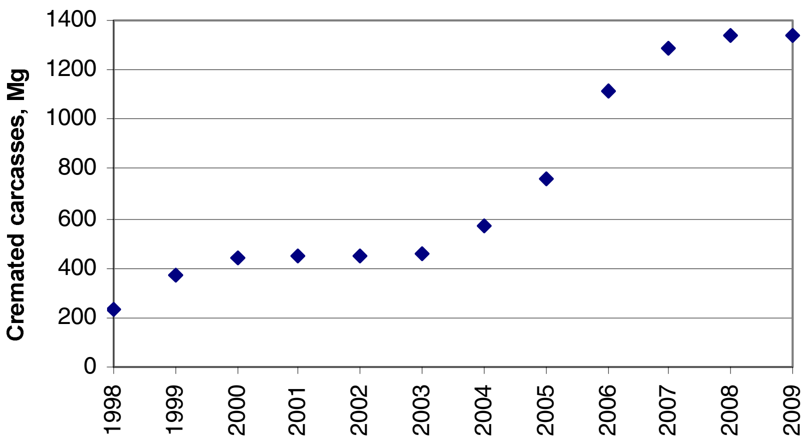

Figure 11.2 Cremated amount of carcasses, 1998-2009.

It is assumed that the 2010-2030 projection of activity data for animal cremation can be described by the constant average of the years 2007-2009.

Table 11.3 Amount of incinerated carcasses.

	2007	2008	2009	Average
Cremated carcasses, Mg	1284.2	1338.3	1338.9	1320.5

The projection of greenhouse gas emissions from animal cremation shown in Table 11.1a-c are calculated by multiplying the estimated activity data from Table 11.3 with the emission factors known from Nielsen et al. (2011).

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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 83 % of the CO_2 emission from accidental building fires to be biogenic.

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

	Unit	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
CO_2 emission from											
Building fires	Gg	17.24	17.24	17.24	17.24	17.24	17.24	17.24	17.24	17.24	17.24
Vehicle fires	Gg	8.97	9.01	9.03	9.04	9.04	9.11	9.19	9.27	9.35	9.45
Total non-biogenic	Gg	26.21	26.25	26.27	26.28	26.27	26.35	26.43	26.50	26.59	26.69
CH_4 emission from											
Building fires	Mg	132.12	132.12	132.12	132.12	132.12	132.12	132.12	132.12	132.12	132.12
Vehicle fires	Mg	18.69	18.77	18.81	18.83	18.82	18.98	19.14	19.30	19.48	19.68
Compost production	Mg	3573.45	3652.26	3731.07	3809.88	3888.69	3967.50	4046.31	4125.11	4203.92	4282.73
Total	Mg	3724.26	3803.15	3882.00	3960.83	4039.63	4118.60	4197.57	4276.54	4355.52	4434.54
N_2O emission from											
Building fires	Mg	NAV	NAV	NAV	NAV	NAV	NAV	NAV	NAV	NAV	NAV
Vehicle fires	Mg	NAV	NAV	NAV	NAV	NAV	NAV	NAV	NAV	NAV	NAV
Compost production	Mg	125.38	128.69	132.01	135.32	138.64	141.96	145.27	148.59	151.90	155.22
Total	Mg	125.38	128.69	132.01	135.32	138.64	141.96	145.27	148.59	151.90	155.22
6C. Waste incineration											
Non-biogenic CO_2 equivalents	Gg	143.28	146.01	148.71	151.40	154.08	156.84	159.61	162.37	165.14	167.93

Continued

	Unit	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
CO_2 emission from											
Building fires	Gg	17.24	17.24	17.24	17.24	17.24	17.24	17.24	17.24	17.24	17.24
Vehicle fires	Gg	9.54	9.66	9.77	9.88	9.99	10.11	10.22	10.33	10.44	10.53
Total biogenic	Gg	26.78	26.89	27.01	27.12	27.22	27.35	27.46	27.57	27.68	27.77
CH_4 emission from											
Building fires	Mg	132.12	132.12	132.12	132.12	132.12	132.12	132.12	132.12	132.12	132.12
Vehicle fires	Mg	19.89	20.12	20.36	20.58	20.80	21.06	21.29	21.53	21.75	21.94
Compost production	Mg	4361.54	4440.35	4519.16	4597.97	4676.78	4755.59	4834.39	4913.20	4992.01	5070.82
Total	Mg	4513.55	4592.59	4671.64	4750.67	4829.70	4908.77	4987.81	5066.85	5145.88	5224.88
N_2O emission from											
Building fires	Mg	NAV	NAV	NAV	NAV	NAV	NAV	NAV	NAV	NAV	NAV
Vehicle fires	Mg	NAV	NAV	NAV	NAV	NAV	NAV	NAV	NAV	NAV	NAV
Compost production	Mg	158.54	161.85	165.17	168.48	171.80	175.12	178.43	181.75	185.06	188.38
Total	Mg	158.54	161.85	165.17	168.48	171.80	175.12	178.43	181.75	185.06	188.38
6C. Waste incineration											
Non-biogenic CO_2 equivalents	Gg	170.71	173.51	176.31	179.11	181.90	184.72	187.51	190.32	193.11	195.89

Continued

	Unit	2030
CO_2 emission from		
Building fires	Gg	17.24
Vehicle fires	Gg	10.66
Total biogenic	Gg	27.90
CH_4 emission from		
Building fires	Mg	132.12
Vehicle fires	Mg	22.21
Compost production	Mg	5149.63
Total	Mg	5303.96
N_2O emission from		
Building fires	Mg	NAV
Vehicle fires	Mg	NAV
Compost production	Mg	191.70
Total	Mg	191.70
6C. Waste incineration		
Non-biogenic CO_2 equivalents	Gg	198.71

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 combustion sources include open burning of yard waste and wild fires.

In Denmark, the open burning of private yard waste is currently 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. There is no registration of private waste burning and the activity data on this subject are very difficult to estimate. People are generally appealed 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.

Due to the cold and wet climate conditions in Denmark wild fires very seldom occurs. Controlled burnings are completely prohibited and the occasional wild fires are of such a small scale that this activity is assumed negligible, both historically and for the future.

12.4 Accidental building fires

Activity data for building fires are classified in three categories: 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 medium and a small scale fire makes up 50 % and 5 % of a FSE respectively, and that a large fire is a full scale fire.

Calculations of greenhouse gas emissions for 1990-2009 are based on surrogate data and on detailed information for 2006-2009 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 2006-2009 data.

Table 12.2 Number of accidental building fires 2006-2009.

		2006	2007	2008	2009	Average
Number of detached house fires	Large	1018	988	1153	1222	1095
	Medium	941	1021	1153	945	1015
	Small	1307	1432	1491	1404	1409
Number of undetached house fires	Large	186	239	206	173	201
	Medium	269	391	306	196	290
	Small	470	717	445	399	508
Number of apartment building fires	Large	141	152	145	169	152
	Medium	650	720	796	638	701
	Small	911	932	1008	1072	981
Number of industrial building fires	Large	240	268	244	282	259
	Medium	237	324	216	246	256
	Small	399	369	443	507	430

Full scale equivalents (FSE) can now be calculated from the assumption that a medium size fire has a damage rate of 50 % compared to a large (full scale) fire and that a small size fire leads to the emission of 5 % of a large fire. Table 12.3 shows the calculated FSEs based on the 2006-2009 average numbers of accidental building fires shown in Table 12.2.

Table 12.3 Projection of FSE fires 2010-2030.

	2010-2030
FSE of detached house fires	1673
FSE of undetached house fires	372
FSE of apartment building fires	551
FSE of industrial building fires	408
All building FSE fires	3004

By assuming that building compositions and sizes will not significantly change over the next two decades, the emission factors known from Nielsen et al. (2011) are accepted for this projection.

Table 12.4 Emission factors for accidental building fires.

	Unit	Detached houses	Undetached houses	Apartment buildings	Industrial buildings
CH_4	Kg pr fire	41.8	34.5	17.4	97.5
CO_2	Mg pr fire	31.2	25.8	14.9	80.0
wherefrom:					
biogenic	Mg pr fire	25.8	21.3	12.3	67.6
non-biogenic	Mg pr fire	5.4	4.5	2.6	12.3
N_2O	-	NAV	NAV	NAV	NAV

Greenhouse gas emissions from accidental building fires in 2010-2030 are shown in Table 12.1a-c.

12.5 Accidental vehicle fires

The Danish Emergency Management Agency (DEMA) provides data for the total number of accidental vehicle fires 2007-2009 divided into the categories; passenger cars, light duty vehicles, heavy duty vehicles, buses and motorcycles/mopeds.

DTU transport (Jensen & Kveiborg, 2009) provides the national population of vehicles in these same categories for historical years as well as a projection of the 2010-2030 vehicle population. This projection is shown in Table 12.5.

Table 12.5 Projection of population of vehicles.

	Passenger cars	Buses	Light duty vehicles	Heavy duty vehicles	Motorcycles/mopeds
2010	2128487	14741	417333	47700	295166
2011	2129561	14729	416090	48348	297039
2012	2125018	14718	411165	48970	298913
2013	2115873	14707	404649	49602	300786
2014	2102246	14697	396345	50236	302660
2015	2103980	14687	402051	51125	304533
2016	2110882	14677	406544	52000	306407
2017	2119165	14669	409997	52872	308280
2018	2128884	14661	414010	53786	310154
2019	2142536	14653	419815	54738	312027
2020	2156872	14647	424593	55699	313901
2021	2174592	14642	431632	56696	315774
2022	2194495	14638	438943	57694	317648
2023	2213392	14634	444980	58679	319521
2024	2231546	14631	450633	59632	320007
2025	2254278	14628	459518	60648	321811
2026	2274790	14626	465664	61584	323615
2027	2295836	14625	472885	62553	325419
2028	2314012	14624	478392	63474	327223
2029	2329027	14623	482695	64391	329027
2030	2352379	14622	493088	65404	332635

By comparing the number of burnt vehicles with the population of vehicles in each category for 2007-2009, the following fractions are calculated.

Table 12.6 Average fraction of vehicles that accidentally burned each year 2007-2009.

Category	Fraction %
Passenger cars	0.09
Light duty vehicles	0.03
Heavy duty vehicles	0.32
Buses	0.43
Motorcycles/Mopeds	0.19

The number of accidental vehicle fires can now be calculated by using data from Tables 12.5 and 12.6, results are shown in Table 12.7.

Table 12.7 Projection of number of accidental vehicle fires

	Passenger cars	Buses	Light duty vehicles	Heavy duty vehicles	Motorcycles/mopeds
2010	1836	64	138	153	546
2011	1837	64	137	155	550
2012	1833	64	136	157	553
2013	1825	64	133	159	557
2014	1813	63	131	161	560
2015	1815	63	133	163	563
2016	1821	63	134	166	567
2017	1828	63	135	169	570
2018	1836	63	136	172	574
2019	1848	63	138	175	577
2020	1861	63	140	178	581
2021	1876	63	142	181	584
2022	1893	63	145	184	588
2023	1909	63	147	188	591
2024	1925	63	149	191	592
2025	1945	63	151	194	595
2026	1962	63	154	197	599
2027	1980	63	156	200	602
2028	1996	63	158	203	605
2029	2009	63	159	206	609
2030	2029	63	163	209	615

It is assumed that no significant changes in the average vehicle weight will occur during the next two decades and that only 70 % of the mass involved in fires actually burns.

Table 12.8 Average vehicle weight in 2010.

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

The total burnt mass of vehicle have been calculated, results are shown in Table 12.9.

Table 12.9 Projection of activity data for accidental vehicle fires.

	Burnt mass of vehicles, Mg
2010	3738
2011	3754
2012	3763
2013	3766
2014	3765
2015	3796
2016	3828
2017	3861
2018	3896
2019	3937
2020	3977
2021	4023
2022	4071
2023	4117
2024	4161
2025	4213
2026	4258
2027	4306
2028	4349
2029	4389
2030	4443

By assuming that vehicle compositions will not significantly change over the next two decades, the emission factors known from Nielsen et al. (2011) are accepted for this projection.

Table 12.10 Emission factors for accidental vehicle fires.

	Unit	Vehicle
CH_4	Kg pr Mg	5
CO_2, fossil	Mg pr Mg	2.4
N_2O	-	NAV

Calculated emissions are shown in Table 12.1a-c.

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 1990-2009 determined based on the Danish waste statistics 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 1999-2008 activity data.

Activity data for both waste-categories; organic waste from households and other sources and sludge, are for the historical years 1990-2009 based on data from the Danish waste statistics. The projection of organic waste is done as an average of the activity data from 1995-2008 and sludge as an expert judgement.

Home composting of garden and vegetable food waste is for 1990-2009 determined based on data from Statistics Denmark and on Petersen & Kielland (2003). The 1990-2009 data is used in a linear regression to project home composting to 2010-2030.

Table 12.11 Projected activity data for compost production.

Gg	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Garden and park waste	816	835	853	872	891	909	928	946	965	983
Organic waste	49	49	49	49	49	49	49	49	49	49
Sludge	100	105	110	115	120	125	130	135	140	145
Home composting	23	23	23	23	23	23	23	24	24	24

Continued

	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
Garden and park waste	1002	1020	1039	1057	1076	1095	1113	1132	1150	1169
Organic waste	49	49	49	49	49	49	49	49	49	49
Sludge	150	155	160	165	170	175	180	185	190	195
Home composting	24	24	24	24	24	25	25	25	25	25

Continued

	2030
Garden and park waste	1187
Organic waste	49
Sludge	200
Home composting	25

By assuming that the process of compost production will not significantly change over the next two decades, the emission factors known from Nielsen et al. (2011) are accepted for this projection.

Table 12.12 Emission factors for compost production.

		Garden and Park waste	Organic waste	Sludge	Home composting
CH_4	Mg pr Gg	4.2	0.268	0.041	5.625
CO_2	Mg pr Gg	0	0	0	0
N_2O	Mg pr Gg	0.12	0.072	0.216	0.105

Calculated emissions are shown in Table 12.1a-c.

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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. For methodology issues for estimation of the sources/sinks from the different sectors please see the LULUCF chapter in Nielsen et al. (2011).

Approximately 2/3 of the total Danish land areas are cultivated and 13.4 per cent are forest, Figure 13.1. Together with high numbers of cattle and pigs there is a high environmental pressure on the landscape. To reduce the impact an active policy has been adopted to protect the environment. The adopted policy aims at doubling the forested area within the next 80-100 years, restoration of former wetlands and establishment of protected national parks. In Denmark almost all natural habitats and all forests are protected. Therefore only limited conversions from forest or wetlands into cropland or grassland has occurred and is expected to occur in the future.

Figure 13.1 shows the land use in 1990, 2009 and the expected land use in 2030. 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.

Changes in the land use affect which category would be a sink or a net source. Under the Kyoto protocol Denmark has beside the obligatory afforestation and deforestation under art. 3.3 selected Forest Management, Cropland Management and Grassland Management under art. 3.4 to meet its reduction commitments. 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 may not be the same as accounted for under the Kyoto-protocol, see Section 13.10.

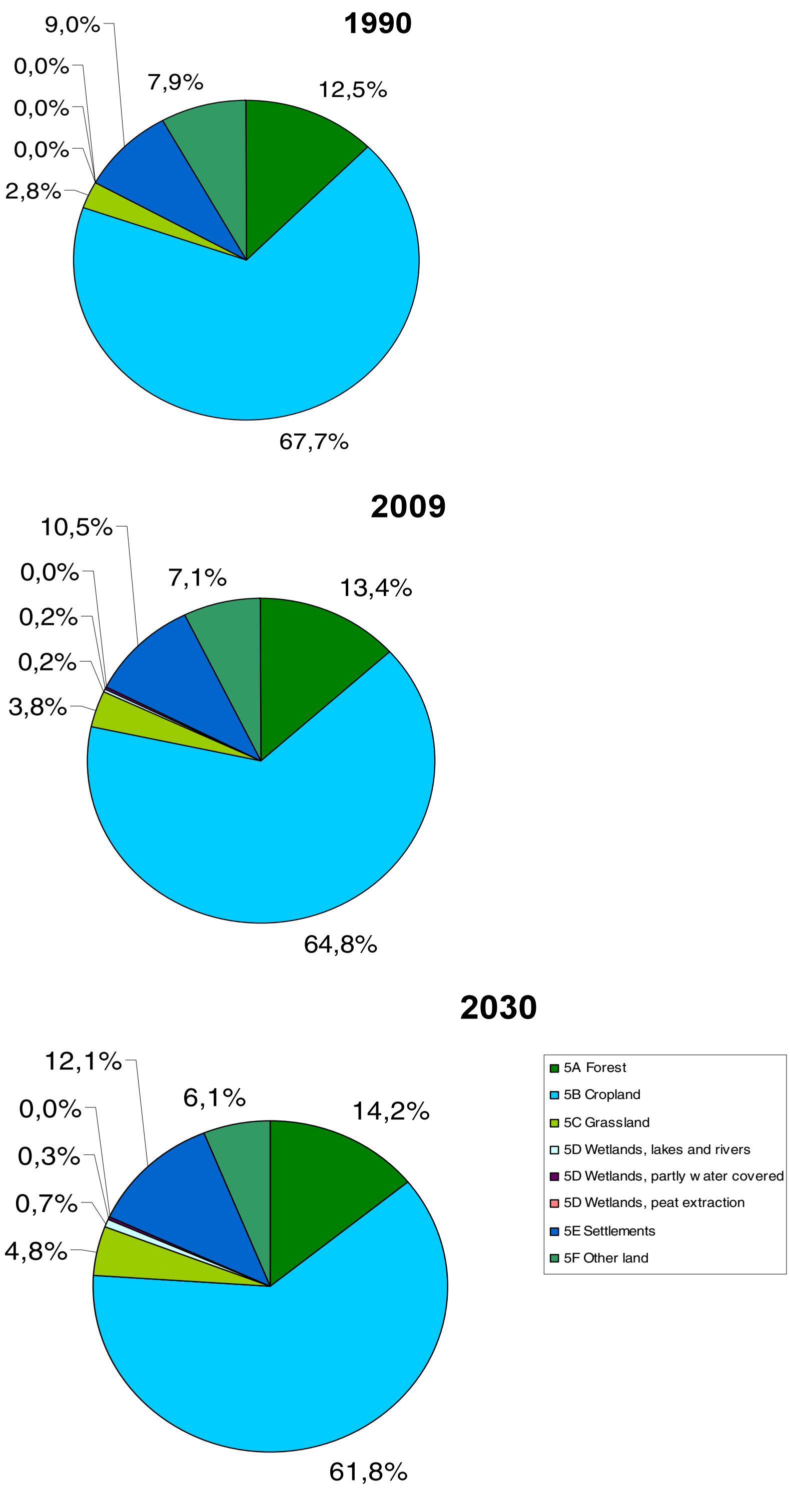

Figure 13.1 Land area use in 1990, 2009 and expected land use in 2030.

13.1 Forest

The emission/sink estimates from the Danish forest is based on the report "Submission of information on forest management reference levels" (Johannsen et al., 2011). This report includes estimated carbon stocks in the Danish forests until 2019. From 2020 to 2030 no data has been reported and hence no projection is included in this period.

Since 1990 the forested area has increased. This is expected to continue in the future as the aim in the Danish policy is to double the afforested area from 1980 to 2080.

Therefore Afforestation will be an issue for coming years with a net carbon sequestration. Table 13.1 shows the Forest & Landscapes expectations until 2019.

Table 13.1 Annual changes in carbon stock in forest until 2019 in Gg C per year.

	1990	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Afforestation/ Reforestation after 1990	10.5	-165.0	-271.3	-689.3	-685.7	-674.7	-608.5	-607.5	-621.1	-612.8	-802.5	-797.9	-778.5
Deforestation after 1990	241.0	32.4	33.5	79.7	75.5	75.4	75.3	75.2	75.0	74.9	74.8	74.6	74.4
Forests before 1990	-709.3	-4816.9	-2579.1	3887.0	2208.8	2205.2	41.6	45.2	41.5	41.5	48.9	52.5	52.5

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

Afforestation is expected to take place on 1 900 hectares per year in the future. The cumulative effect of the afforestation since 1990 is estimated to be a net sink of approximately 600-800 Gg C per year in the period 2010 to 2019. No estimates have been made for the period 2020 to 2030.

The Danish forests are well protected and only a small 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 114 hectares per year until 2019. Deforestation is therefore estimated to be responsible for an emission of around 75 Gg C per year.

The old forest existing before 1990 is assumed to be net source on the longer term of approx. 40-50 Gg C per year after a reduction for deforestation.

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., Hedgerow 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. 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 organic 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 which do not meet the definition of forest.

Agricultural cropland

Primarily due to urbanisation and afforestation the area with Cropland has decreased over the last 20 years. 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 2009 the reduction in 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 both 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 6 000 hectares of agricultural cropland every year in the projection.

The Danish government has planned that 50 000 hectares along rivers and watersheds shall be unmanaged grassland by the end of 2012 (Ministry of the Environment, 2009). This is taken into account, however, this has only marginal effects on the GHG emission, since the area is converted to grassland which has a high amount of roots. In future when the plans are implemented these changes whould result in a land use conversion to Grassland.

13.2.1 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 accordingly and thus reported as a loss. Due to the reduced area with agricultural cropland an average loss of approx. 36 Gg C per year is expected. This will only have limited effect on the Danish reduction commitments under the Kyoto-protocol as land leaving the Cropland category shall be included in the reduction commitment and as Grassland this land will have a certain amount of living biomass although less than Cropland.

The change in Soil Organic Carbon (SOC) in mineral agricultural soils is estimated with C-TOOL version 1.1 (www.agrsci.dk/c-tool). 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. The average crop yield for the latest eight years is used as input for crop yield. No increase in the yield level for agricultural crops is included in the projection. No further removal of straw has been included as there are no actual plans for increasing the burning of straw in central power plants.

Due to the increased global warming there is an assumed net increase in the average annual temperature of 0.03 °C in the projection, which increases the degradation rate of SOM. Currently there is an estimated small net loss from mineral agricultural soils, depending on the actual temperature and harvest conditions. In future the expected annual loss will increase due to the expected global warming. In 2020 a loss of 0.2 Gg C per year is expected increasing to 0.23 Gg in 2030. 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 subsidiary register and a new soil map for organic soils and thus assumed to be very precise. In 1990 it was estimated that 44 000 hectares were organic and in 2009 42 000 hectares. Due to the environmental regulation a decrease in the area with organic soils and annual crops is expected. The above mentioned plan for turning 50 000 hectares along rivers and water sheds into grassland is not operational yet, so it is not possible to estimate a more precise area of organic soils to be converted. If the area is on organic soil this will probably anyway be located along the water sheds and due to unsecure growing conditions be permanent grassland already. The overall effect on the emission estimate of implementation of the 50 000 hectare boarder strips will therefore probably be low. Hence a simple assumption has been made that the decrease in organic soils follows the decrease in Cropland. In total it is assumed that 1 972 ha of organic soils will be converted from Cropland to other land use categories. 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 therefore a decrease in the emission from the organic soils reported in Cropland from 349 Gg C to 333 Gg C or a decrease of 16 Gg C per year in 2030 compared with 2009.

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 around 3 000 hectares today by 1 000 hectares per year until 2030. 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 2030 is estimated for Perennial wooden crops.

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 dynamics in the landscape where old hedges are removed and replaced with new ones to facilitate new farming technologies. Establishing hedges and small biotopes are partly subsidised by the Danish government. It is assumed that the subsidiary system combined with legal protection of the existing hedges will not change in future. Therefore the area is expected to be maintained at the same level, but due to a changes composition of the hedges towards higher carbon densities a small increase in the total carbon stock in hedges is estimated with an average annual increase of 24.4 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 is the expected increase in average temperatures which causes a higher emission from mineral soils.

Table 13.2 Overall emission trend for Cropland from 1990 to 2030.

Cropland	1990	2008	2009	2010	2011	2012	2015	2020	2030
Area, Hectare	2,917,942	2,801,039	2,793,921	2,787,646	2,781,371	2,775,096	2,756,270	2,724,895	2,662,143
Living and dead biomass, Gg C	-49.1	-25.2	-21.0	-11.0	-13.1	-13.1	-13.1	-13.1	-13.1
Soil, Gg C	-653.7	-593.8	-295.5	-414.0	-335.1	-310.0	-444.9	-538.4	-563.3
Total, Gg C	-702.8	-619.1	-316.6	-425.0	-348.2	-323.1	-458.0	-551.5	-576.4
N_2O, Mg N_2O	10.3	1.3	1.3	3.1	3.1	3.1	3.1	3.1	3.1
Total, Gg CO_2 eqv.	-2573.7	-2269.5	-1160.3	-1557.4	-1275.7	-1183.6	-1678.2	-2021.1	-2112.5

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.

In total 163 000 hectares has been reported in the Grassland sector. The area is expected to increase until 2030 primarily due to regulation aiming at turning Danish agriculture into more environmental friendly farming. In total it is expected that the Grassland area will increase to 210 700 hectares in 2030. 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 no major 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 organic soils in Grassland an average emission of 1 250 kg C per ha per year is assumed. Due to the increased area of Grassland this will increase the emission from Grassland from 33 Gg C per year in 2009 to 42 Gg C per year in 2030. As the major change is conversion from Cropland where the organic soils are having a higher emission factor the overall emission from organic soils would 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 fact that the amount of living biomass is lower in Grassland than in the area from which it was converted, e.g. cropland 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.

Table 13.3 Overall emission trend for Grassland from 1990 to 2030.

Grassland	1990	2008	2009	2010	2011	2012	2015	2020	2030
Area, Hectare	119,867	160,856	162,979	165,102	167,225	169,348	175,716	186,330	207,557
Living and dead biomass, Gg C	-91.7	-10.2	-10.2	-22.6	-21.8	-21.8	-21.8	-21.7	-21.7
Soil, Gg C	-37.7	-43.7	-44.1	-44.4	-45.4	-46.4	-49.2	-54.1	-63.7
Total, Gg C	-129.4	-53.9	-54.3	-67.1	-67.2	-68.1	-71.0	-75.7	-85.4
Total, Gg CO_2 eqv.	-474.3	-197.6	-199.2	-245.9	-246.4	-249.8	-260.3	-277.6	-313.2

13.4 Wetlands

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

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 influence of peat excavation. Pinstrup Mosebrug A/S is operating under a 10 years licence. Recently the license has been renewed (Pindstrup Mosebrug, pers. com). It is therefore not expected that any major changes will take place in the near future. For the whole period the same activity as in 2009 is assumed.

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 2009 211 000 m^3 of peat were excavated. The total emission from this is estimated at 12.8 Gg C and 0.000435 Gg N_2O per year.

Re-established wetlands

Only re-established wetlands are included in the Wetland category. Naturally occurring wetlands are reported under Other Land. Some larger wetland restoration projects were carried out in the 1990's. Lately only smaller areas has been converted. Previous GIS analysis of re-established 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 re-established wetlands within the past years. In the projection is it assumed that 200 hectares of Cropland, 68 hectare of Grassland and 1000 hectares of Other Land are converted to wetland per year.

The wetlands are assumed to be a net sink because they are only partial water covered leading to a net build up of organic matter in the soil each year (like a new peat land). It is assumed that there is net build up of 500 kg C per hectare per year. Based on this a net accumulation of carbon in the wetlands in 2009 of 2.9 Gg C is estimated. In 2030 a net accumulation of 5.0 Gg C per year is expected. The increase is due to the fact that there is a net increase in the accumulated area with wetlands.

No CH_4 emission from the wetlands has been estimated as there is no methodological guidance from IPCC on this issue.

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 re-established wetlands. The major source in 1990 is due to the fact that peat extraction was the only source in this category.

Table 13.4 Overall emission trend for Grassland from 1990 to 2030.

Wetlands	1990	2008	2009	2010	2011	2012	2015	2020	2030
Area, Hectare	1,598	17,062	18,340	19,618	20,896	22,174	26,008	32,398	45,179
Living and dead biomass, Gg C	-0.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1
Soil, Gg C	-23.5	-1.3	-4.4	8.2	8.9	9.5	11.4	14.6	16.0
Total, Gg C	-23.6	1.7	-1.4	11.3	11.9	12.6	14.5	17.7	19.1
N_2O, Mg N_2O	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Total CO_2 eqv.	-86.5	6.5	-5.0	41.5	43.8	46.2	53.2	64.9	70.0

13.5 Settlements

The need for areas for housing and other infrastructure has resulted in an increase in the Settlement area from 1990 to 2009 of 62 617 hectare or 3 300 hectare per year. In 2011 the Danish Nature Agency estimated the need for area for settlements in the vicinity of Copenhagen between 2013 to 2025 to 1 250 hectares per year (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 will continue in the future and mainly come from conversion of Cropland.

The overall expected emission trend is shown in Table 13.5. A constant emission from Settlements is expected due to a constant need for land for houses and roads. The reason for the net emission in living biomass is that the amount of living biomass is lower in Settlements than in the area from which it was converted.

Table 13.5 Overall emission trend for Settlements from 1990 to 2030.

Settlements	1990	2008	2009	2010	2011	2012	2015	2020	2030
Area, Hectare	388,847	448,194	451,464	454,735	458,006	461,276	471,088	487,442	520,148
Living and dead biomass, Gg C	-24.4	-14.8	-14.9	-15.0	-14.8	-14.8	-14.8	-14.8	-14.8
Soil, Gg C	0.0	1.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0
Total, Gg C	-24.4	-13.8	-12.9	-15.0	-14.8	-14.8	-14.8	-14.8	-14.8
Total, Gg CO_2 eqv.	-89.5	-50.7	-47.4	-54.9	-54.4	-54.4	-54.3	-54.3	-54.3

13.6 Other Land

Other Land is defined as areas without or only with 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 has now been stabilised around 400 000 - 500 000 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 in the application of reduced nitrogen 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 2030 from liming.

Table 13.6 Emission from liming of agricultural soils.

Liming	1990	2008	2009	2010	2011	2012	2015	2020	2030
Amount, Mg $CaCO_3$	1416684	524938	423551	423551	423551	423551	423551	423551	423551
Emission, Gg CO_2	-623	-231	-186	-186	-186	-186	-186	-186	-186

13.8 Total emission

The total emission from the LULUC (except the Forestry category) is shown in Table 13.7. For these categories an overall emission of around 1 700 Gg CO_2 eqv. per year in 2012 is assumed, increasing to 2 600 Gg CO_2 eqv. per year in 2030.

Utilisation of the organic soils for agricultural purposes is responsible for 1 400 million tonnes CO_2 emission per year. 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 for forestry. The reason for this is that the current carbon stock for annual crops is defined 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 due to the increased global warming which increase the degradation rate of soil organic matter. It may be very difficult to counteract this process. Increasing the input of organic matter into the soil 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.

Overall, no major changes are expected because no major land use changes are foreseen for these categories.

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 13.7 Total emission from the LULUC-categories (excluding Foresty), Gg per year.

Total emission excluding forest	1990	2008	2009	2010	2011	2012	2015	2020	2030
Living and dead biomass, Gg C	-165.3	-47.2	-43.1	-45.5	-46.6	-46.6	-46.6	-46.5	-46.6
Soil, Gg C	-728.8	-653.7	-358.2	-457.6	-379.2	-354.7	-491.4	-587.9	-623.7
Total, Gg C	-894.1	-700.9	-401.3	-503.1	-425.9	-401.3	-538.0	-634.3	-670.3
N_2O, Mg N_2O	10.7	1.8	1.8	3.5	3.5	3.5	3.5	3.5	3.5
Total CO_2 eqv.	-3897.9	-2800.2	-1657.2	-2029.9	-1746.6	-1656.7	-2157.8	-2511.1	-2642.8

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 2019. Including the expected sink in the afforested areas will reduce the overall loss from the Danish territory (Table 13.8) by approx. 1 800 Gg CO_2 eqv. in 2019.

Table 13.8 Total emission from all LULUCF-categories until 2019, Gg per year.

Total including Forestry	1990	2008	2009	2010	2011	2012	2015	2019
Living and dead biomass, Gg C	43,4	1298,0	719,3	-819,0	109,2	109,9	117,0	128,5
Soil, Gg C	-728,8	-653,7	-358,2	-457,6	-379,2	-354,7	-491,4	-570,5
Total, Gg C	-685,4	644,3	361,1	-1276,6	-270,1	-244,8	-374,4	-442,0
N_2O, Mg N_2O	10,7	1,8	1,8	3,5	3,5	3,5	3,5	3,5
Total CO_2 eqv.	-3132,5	2132,0	1138,4	-4865,8	-1175,4	-1082,8	-1557,8	-1805,6

13.9 Uncertainty

The uncertainties in some of the estimates are low whereas in others very high. Generally the conversion of land to other land use categories (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 a large 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. In the projection an average increase of 0.03 °C per year is used. A high uncertainty should therefore be expected for the emission estimate from especially mineral agricultural soils.

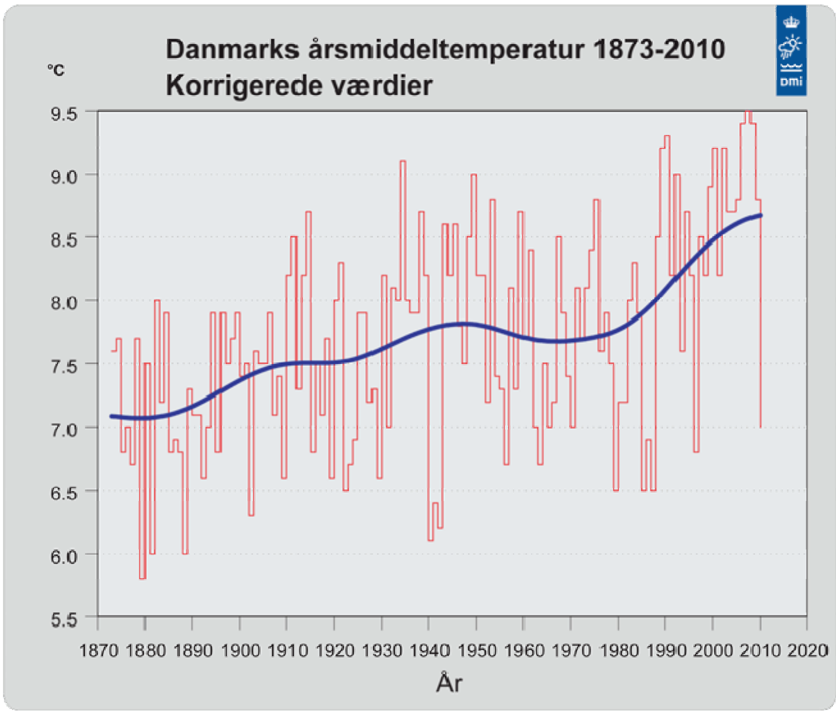

Figure 13.2 Average temperature in Denmark 1873 to 2010. Source: www.dmi.dk.

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 estimate for the overall emission will be in the range of + 500 Gg CO_2 eqv. or 0.5 million tonnes CO_2 eqv.

13.10 The Danish Kyoto commitment

Denmark has beside the obligatory inclusion of Afforestation and Deforestation (art. 3.3) selected Forest Management, Cropland Management and Grassland Management under article 3.4 to meet its reduction commitment. Although that the reduction commitment is based on the national inventory to UNFCCC there are several differences. The major differences are that for Cropland and Grassland Management the reduction is estimated on the net-net principles. Furthermore a land selected for any activity in 1990 can not 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 (CAP) which can be included in the Danish reduction commitment. There is no CAP on Cropland and Grassland Management.

The first commitment period is from 2008 to 2012. Table 13.9 shows the projected estimates for the different categories as conservative estimates both with and without the CAP.

For Afforestation/Reforestation under art. 3.3 an average sink of 497 Gg CO_2 eqv. per year is projected. Deforestation is projected to be a net average source of 59 Gg CO_2 eqv. per year in the first commitment period.

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. In total it is projected that Forest Management will be a net source of 181 Gg CO_2 eqv. per year. This is almost equivalent to the Danish CAP of 183 Gg CO_2 eqv. per year. The CAP is symmetric so if the final emission from Forest Management exceed 183 Gg CO_2 eqv. per year the maximum emission, which shall be included in the accounting is 183 Gg CO_2 eqv. per year.

Cropland Management and Grassland Management is projected to give a net revenue to the Danish reduction commitment of 1 300 Gg CO_2 eqv. per year or in total 6 500 Gg CO_2 eqv. 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 the Danish reduction commitment.

Overall it is expected that art. 3.3. and the election of art. 3.4 activities will add 1 557 Gg CO_2 eqv. per year or in total 7 784 Gg CO_2 eqv. for the first commitment period to the Danish reduction commitment.

Table 13.9 Projected conservative accounting estimates for Art. 3.3 and Art. 3.4 activities 2008 to 2012.

	2008	2009	2010	2011	2012	2008-12	2008-12 per year, Gg CO_2 eqv.	2008-12, M tonne CO_2 eqv.
3.3								
AR	-165.0	-271.3	-689.3	-685.7	-674.7	-2486.0	-497.2	-0.5
D	32.4	33.5	79.7	75.5	75.4	296.5	59.3	0.1
3.3 in total	-132.6	-237.9	-609.7	-610.1	-599.3	-2189.5	-437.9	-0.4
3.4								
FM	-4816.9	-2579.1	3887.0	2208.8	2205.2	905.0	181.0	0.2
CM	-658.5	-1822.5	-910.4	-1194.0	-1286.4	-5871.7	-1174.3	-1.2
GM	-129.1	-130.2	-126.6	-123.0	-119.3	-628.3	-125.7	-0.1
CM+GM	-787.6	-1952.7	-1037.0	-1316.9	-1405.8	-6500.0	-1300.0	-1.3
3.4 in total (before FM CAP)	-5604.5	-4531.8	2850.1	891.9	799.4	-5595.0	-1119.0	-1.1
3.3 og 3.4 (before FM CAP)	-5737.1	-4769.7	2240.4	281.8	200.1	-7784.5	-1556.9	-1.6
FM cap						± 915.0	± 183.0	n.a.
3.4 in total (with FM CAP)	-5604.5	-4531.8	2850.1	891.9	799.4	-5595.0	-1119.0	-1.1
3.3 og 3.4 (with FM CAP)	-5737.1	-4769.7	2240.4	281.8	200.1	-7784.5	-1556.9	-1.6

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14 Conclusions

The historic and projected greenhouse gas (GHG) emissions are shown in Tables 14.2 – 14.9 and illustrated in Figure 14.1. Projected GHG emissions include the estimated effects of policies and measures implemented until April 2011 and the projection of total GHG emissions is therefore a so-called 'with existing measures' projection. CO_2 emissions covered by EU ETS are shown for selected years in Table 14.1. The emission/removals by LULUCF is included in Table 14.10.

The main sectors in the years 2008-2012 ('2010') are expected to be energy industries (38 %), transport (22 %), agriculture (16 %) and other sectors (11 %). For the latter sector the most important sources are fuel use in the residential sector. GHG emissions show a decreasing trend in the projection period from 2010 to 2030. 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 60 351 ktonnes CO_2 equivalents and 51 595 ktonnes in 2030, corresponding to a decrease of about 15 %. From 1990 to '2010' the emissions are estimated to decrease by about 11 %. 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 either by national reductions, use of the flexible mechanisms under the Kyoto Protocol or by including CO_2 uptake in forestry and soil.

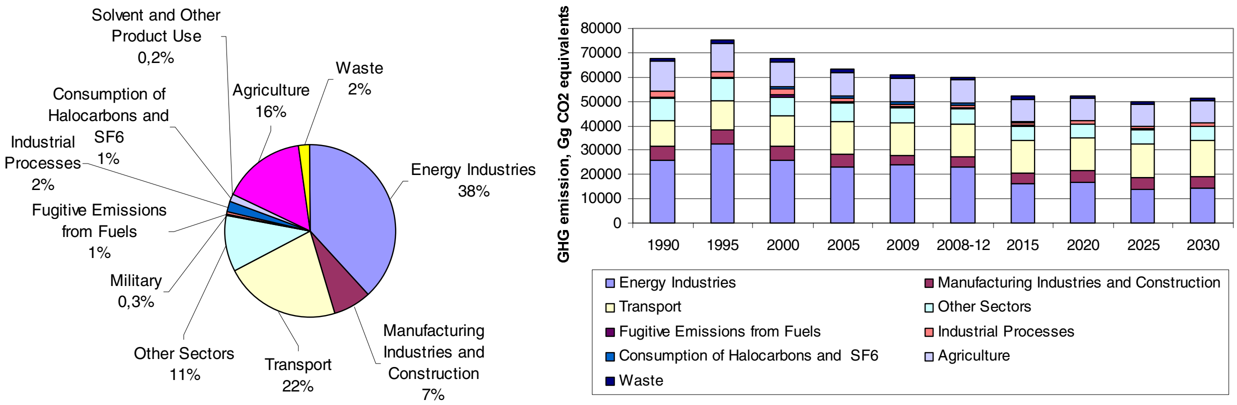

Figure 14.1 Total GHG emissions in CO_2 equivalents. Distribution according to main sectors ('2010') and time-series for 1990 to 2030.

14.1 Stationary combustion

The GHG emissions in '2010' from the main source, which is public power (63 %), are estimated to decrease significantly in the period from 2010 to 2030 due to a partial shift in fuel type from coal to wood and municipal waste. Also, for residential combustion plants a significant decrease in emissions is seen; the emissions decreases by 68 % from 1990 to 2030. The emissions from the other sectors remain almost constant over the period except for energy use in offshore industry (oil and gas extraction), where the emissions are projected to increase by almost 200 % from 1990 to '2010' and by more than 30 % from '2010' to 2030.

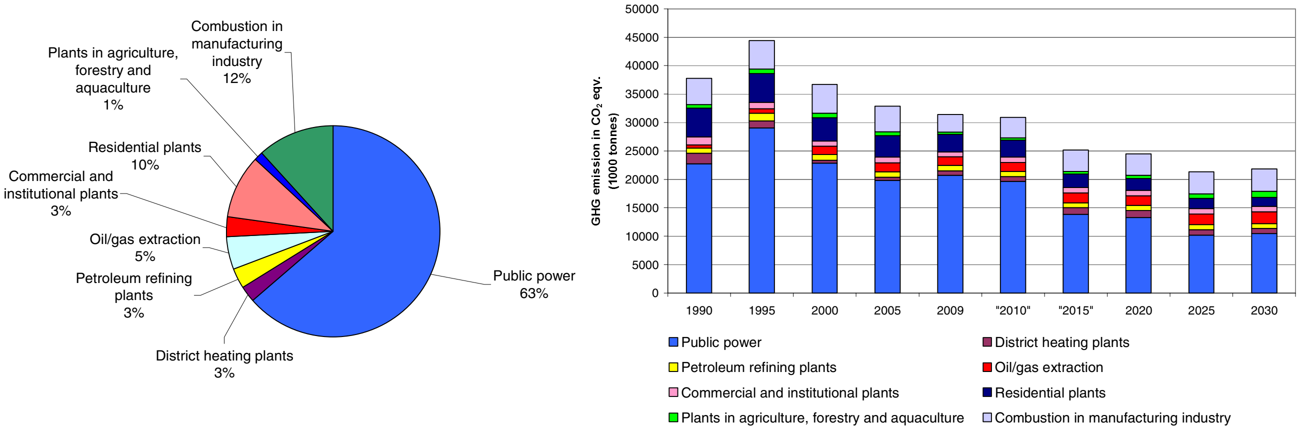

Figure 14.2 GHG emissions in CO_2 equivalents for stationary combustion. Distribution according to sources ('2010') and time-series for 1990 to 2030 for main sources.

14.2 Fugitive emission

The GHG emissions from the sector fugitive emissions from fuels increased in the years 1990-2000 where a maximum was reached. The emissions are estimated to decrease in the projection years 2010-2030, mainly from 2010-2015. The decreasing trend mainly owe to decreasing amounts of gas being flared at offshore installations. Further, the decrease owe 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 less degree from onshore loading of ships. Emissions from extraction of oil and gas are estimated to decrease in the period 2010-2030 due to a decreasing oil and natural gas production. GHG emissions from the remaining sources show no or only minor changes in the projection period 2010-2030.

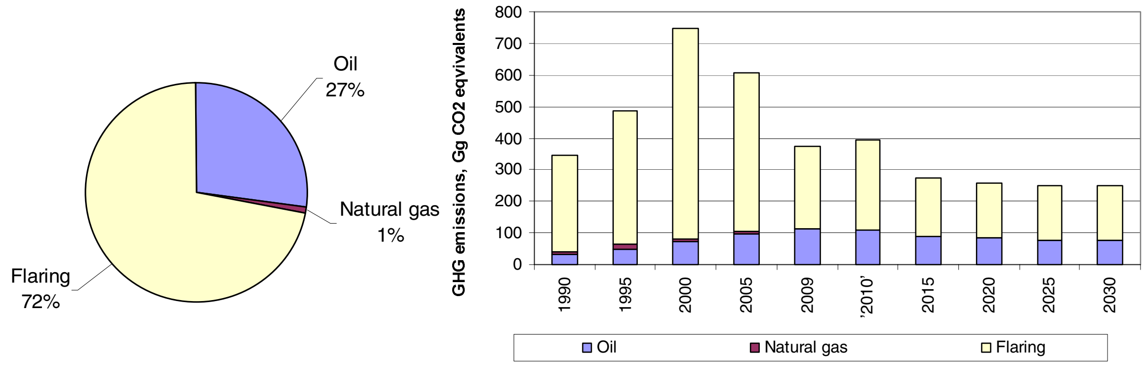

Figure 14.3 GHG emissions in CO_2 equivalents for fugitive emissions. Distribution according to sources ('2010') and time-series for 1990 to 2030 for main sources.

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 82 % 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 MSW 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.

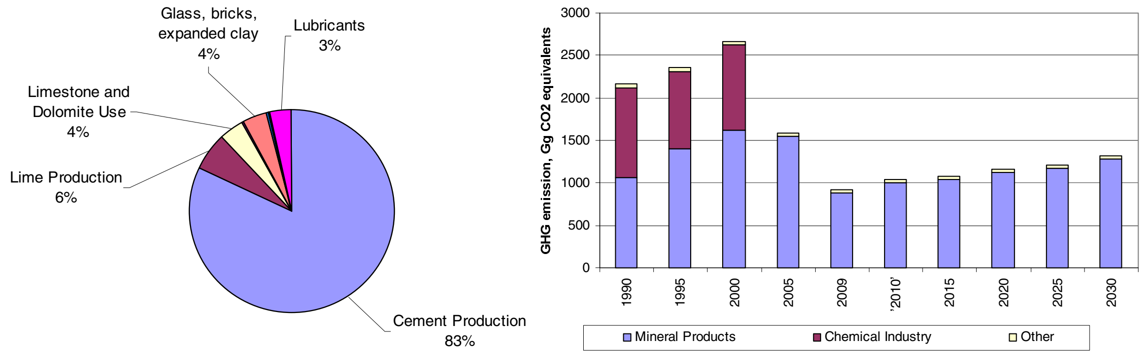

Figure 14.4 Total GHG emissions in CO_2 equivalents for industrial processes. Distribution according to main sectors ('2010') and time-series for 1990 to 2030.

14.4 Solvents

In 2009 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.

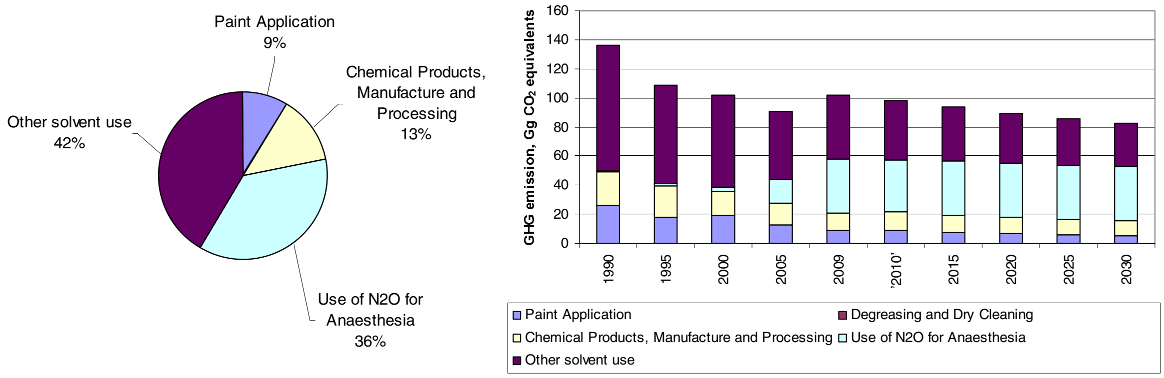

Figure 14.5 Total GHG emissions in CO_2 equivalents for solvent use. Distribution according to main sectors ('2010') and time-series for 1990 to 2030.

14.5 Transport

Road transport is the main source of GHG emissions in '2010' and emissions from this sector are expected to increase by 33 % from 1990 to 2030 due to growth in traffic. The emission shares for the remaining mobile sources are small compared with road transport, and from 1990 to 2030 the total share for these categories reduces from 32 % to 25 %. For industry, the emissions decrease by 35 % from 1990-2030. 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. For agriculture /fishing and navigation the projected emission in 2030 is almost the same as the 1990 emission.

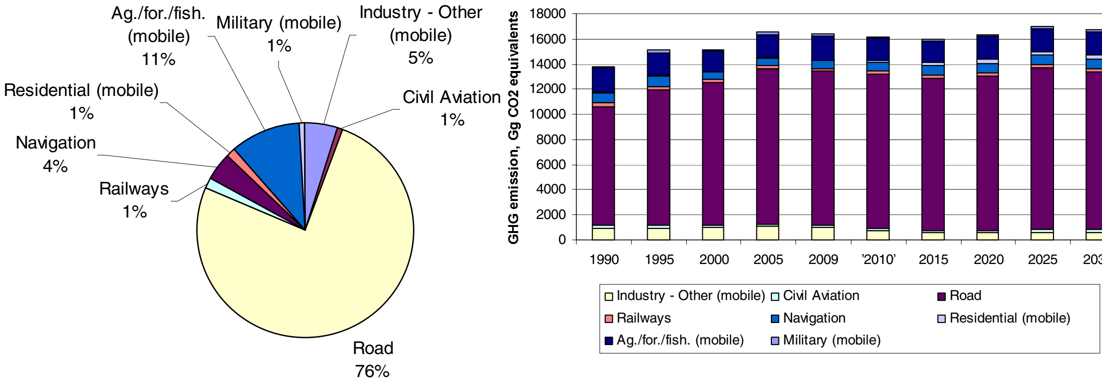

Figure 14.6 GHG emissions in CO_2 equivalents for mobile sources. Distribution according to sources ('2010') and time-series for 1990 to 2030 for main sources.

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.

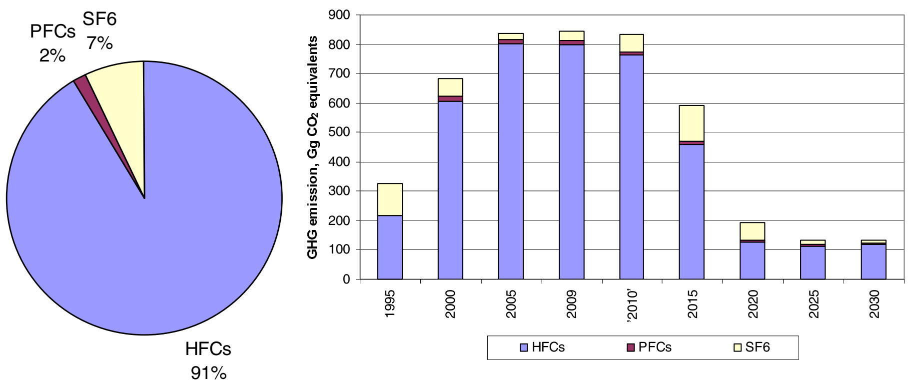

Figure 14.7 GHG emissions in CO_2 equivalents for F-gases. Distribution according to F-gas type ('2010') and time-series for 1990 to 2030 for F-gas type.

14.7 Agriculture

From 1990 to 2009, the emission of GHGs in the agricultural sector has decreased from 12 384 ktonnes CO_2 equivalents to 9 606 ktonnes CO_2 equivalents, which corresponds to a 22 % reduction. This development continues and the emission to 2030 is expected to decrease further to 8 801 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.

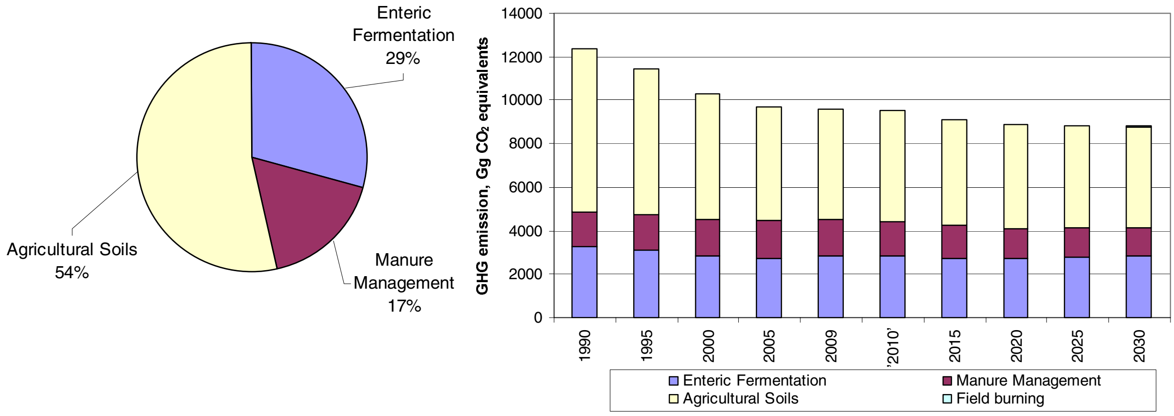

Figure 14.8 GHG emissions in CO_2 equivalents for agriculture sources. Distribution according to sources ('2010') and time-series for 1990 to 2030 of main sources.

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 78 %, 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 11 %. 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 11 % of the total GHG emission from the waste sector. The emission is expected to increase due to increasing use of composting as waste disposal.

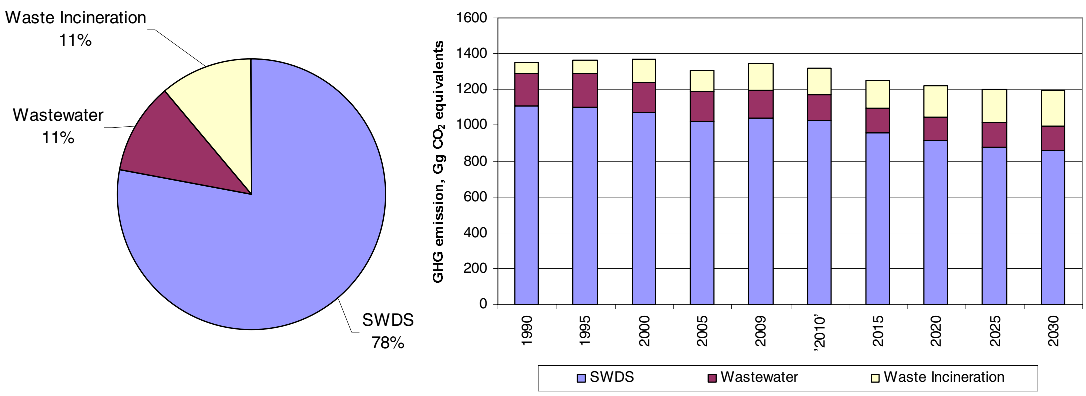

Figure 14.9 GHG emissions in CO_2 equivalents for Waste. Distribution according to main sources ('2010') and the time-series for 1990 to 2030.

14.9 LULUCF

The overall picture of the LULUCF sector is a net source of 3 133 Gg CO_2 eqv. in 1990. In 2009 it was turned into a net sink of 1 118 Gg CO_2 eqv. In the future it is expected that the whole LULUCF sector will be a net source of 1 500 Gg CO_2 eqv. in 2015 and increasing to 1 800 Gg CO_2 eqv. per year in 2019. Until 2030 a further increase is expected. The major reason for this increase is that agricultural soils, which is one of the major sources in Denmark, is estimated with a temperature dependent model which take into account the expected increased global warming. Afforestation is expected to continue to take place in Denmark with an estimated rate of 1 900 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 are a major steady source of approx. 1 300 Gg CO_2 eqv. per year. Agricultural regulations will reduce the area with cultivated agricultural organic soils further in the future, but still there will be a large net emission from these soils.

The result of the projection is shown in Table 14.10.

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.

			2010	2015	2020	2025	2030
1A1a	0101	Public power	19962	11088	11676	8536	8690
1A1a	0102	District heating plants	288	804	801	833	571
1A1b	0103	Petroleum refining plants	882	882	882	882	882
1A1c	0105	Coal mining, oil / gas extraction, pipeline c	1471	1454	1649	1814	2037
1A2	03	Combustion in manufacturing industry	2218	2365	2431	2479	2615
1A2f		Industry - Other (mobile)					
1A3a		Civil Aviation		170	195	202	189
1A3b		Road					
1A3c		Railways					
1A3d		Navigation					
1A4a	0201	Commercial and institutional plants (t)	8	7	7	7	6
1A4b	0202	Residential plants					
1A4b		Residential (mobile)					
1A4c	0203	Plants in agriculture, forestry and aquaculture	93	98	105	110	115
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	344	180	169	169	169
2A		Mineral Products	903	1018	1104	1153	1259
2B		Chemical Industry					
2C		Metal Production					
2D		Food and drink	2	2	2	2	2
2F		Consumption of Halocarbons and SF6					
2G		Consumption of lubricants					
		Total	26172	18068	19022	16186	16536
1A3a		Civil Aviation, international		2765	3158	3271	3063
1A3d		Navigation, international					

Table 14.2 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
Denmark's total emissions excluding net emissions from LULUCF		**69323,336**	**67962**	**75655**	**67847**	**63634**	**63654**	**60985**	**62464**	**56637**	**58031**	**60351**	**52323**	**52548**	**50198**	**51595**
1. Energy		**52121**	**51898**	**60017**	**52674**	**50109**	**50125**	**48167**	**49702**	**44066**	**45545**	**47521**	**40215**	**41009**	**38727**	**40065**
A. Fuel Combustion (Sectoral Approach)		**51817**	**51554**	**59532**	**51927**	**49502**	**49621**	**47793**	**49244**	**43740**	**45241**	**47128**	**39942**	**40752**	**38478**	**39817**
1. Energy Industries		**26315**	**26048**	**32397**	**25832**	**22936**	**24030**	**23997**	**24832**	**20053**	**21787**	**22940**	**16215**	**16941**	**14070**	**14273**
a Public Electricity and Heat Production		24861	24606	30259	23356	20361	21469	21502	22459	17572	19309	20462	13859	14388	11350	11327
b Petroleum Refining		908	908	1387	1001	939	927	934	884	884	884	902	884	884	884	884
c Manufacture of Solid Fuels and Other Energy Industries		546	534	751	1475	1636	1634	1561	1489	1597	1595	1575	1472	1670	1837	2062
2. Manufacturing Industries and Construction		**5493**	**5472**	**5881**	**6022**	**5499**	**4959**	**3960**	**4313**	**4268**	**4260**	**4352**	**4342**	**4406**	**4463**	**4651**
3. Transport		**10529**	**10785**	**12138**	**12366**	**13339**	**14093**	**13259**	**13233**	**13114**	**12975**	**13335**	**13304**	**13483**	**14065**	**14934**
a Civil Aviation		246	246	202	157	138	165	158	155	160	164	160	172	197	204	191
b Road Transport		9418	9428	10764	11380	12371	13085	12260	12073	11951	11808	12235	12128	12283	12858	13739
c Railways		300	300	306	230	234	239	232	232	232	232	234	232	232	232	232
d Navigation		566	811	867	600	597	604	609	771	771	771	706	771	771	771	771
4. Other Sectors		**9359**	**9128**	**8861**	**7596**	**7455**	**6431**	**6414**	**6705**	**6144**	**6057**	**6350**	**5919**	**5759**	**5718**	**5797**
a Commercial and Institutional		1419	1487	1240	1019	1155	1053	1009	1034	1004	991	1018	983	963	962	968
b Residential		5208	5098	5122	4147	3847	3066	3180	3667	3151	3055	3224	2805	2434	2138	1895
c Agriculture/Forestry/Fisheries		2732	2544	2499	2430	2453	2311	2226	2004	1988	2011	2108	2131	2363	2618	2934
5. Other	(1)	**120**	**120**	**254**	**112**	**274**	**109**	**162**	**162**	**162**	**162**	**151**	**162**	**162**	**162**	**162**
B. Fugitive Emissions from Fuels		**304**	**344**	**486**	**747**	**607**	**504**	**375**	**458**	**326**	**303**	**393**	**273**	**257**	**249**	**248**
1. Solid Fuels		**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**
2. Oil and Natural Gas		**304**	**344**	**486**	**747**	**607**	**504**	**375**	**458**	**326**	**303**	**393**	**273**	**257**	**249**	**248**
a Oil		32	33	49	72	97	120	111	107	101	97	107	87	83	76	75
b Natural Gas		6	9	18	8	8	4	3	3	3	3	3	3	2	2	2
c Flaring		267	303	419	667	502	381	261	348	222	204	283	183	172	172	172
2. Industrial Processes		**2470**	**2195**	**2727**	**3388**	**2442**	**2257**	**1766**	**1787**	**1784**	**1790**	**1877**	**1670**	**1358**	**1346**	**1449**
A. Mineral Products		**1072**	**1069**	**1405**	**1616**	**1544**	**1320**	**881**	**923**	**936**	**961**	**1004**	**1038**	**1124**	**1172**	**1278**
1 Cement Production		882	882	1204	1385	1363	1155	764	764	790	808	856	893	973	1030	1131
2 Lime Production		152	116	88	77	63	66	43	67	66	66	62	67	65	61	60
3 Limestone and Dolomite Use		18	14	54	90	56	39	38	51	39	45	42	31	34	27	27
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
6 Road Paving with Asphalt		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	38	39	40	42	45	49	53	58

Continued																
B. Chemical Industry		**1044**	**1044**	**905**	**1004**	**3**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**1**	**1**
2 Nitric Acid Production		1043	1043	904	1004	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
5 Other	(3)	1	1	1	1	3	2	2	2	2	2	2	2	2	1	1
C. Metal Production		**64**	**28**	**74**	**62**	**16**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
1 Iron and Steel Production		28	28	39	41	16	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
D. Other Production		**NE, NA**	**4**	**4**	**4**	**4**	**3**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**
E. Production of Halocarbons and SF_6	NO															
F. Consumption of Halocarbons and SF_6		**290**		**290**	**663**	**838**	**897**	**850**	**823**	**807**	**788**	**833**	**591**	**193**	**135**	**132**
1. Refrigeration and Air Conditioning Equipment		36		36	436	676	739	691								
2 Foam Blowing		183		183	168	119	103	96								
3 Fire Extinguishers		0		0	0	0	0	0								
4 Aerosol/Metered Dose Inhalers		0		0	19	21	19	18								
8 Electrical Equipment		4		4	11	13	16	15								
9 Other		**68**		**68**	**29**	**9**	**21**	**31**								
C_3F_8	(4)	0		0	2	0	4	6								
SF_6	(5)	68		68	27	9	15	22								
G. Other		**NO**	**50**	**49**	**40**	**38**	**34**	**31**	**36**	**36**	**36**	**35**	**36**	**36**	**36**	**36**
3. Solvent and Other Product Use		**137**	**136**	**109**	**102**	**91**	**95**	**102**	**99**	**98**	**97**	**98**	**94**	**89**	**85**	**82**
A Paint Application		24	26	18	19	12	9	9	9	8	8	9	7	7	6	6
B Degreasing and Dry Cleaning		46	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C Chemical Products, Manufacture and Processing		3	23	21	16	15	15	12	13	13	13	13	12	11	10	10
D Other		**64**	**87**	**70**	**66**	**63**	**71**	**81**	**78**	**77**	**76**	**77**	**74**	**71**	**69**	**67**
1 Use of N_2O for Anaesthesia		NE	1	2	3	16	30	37	37	37	37	36	37	37	37	37
5 Other	(6)	64	86	68	63	47	41	44	41	40	39	41	37	34	32	30
4. Agriculture		**13048**	**12384**	**11436**	**10313**	**9682**	**9797**	**9606**	**9576**	**9401**	**9323**	**9538**	**9094**	**8873**	**8837**	**8801**
A Enteric Fermentation		**3259**	**3249**	**3119**	**2852**	**2711**	**2796**	**2859**	**2828**	**2794**	**2761**	**2808**	**2726**	**2733**	**2793**	**2854**
1 Cattle		**2950**	**2950**	**2787**	**2483**	**2298**	**2384**	**2466**								
Dairy Cattle		1844	1844	1762	1564	1518	1529	1582								
Non-Dairy Cattle		1106	1106	1025	920	780	855	885								
2 Buffalo	NO															
3 Sheep		33	33	29	40	46	42	42								
4 Goats		2	2	2	2	3	4	4								
5 Camels and Llamas	NO															

Continued																
6 Horses		60	62	65	69	80	87	81								
7 Mules and Asses	NO															
8 Swine		213	198	232	254	280	276	262								
9 Poultry	NE	0	1	1	1	1	1	1								
10 Other		**NO**	**2**	**2**	**2**	**2**	**2**	**2**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Fur farming & Deer	NE	NO	2	2	2	2	2	2	0	0	0	0	0	0	0	0
B. Manure Management		**1437**	**1580**	**1634**	**1671**	**1732**	**1668**	**1654**	**1612**	**1592**	**1571**	**1620**	**1511**	**1369**	**1325**	**1281**
1 Cattle		**282**	**535**	**549**	**564**	**561**	**585**	**606**								
Dairy Cattle		213	327	329	343	371	376	391								
Non-Dairy Cattle		69	209	221	221	190	209	215								
2 Buffalo	NO															
3 Sheep		1	5	5	7	7	7	7								
4 Goats		0	0	0	0	1	1	1								
5 Camels and Llamas	NO															
6 Horses		4	8	9	9	11	12	11								
7 Mules and Asses	NO															
8 Swine		448	389	468	506	560	551	539								
9 Poultry		6	10	11	11	12	10	10								
10 Other livestock		**9**	**27**	**23**	**30**	**41**	**53**	**55**								
Fur farming		9	27	23	30	41	53	55								
11 Anaerobic Lagoons	NO															
12 Liquid Systems		96	95	83	79	81	80	77								
13 Solid Storage and Dry Lot		589	314	251	199	188	111	93								
14 Other AWMS		NO	195	235	264	270	258	256								
C. Rice Cultivation	NO															
D. Agricultural Soils		**8352**	**7553**	**6680**	**5787**	**5234**	**5329**	**5088**	**5132**	**5012**	**4987**	**5110**	**4853**	**4768**	**4715**	**4662**
1 Direct Soil Emissions		4225	4321	3741	3355	3197	3253	3163								
2 Pasture, Range and Paddock Manure		312	311	323	312	236	213	213								
3 Indirect Emissions		3787	2920	2616	2120	1801	1864	1712								
4 Other		**28**	**IE**	**IE**	**IE**	**IE**	**IE**	**IE**								
Industrial waste used as fertilizer		9	IE	IE	IE	IE	IE	IE								
Use of sewage sludge as fertilizers		19	IE	IE	IE	IE	IE	IE								
E. Prescribed Burning of Savannas	NO															
F. Field Burning of Agricultural Residues		**NO**	3	3	4	4	3	4	4	4	4	4	4	4	4	4
G. Other	NO															

Continued																
6. Waste		**1547**	**1349**	**1366**	**1370**	**1310**	**1381**	**1344**	**1300**	**1287**	**1276**	**1318**	**1251**	**1219**	**1201**	**1197**
A. Solid Waste Disposal on Land		**1334**	**1111**	**1104**	**1069**	**1019**	**1057**	**1039**	**1024**	**1008**	**994**	**1025**	**960**	**912**	**879**	**858**
B. Waste-water Handling		**213**	**176**	**184**	**172**	**168**	**186**	**156**	**132**	**132**	**133**	**148**	**134**	**136**	**138**	**140**
C. Waste Incineration		**IE**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
D. Other		**NO**	**63**	**78**	**128**	**123**	**138**	**149**	**143**	**146**	**149**	**145**	**157**	**171**	**185**	**199**
7. Other	NO															
Memo Items (not included above):																
International Bunkers		**4904**	**4820**	**6963**	**6627**	**5002**	**5542**	**3856**	**4114**	**4227**	**4343**	**4416**	**4482**	**4881**	**4995**	**4784**
Aviation		1755	1755	1888	2376	2602	2677	2340	2436	2549	2665	2533	2804	3203	3317	3106
Marine		3149	3065	5076	4251	2400	2866	1516	1678	1678	1678	1883	1678	1678	1678	1678
Multilateral Operations		**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**
CO_2 Emissions from Biomass		**4641**	**4596**	**5575**	**6725**	**10361**	**11802**	**11886**	**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 14.3 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
Denmark's total emissions excluding net emissions from LULUCF		**52712**	**52653**	**60742**	**53479**	**50801**	**50608**	**48283**	**49715**	**44177**	**45697**	**47696**	**40573**	**41416**	**39208**	**40610**
1. Energy		**51474**	**51343**	**59112**	**51655**	**49098**	**49155**	**47274**	**48662**	**43113**	**44609**	**46563**	**39411**	**40174**	**37921**	**39220**
A. Fuel Combustion (Sectoral Approach)		**51211**	**51043**	**58697**	**50992**	**48600**	**48779**	**47017**	**48318**	**42893**	**44408**	**46283**	**39231**	**40005**	**37752**	**39051**
1. Energy Industries		**26173**	**25952**	**32046**	**25414**	**22566**	**23705**	**23698**	**24334**	**19622**	**21360**	**22544**	**15887**	**16566**	**13731**	**13913**
a Public Electricity and Heat Production		24736	24518	29920	22959	20013	21165	21224	21981	17162	18903	20087	13550	14035	11035	10993
b Petroleum Refining		897	906	1384	998	938	926	933	882	882	882	901	882	882	882	882
c Manufacture of Solid Fuels and Other Energy Industries		540	527	741	1457	1615	1614	1542	1471	1577	1575	1556	1454	1649	1814	2037
2. Manufacturing Industries and Construction		**5423**	**5412**	**5829**	**5953**	**5438**	**4905**	**3915**	**4280**	**4235**	**4227**	**4312**	**4308**	**4371**	**4427**	**4614**
3. Transport		**10336**	**10617**	**11940**	**12173**	**13166**	**13929**	**13109**	**13082**	**12964**	**12826**	**13182**	**13157**	**13334**	**13902**	**14757**
a Civil Aviation		243	243	199	154	135	162	156	154	158	162	158	170	195	202	189
b Road Transport		9241	9282	10588	11203	12214	12938	12126	11941	11819	11677	12100	11999	12152	12714	13581
c Railways		297	297	303	228	232	237	230	230	230	230	231	230	230	230	230
d Navigation		555	796	850	588	585	593	598	757	757	757	692	757	757	757	757
4. Other Sectors		**9159**	**8943**	**8631**	**7341**	**7159**	**6133**	**6135**	**6462**	**5913**	**5835**	**6096**	**5720**	**5574**	**5531**	**5607**
a Commercial and Institutional		1403	1476	1214	989	1123	1024	980	1020	991	978	999	969	950	949	955
b Residential		5084	4983	4985	4003	3660	2858	2988	3489	2985	2899	3044	2678	2339	2048	1809
c Agriculture/Forestry/Fisheries		2673	2485	2432	2349	2376	2251	2167	1953	1938	1959	2053	2072	2286	2535	2844
5. Other	(1)	**119**	**119**	**252**	**111**	**271**	**108**	**160**	**160**	**160**	**160**	**150**	**160**	**160**	**160**	**160**
B. Fugitive Emissions from Fuels		**263**	**300**	**415**	**662**	**499**	**376**	**258**	**344**	**219**	**201**	**280**	**180**	**169**	**169**	**169**
1. Solid Fuels		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2. Oil and Natural Gas		**263**	**300**	**415**	**662**	**499**	**376**	**258**	**344**	**219**	**201**	**280**	**180**	**169**	**169**	**169**
a Oil		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
b Natural Gas		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
c Flaring		263	300	415	662	499	376	258	344	219	201	280	180	169	169	169
2. Industrial Processes		**1101**	**1152**	**1497**	**1701**	**1604**	**1360**	**916**	**964**	**977**	**1002**	**1044**	**1079**	**1164**	**1212**	**1317**
A. Mineral Products		**1072**	**1069**	**1405**	**1616**	**1544**	**1320**	**881**	**923**	**936**	**961**	**1004**	**1038**	**1124**	**1172**	**1278**
1 Cement Production		882	882	1204	1385	1363	1155	764	764	790	808	856	893	973	1030	1131
2 Lime Production		152	116	88	77	63	66	43	67	66	66	62	67	65	61	60
3 Limestone and Dolomite Use		18	14	54	90	56	39	38	51	39	45	42	31	34	27	27
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
6 Road Paving with Asphalt		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	38	39	40	42	45	49	53	58

Continued																
B. Chemical Industry		**1**	**1**	**1**	**1**	**3**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**1**	**1**
2 Nitric Acid Production																
5 Other	(3)	1	1	1	1	3	2	2	2	2	2	2	2	2	1	1
C. Metal Production		**28**	**28**	**39**	**41**	**16**	**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
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**	**2**
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			**50**	**49**	**40**	**38**	**34**	**31**	**36**	**36**	**36**	**35**	**36**	**36**	**36**	**36**
3. Solvent and Other Product Use		**137**	**135**	**107**	**99**	**75**	**65**	**65**	**62**	**61**	**60**	**62**	**56**	**52**	**48**	**45**
A Paint Application		24	26	18	19	12	9	9	9	8	8	9	7	7	6	6
B Degreasing and Dry Cleaning		46	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C Chemical Products, Manufacture and Processing		3	23	21	16	15	15	12	13	13	13	13	12	11	10	10
D Other		**64**	**86**	**68**	**63**	**47**	**41**	**44**	**41**	**40**	**39**	**41**	**37**	**34**	**32**	**30**
1 Use of N_2O for Anaesthesia																
5 Other	(6)	**64**	86	68	63	47	41	44	41	40	39	41	37	34	32	30
4. Agriculture																
A Enteric Fermentation																
1 Cattle																
Dairy Cattle																
Non-Dairy Cattle																
2 Buffalo																
3 Sheep																
4 Goats																
5 Camels and Llamas																

Continued

6 Horses																
7 Mules and Asses																
8 Swine																
9 Poultry	NE															
10 Other																
Fur farming	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																
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															

Continued

6. Waste		**IE**	**22**	**25**	**24**	**24**	**28**	**28**	**26**	**26**	**26**	**27**	**26**	**27**	**27**	**28**
A. Solid Waste Disposal on Land	NE															
B. Waste-water Handling																
C. Waste Incineration		IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
D. Other		NO	22	25	24	24	28	28	26	26	26	27	26	27	27	28
7. Other	NO															
Memo Items (not included above):																
International Bunkers		**4823**	**4741**	**6843**	**6517**	**4926**	**5457**	**3800**	**4047**	**4159**	**4273**	**4347**	**4410**	**4803**	**4916**	**4708**
Aviation		1736	1736	1867	2350	2574	2648	2314	2402	2514	2628	2501	2765	3158	3271	3063
Marine		3087	3005	4976	4168	2352	2809	1487	1645	1645	1645	1846	1645	1645	1645	1645
Multilateral Operations		NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
CO_2 Emissions from Biomass		**4641**	**4596**	**5575**	**6725**	**10361**	**11802**	**11886**								

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 14.4 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
Denmark's total emissions excluding net emissions from LULUCF		**5692**	**5664**	**5925**	**5829**	**5693**	**5800**	**5806**	**5864**	**5739**	**5658**	**5771**	**5446**	**5369**	**5340**	**5382**
1. Energy		**222**	**231**	**529**	**641**	**626**	**579**	**521**	**665**	**598**	**573**	**587**	**449**	**464**	**421**	**436**
A. Fuel Combustion (Sectoral Approach)		**182**	**187**	**459**	**557**	**519**	**451**	**404**	**552**	**492**	**471**	**474**	**357**	**376**	**341**	**357**
1. Energy Industries		**23**	**11**	**239**	**307**	**260**	**214**	**186**	**380**	**332**	**321**	**287**	**232**	**270**	**237**	**253**
a Public Electricity and Heat Production		22	10	238	307	259	212	185	379	331	320	285	231	269	236	251
b Petroleum Refining		1	0	1	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
2. Manufacturing Industries and Construction		**15**	**8**	**10**	**25**	**22**	**16**	**14**	**6**	**6**	**6**	**10**	**6**	**6**	**6**	**7**
3. Transport		**53**	**54**	**50**	**38**	**27**	**19**	**16**	**15**	**14**	**13**	**16**	**11**	**9**	**8**	**8**
a Civil Aviation	(<0,5)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
b Road Transport		52	53	49	37	26	18	15	15	14	13	15	10	8	8	7
c Railways	(<0,5)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
d Navigation		1	1	1	1	1	1	1	0	0	0	1	0	0	0	0
4. Other Sectors		**91**	**115**	**159**	**187**	**209**	**203**	**187**	**150**	**139**	**130**	**162**	**107**	**90**	**89**	**90**
a Commercial and Institutional		4	3	16	21	21	19	19	3	3	3	9	3	3	3	3
b Residential		68	86	107	115	144	157	143	126	115	105	129	77	45	41	38
c Agriculture/Forestry/Fisheries		20	25	35	51	44	27	26	21	21	22	23	27	42	45	49
5. Other	(<0,5)	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
B. Fugitive Emissions from Fuels		**40**	**44**	**70**	**83**	**107**	**127**	**117**	**113**	**106**	**102**	**113**	**92**	**88**	**80**	**79**
1. Solid Fuels		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0	0	0	0
2. Oil and Natural Gas		**40**	**44**	**70**	**83**	**107**	**127**	**117**	**113**	**106**	**102**	**113**	**92**	**88**	**80**	**79**
a Oil		32	33	49	72	97	120	111	107	101	97	107	87	83	76	75
b Natural Gas		6	9	18	8	8	4	3	3	3	3	3	3	2	2	2
c Flaring		2	2	4	3	2	4	2	3	3	3	3	3	3	3	3
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																
7 Other																

Continued

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																
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																
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**	**4226**	**4186**	**3982**	**3907**	**4017**	**4090**	**4022**	**3977**	**3934**	**4005**	**3875**	**3821**	**3859**	**3897**
A Enteric Fermentation		**3259**	**3249**	**3119**	**2852**	**2711**	**2796**	**2859**	**2828**	**2794**	**2761**	**2808**	**2726**	**2733**	**2793**	**2854**
1 Cattle		**2950**	**2950**	**2787**	**2483**	**2298**	**2384**	**2466**								
Dairy Cattle		1844	1844	1762	1564	1518	1529	1582								
Non-Dairy Cattle		1106	1106	1025	920	780	855	885								
2 Buffalo	NO															
3 Sheep		33	33	29	40	46	42	42								
4 Goats		2	2	2	2	3	4	4								
5 Camels and Llamas	NO															

Continued																
6 Horses		60	62	65	69	80	87	81								
7 Mules and Asses	NO															
8 Swine		213	198	232	254	280	276	262								
9 Poultry		NE	1	1	1	1	1	1								
10 Other		**NE**	**2**	**2**	**2**	**2**	**2**	**2**								
Fur farming		NE	2	2	2	2	2	2								
B. Manure Management		**752**	**976**	**1066**	**1127**	**1193**	**1219**	**1228**	**1191**	**1181**	**1171**	**1198**	**1147**	**1085**	**1063**	**1041**
1 Cattle		**282**	**535**	**549**	**564**	**561**	**585**	**606**								
Dairy Cattle		213	327	329	343	371	376	391								
Non-Dairy Cattle		69	209	221	221	190	209	215								
2 Buffalo	NO															
3 Sheep		1	5	5	7	7	7	7								
4 Goats		0	0	0	0	1	1	1								
5 Camels and Llamas	NO															
6 Horses		4	8	9	9	11	12	11								
7 Mules and Asses	NO															
8 Swine		448	389	468	506	560	551	539								
9 Poultry		6	10	11	11	12	10	10								
10 Other livestock		**9**	**27**	**23**	**30**	**41**	**53**	**55**								
Fur farming		9	27	23	30	41	53	55								
11 Anaerobic Lagoons																
12 Liquid Systems																
13 Solid Storage and Dry Lot																
14 Other AWMS																
C. Rice Cultivation	NO															
D. Agricultural Soils		**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**
1 Direct Soil Emissions		NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
2 Pasture, Range and Paddock Manure																
3 Indirect Emissions		NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
4 Other		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Industrial waste used as fertilizer		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Use of sewage sludge as fertilizers		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
E. Prescribed Burning of Savannas	NO															
F. Field Burning of Agricultural Residues		NO	**2**	**2**	**3**	**3**	**2**	**3**	**3**	**3**	**3**	**3**	**3**	**3**	**3**	**3**
G. Other	NO															

Continued																
6. Waste		**1460**	**1206**	**1210**	**1206**	**1160**	**1204**	**1195**	**1177**	**1163**	**1151**	**1178**	**1122**	**1084**	**1060**	**1048**
A. Solid Waste Disposal on Land		1334	1111	1104	1069	1019	1057	1039	1024	1008	994	1025	960	912	879	858
B. Waste-water Handling		126	66	69	74	74	74	75	75	75	75	75	76	77	78	79
C. Waste Incineration	(<0,5)	IE	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D. Other		NO	29	37	63	68	73	81	78	80	82	79	86	95	103	111
7. Other		**NO**														
Memo Items (not included above):																
International Bunkers		**2**	**2**	**3**	**3**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**
Aviation		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Marine		1	1	2	2	1	1	1	1	1	1	1	1	1	1	1
Multilateral Operations		**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**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 14.5 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
Denmark's total emissions excluding net emissions from LULUCF		**10593**	**9646**	**8663**	**7856**	**6302**	**6349**	**6047**	**6063**	**5914**	**5887**	**6052**	**5713**	**5569**	**5515**	**5470**
1. Energy		**425**	**324**	**377**	**379**	**385**	**391**	**372**	**375**	**355**	**362**	**371**	**355**	**372**	**385**	**409**
A. Fuel Combustion (Sectoral Approach)		**424**	**323**	**376**	**377**	**384**	**390**	**372**	**374**	**355**	**362**	**371**	**354**	**371**	**384**	**409**
1. Energy Industries		**119**	**85**	**112**	**110**	**110**	**112**	**113**	**118**	**99**	**106**	**110**	**96**	**105**	**102**	**108**
a Public Electricity and Heat Production		103	78	101	91	89	92	93	99	79	86	90	78	84	79	83
b Petroleum Refining		9	1	3	2	1	1	1	1	1	1	1	1	1	1	1
c Manufacture of Solid Fuels and Other Energy Industries		6	6	9	17	19	19	18	17	19	19	19	17	20	22	24
2. Manufacturing Industries and Construction		**54**	**52**	**42**	**44**	**38**	**38**	**31**	**27**	**27**	**27**	**30**	**28**	**29**	**29**	**31**
3. Transport		**141**	**114**	**148**	**155**	**147**	**145**	**134**	**135**	**136**	**136**	**137**	**136**	**141**	**154**	**169**
a Civil Aviation		3	3	3	2	3	3	3	2	2	2	2	2	2	2	2
b Road Transport		125	93	126	140	132	129	119	117	118	118	120	118	122	136	151
c Railways		3	3	3	2	2	2	2	2	2	2	2	2	2	2	2
d Navigation		10	15	16	11	10	11	11	14	14	14	13	14	14	14	14
4. Other Sectors		**109**	**71**	**71**	**68**	**86**	**94**	**92**	**93**	**91**	**91**	**92**	**93**	**95**	**97**	**100**
a Commercial and Institutional		12	8	10	8	11	10	10	11	11	10	10	10	10	10	10
b Residential		57	28	29	29	42	51	50	52	51	51	51	50	50	49	48
c Agriculture/Forestry/Fisheries		40	34	32	30	33	33	33	30	30	30	31	32	36	38	41
5. Other	(1)	**1**	**1**	**2**	**1**	**3**	**1**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**
B. Fugitive Emissions from Fuels		**1**	**1**	**1**	**2**	**1**	**1**	**1**	**1**	**1**	**0**	**1**	**0**	**0**	**0**	**0**
1. Solid Fuels		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2. Oil and Natural Gas		**1**	**1**	**1**	**2**	**1**	**1**	**1**	**1**	**1**	**0**	**1**	**0**	**0**	**0**	**0**
a Oil		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
b Natural Gas		NA,NO	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
c Flaring		1	1	1	2	1	1	1	1	1	0	1	0	0	0	0
2. Industrial Processes		**1043**	**1043**	**904**	**1004**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**
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																
7 Other																

Continued

B. Chemical Industry		**1043**	**1043**	**904**	**1004**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**
2 Nitric Acid Production		1043	1043	904	1004	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
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																
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**	**16**	**30**	**37**	**37**	**37**	**37**	**36**	**37**	**37**	**37**	**37**
A Paint Application																
B Degreasing and Dry Cleaning																
C Chemical Products, Manufacture and Processing																
D Other		NA	**1**	**2**	**3**	**16**	**30**	**37**	**37**	**37**	**37**	**36**	**37**	**37**	**37**	**37**
1 Use of N_2O for Anaesthesia	(6)	NA	1	2	3	16	30	37	37	37	37	36	37	37	37	37
5 Other																
4. Agriculture		**9037**	**8157**	**7249**	**6331**	**5775**	**5780**	**5516**	**5554**	**5424**	**5389**	**5532**	**5219**	**5052**	**4978**	**4903**
A Enteric Fermentation																
1 Cattle																
Dairy Cattle																
Non-Dairy Cattle																
2 Buffalo	NO															
3 Sheep																
4 Goats																
5 Camels and Llamas	NO															

Continued

6 Horses																
7 Mules and Asses	NO															
8 Swine																
9 Poultry																
10 Other																
Fur farming																
B. Manure Management		**685**	**604**	**569**	**543**	**539**	**449**	**426**	**421**	**411**	**401**	**422**	**365**	**284**	**262**	**240**
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	95	83	79	81	80	77								
13 Solid Storage and Dry Lot		589	314	251	199	188	111	93								
14 Other AWMS		NO	195	235	264	270	258	256								
C. Rice Cultivation	NO															
D. Agricultural Soils		**8352**	**7553**	**6680**	**5787**	**5234**	**5329**	**5088**	**5132**	**5012**	**4987**	**5110**	**4853**	**4768**	**4715**	**4662**
1 Direct Soil Emissions		4225	4321	3741	3355	3197	3253	3163								
2 Pasture, Range and Paddock Manure		312	311	323	312	236	213	213								
3 Indirect Emissions		3787	2920	2616	2120	1801	1864	1712								
4 Other		**28**	**IE**	**IE**	**IE**	**IE**	**IE**	**IE**								
Industrial waste used as fertilizer		9	IE	IE	IE	IE	IE	IE								
Use of sewage sludge as fertilizers		19	IE	IE	IE	IE	IE	IE								
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**
G. Other	NO															

Continued																
6. Waste		**88**	**121**	**131**	**140**	**126**	**148**	**122**	**96**	**98**	**99**	**112**	**102**	**108**	**114**	**120**
A. Solid Waste Disposal on Land																
B. Waste-water Handling		88	109	115	99	94	111	81	57	57	58	73	58	59	60	61
C. Waste Incineration	(<0,5)	IE	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D. Other		NO	11	15	41	31	36	40	39	40	41	39	44	49	54	59
7. Other	**NO**															
Memo Items (not included above):																
International Bunkers		**78**	**77**	**117**	**107**	**73**	**83**	**54**	**65**	**66**	**68**	**67**	**70**	**75**	**77**	**74**
Aviation		18	18	20	25	28	28	25	33	34	36	31	38	43	45	42
Marine		60	59	97	81	46	55	29	32	32	32	36	32	32	32	32
Multilateral Operations		**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**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 14.6 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
Denmark's total emissions excluding net emissions from LULUCF	218		218	607	802	853	799	773	725	661	762	458	125	114	118
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	773	725	661	762	458	125	114	118
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															
7 Other															

Continued																
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
F. Consumption of Halocarbons and SF_6		**218**		**218**	**607**	**802**	**853**	**799**	**773**	**725**	**661**	**762**	**458**	**125**	**114**	**118**
1. Refrigeration and Air Conditioning Equipment		35		35	420	663	730	683								
2 Foam Blowing		183		183	168	119	103	96								
3 Fire Extinguishers		NO		NO	NO	NO	NO	NO								
4 Aerosol/Metered Dose Inhalers		NO		NO	19	21	19	18								
8 Electrical Equipment		NO		NO	NO	NO	NO	NO								
9 Other		NO		NO	NO	NO	1	3								
C_3F_8																
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																
Non-Dairy Cattle																
2 Buffalo	NO															
3 Sheep																
4 Goats																
5 Camels and Llamas	NO															

Continued																
6 Horses																
7 Mules and Asses	NO															
8 Swine																
9 Poultry																
10 Other																
Fur farming																
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																
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															

Continued																
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 14.7 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
Denmark's total emissions excluding net emissions from LULUCF		**1**		**1**	**18**	**14**	**13**	**14**	**13**	**13**	**12**	**13**	**10**	**9**	**7**	**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**
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																
7 Other																

Continued																
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**
1. Refrigeration and Air Conditioning Equipment		1		1	16	14	9	8								
2 Foam Blowing		NO		NO	NO	NO	NO	NO								
3 Fire Extinguishers		NO		NO	NO	NO	NO	NO								
4 Aerosol/Metered Dose Inhalers		NO		NO	NO	NO	NO	NO								
8 Electrical Equipment		NO		NO	NO	NO	NO	NO								
9 Other		**NO**		**NO**	**2**	**NO**	**4**	**6**								
C_3F_8	(4)	NO		NO	2	NO	4	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																
Non-Dairy Cattle																
2 Buffalo	NO															
3 Sheep																
4 Goats																
5 Camels and Llamas	NO															

Continued																
6 Horses																
7 Mules and Asses	NO															
8 Swine																
9 Poultry																
10 Other																
Fur farming																
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																
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															

Continued																
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 14.8 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
Denmark's total emissions excluding net emissions from LULUCF	107		107	59	22	32	37	36	69	115	58	123	59	14	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	107		107	59	22	32	37	36	69	115	58	123	59	14	8
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															
7 Other															

Continued

B. Chemical Industry																
2 Nitric Acid Production																
5 Other																
C. Metal Production		**36**		**36**	**21**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**
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
D. Other Production																
E. Production of Halocarbons and SF_6	NO															
F. Consumption of Halocarbons and SF_6		**71**		**71**	**38**	**22**	**32**	**37**	**36**	**69**	**115**	**58**	**123**	**59**	**14**	**8**
1. Refrigeration and Air Conditioning Equipment		NO		NO	NO	NO	NO	NO								
2 Foam Blowing		NO		NO	NO	NO	NO	NO								
3 Fire Extinguishers		NO		NO	NO	NO	NO	NO								
4 Aerosol/Metered Dose Inhalers		NO		NO	NO	NO	NO	NO								
8 Electrical Equipment		4		4	11	13	16	15								
9 Other		**68**		**68**	**27**	**9**	**15**	**22**								
C_3F_8																
SF_6	(5)	68		68	27	9	15	22								
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																
Non-Dairy Cattle																
2 Buffalo	NO															
3 Sheep																
4 Goats																
5 Camels and Llamas	NO															

Continued																
6 Horses																
7 Mules and Asses																
8 Swine																
9 Poultry																
10 Other																
Fur farming																
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																
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															

Continued																
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 14.9 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
Distribution by gases (%):															
CO_2	76.0	77.5	80.3	78.8	79.8	79.5	79.2	79.6	78.0	78.7	79.0	77.5	78.8	78.1	78.7
CH_4	8.2	8.3	7.8	8.6	8.9	9.1	9.5	9.4	10.1	9.8	9.6	10.4	10.2	10.6	10.4
N_2O	15.3	14.2	11.5	11.6	9.9	10.0	9.9	9.7	10.4	10.1	10.0	10.9	10.6	11.0	10.6
HFCs	0.3	NA	0.3	0.9	1.3	1.3	1.3	1.2	1.3	1.1	1.3	0.9	0.2	0.2	0.2
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
SF_6	0.2	NA	0.1	0.1	0.0	0.0	0.1	0.1	0.1	0.2	0.1	0.2	0.1	0.0	0.0
Total	**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	1.3	1.4	1.4	1.4	1.1	0.4	0.3	0.3
Trends relative to the KP base year 1990/95:															
CO_2	100	100	115	101	96	96	92	94	84	87	90	77	79	74	77
CH_4	100	100	104	102	100	102	102	103	101	99	101	96	94	94	95
N_2O	100	91	82	74	59	60	57	57	56	56	57	54	53	52	52
HFCs	100	NA	100	279	368	392	367	355	333	304	350	210	58	52	54
PFCs	100	NA	100	3562	2768	2547	2823	2642	2495	2365	2574	2055	1723	1354	1234
SF_6	100	NA	100	55	20	29	34	34	65	107	54	115	55	13	7
Total	**100**	**98**	**109**	**98**	**92**	**92**	**88**	**90**	**82**	**84**	**87**	**75**	**76**	**72**	**74**
Industrial gases (HFCs+PFCs+SF_6)	100	NA	100	210	257	276	261	253	248	242	256	182	59	41	41
Distribution by IPCC main sector categories:															
Energy	75.2	76.4	79.3	77.6	78.7	78.7	79.0	79.6	77.8	78.5	78.7	76.9	78.0	77.1	77.7
Industrial Processes	3.6	3.2	3.6	5.0	3.8	3.5	2.9	2.9	3.1	3.1	3.1	3.2	2.6	2.7	2.8
Solvent and Other Product Use	0.2	0.2	0.1	0.2	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Agriculture	18.8	18.2	15.1	15.2	15.2	15.4	15.8	15.3	16.6	16.1	15.8	17.4	16.9	17.6	17.1
Waste	2.2	2.0	1.8	2.0	2.1	2.2	2.2	2.1	2.3	2.2	2.2	2.4	2.3	2.4	2.3
Total	**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	96	96	92	95	85	87	91	77	79	74	77
Industrial Processes	100	89	110	137	99	91	71	72	72	72	76	68	55	55	59
Solvent and Other Product Use	100	99	80	74	66	69	74	73	72	71	72	68	65	62	60
Agriculture	100	95	88	79	74	75	74	73	72	71	73	70	68	68	67
Waste	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Total	**100**	**98**	**109**	**98**	**92**	**92**	**88**	**90**	**82**	**84**	**87**	**75**	**76**	**72**	**74**
Economic sector categories* Gg CO_2 eqv.:															
Energy	26 620	26 392	32 883	26 579	23 543	24 534	24 372	25 290	20 379	22 090	23 333	16 488	17 199	14 320	14 522

Continued															
Transport	10 650	10 905	12 392	12 477	13 613	14 202	13 421	13 394	13 276	13 137	13 486	13 466	13 645	14 227	15 096
Agriculture, forestry, fisheries	15 780	14 928	13 935	12 743	12 135	12 108	11 831	11 580	11 390	11 333	11 646	11 225	11 236	11 455	11 735
Business	9 518	9 290	9 957	10 531	9 187	8 363	6 836	7 233	7 154	7 139	7 345	7 088	6 815	6 856	7 151
Domestic sector	5 208	5 098	5 122	4 147	3 847	3 066	3 180	3 667	3 151	3 055	3 224	2 805	2 434	2 138	1 895
Waste	1 547	1 349	1 366	1 370	1 310	1 381	1 344	1 300	1 287	1 276	1 318	1 251	1 219	1 201	1 197
Total	**69 323**	**67 962**	**75 655**	**67 847**	**63 634**	**63 654**	**60 985**	**62 464**	**56 637**	**58 031**	**60 351**	**52 323**	**52 548**	**50 198**	**51 595**
Distribution by economic sector ():															
Energy	38.4	38.8	43.5	39.2	37.0	38.5	40.0	40.5	36.0	38.1	38.7	31.5	32.7	28.5	28.1
Transport	15.4	16.0	16.4	18.4	21.4	22.3	22.0	21.4	23.4	22.6	22.3	25.7	26.0	28.3	29.3
Agriculture, forestry, fisheries	22.8	22.0	18.4	18.8	19.1	19.0	19.4	18.5	20.1	19.5	19.3	21.5	21.4	22.8	22.7
Business	13.7	13.7	13.2	15.5	14.4	13.1	11.2	11.6	12.6	12.3	12.2	13.5	13.0	13.7	13.9
Domestic sector	7.5	7.5	6.8	6.1	6.0	4.8	5.2	5.9	5.6	5.3	5.3	5.4	4.6	4.3	3.7
Waste	2.2	2.0	1.8	2.0	2.1	2.2	2.2	2.1	2.3	2.2	2.2	2.4	2.3	2.4	2.3
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**
Trends relative to the KP base year 1990/95:															
Energy	100	99	124	100	88	92	92	95	77	83	88	62	65	54	55
Transport	100	102	116	117	128	133	126	126	125	123	127	126	128	134	142
Agriculture, forestry, fisheries	100	95	88	81	77	77	75	73	72	72	74	71	71	73	74
Business	100	98	105	111	97	88	72	76	75	75	77	74	72	72	75
Domestic sector	100	98	98	80	74	59	61	70	61	59	62	54	47	41	36
Waste	100	87	88	89	85	89	87	84	83	82	85	81	79	78	77
Total	**100**	**98**	**109**	**98**	**92**	**92**	**88**	**90**	**82**	**84**	**87**	**75**	**76**	**72**	**74**

Table 14.10 Emission estimates for 1990 to 2030 for Afforestation, Reforestation, Deforestation under Art. 3.3. and Forest Management, Cropland Management and Grassland Management under Art. 3.4 of the Kyoto-protocol.

	1990	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
3.3												
AR	10.5	-165.0	-271.3	-689.3	-685.7	-674.7	-608.5	-607.5	-621.1	-612.8	-802.5	-797.9
D	241.0	32.4	33.5	79.7	75.5	75.4	75.3	75.2	75.0	74.9	74.8	74.6
3.3 total	251.6	-132.6	-237.9	-609.7	-610.1	-599.3	-533.2	-532.3	-546.1	-537.9	-727.7	-723.3
3.4												
FM	-709.3	-4816.9	-2579.1	3887.0	2208.8	2205.2	41.6	45.2	41.5	41.5	48.9	52.5
CM	3188.6	2530.1	1366.1	2278.2	1994.7	1902.2	1655.8	1750.6	1884.4	1949.7	2018.5	2097.6
GM	313.6	184.5	183.4	187.1	190.7	194.3	197.9	201.6	205.2	208.8	212.4	216.1
CM+GM	*3502.3*	*2714.7*	*1549.5*	*2465.3*	*2185.3*	*2096.5*	*1853.7*	*1952.2*	*2089.6*	*2158.6*	*2230.9*	*2313.7*
3.4 total	2793.0	-2102.3	-1029.6	6352.3	4394.2	4301.7	1895.3	1997.4	2131.2	2200.1	2279.8	2366.2
3.3 and 3.4	3044.6	-2234.8	-1267.4	5742.7	3784.1	3702.4	1362.1	1465.1	1585.1	1662.2	1552.1	1643.0

Continued

	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
3.3												
AR	-778.5	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
D	74.4	74.1	74.1	74.0	74.0	73.9	73.9	73.8	73.8	73.7	73.6	73.6
3.3 total	-704.2	74.1	74.1	74.0	74.0	73.9	73.9	73.8	73.8	73.7	73.6	73.6
3.4												
FM	52.5	45.2	45.2	45.2	45.1	45.1	45.1	45.1	45.1	45.1	45.1	45.1
CM	2164.1	2225.2	2245.7	2268.0	2274.2	2311.3	2329.7	2326.2	2322.7	2319.2	2315.7	2312.2
GM	219.7	223.3	226.9	230.6	234.2	237.8	241.5	245.1	248.7	252.3	256.0	259.6
CM+GM	*2383.7*	*2448.5*	*2472.6*	*2498.5*	*2508.4*	*2549.1*	*2571.2*	*2571.3*	*2571.4*	*2571.6*	*2571.7*	*2571.8*
3.4 total	2436.3	2493.7	2517.8	2543.7	2553.5	2594.2	2616.3	2616.4	2616.5	2616.7	2616.8	2616.9
3.3 and 3.4	1732.1	2567.8	2591.8	2617.7	2627.5	2668.1	2690.2	2690.2	2690.3	2690.4	2690.4	2690.5

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